Supporting Information

Atmospheric lead emissions from coal-fired power plants with different boilers and APCDs in Guizhou, Southwest China

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This supporting information document includes four Figures and six Tables.

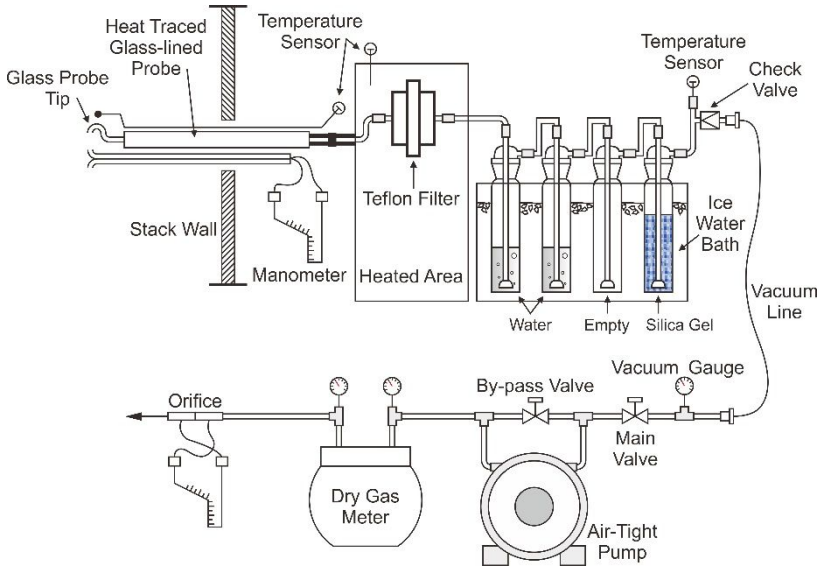

Figure S1. The U.S. EPA test method 5 for particulate matter sampling in the stack flue gas[1] (U.S. EPA, 1996)

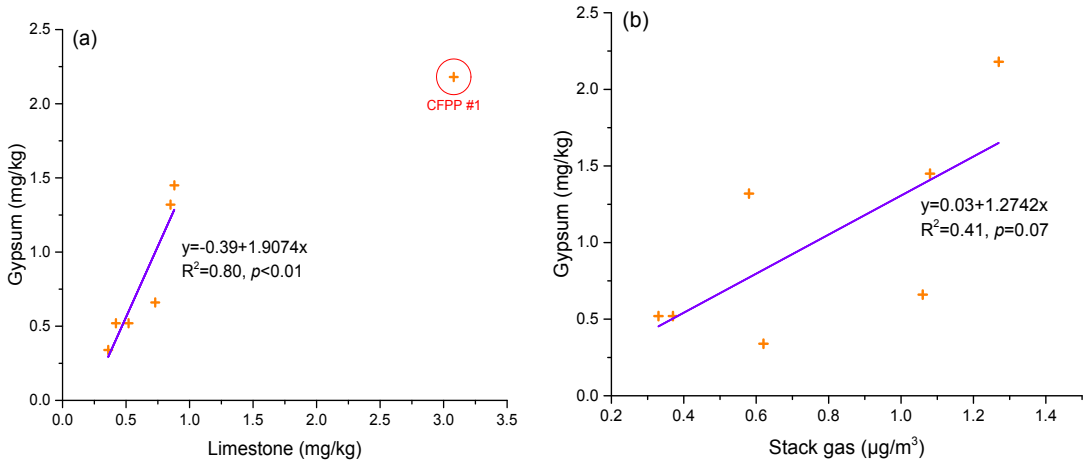

Figure S2. The correlation between Pb concentration in desulfurizing gypsum and (a) limestone, and (b) stack gas of the eight tested CFPPs

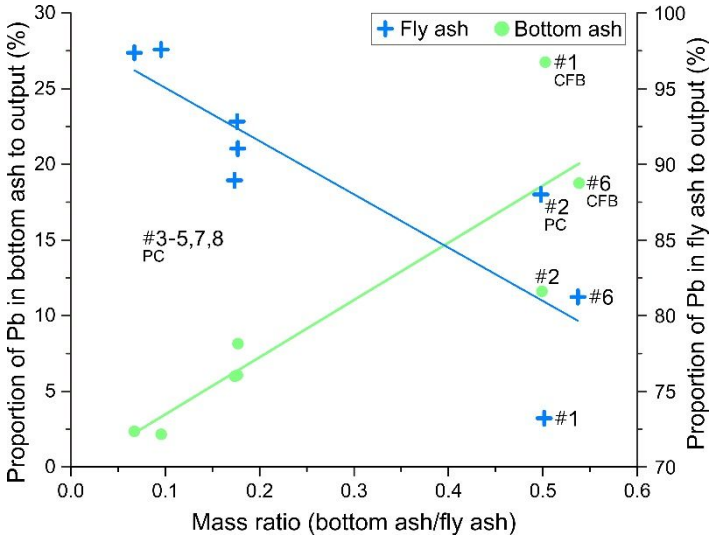

Figure S3. Trends of Pb proportion in CCPs to output with mass ratio (bottom ash/fly ash) in the tested CFPPs

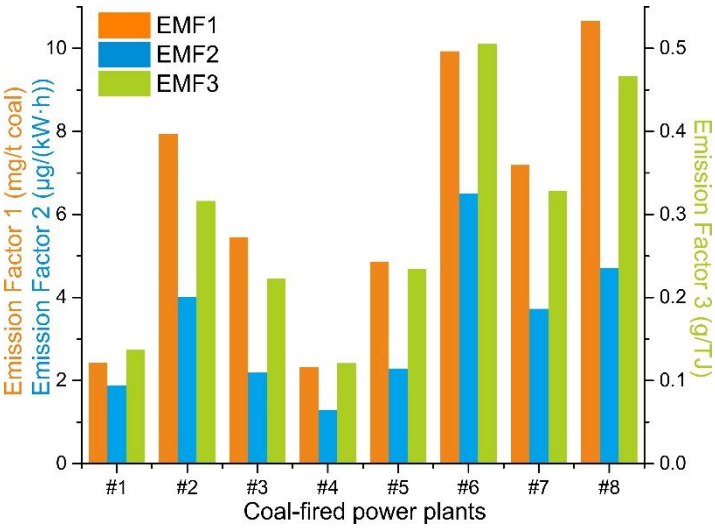

Figure S4. Pb emission factors (EMFs) of the eight tested CFPPs

Table S1. The material consumption and production rate and PM content in the stack flue gas of the eight utility boiler system

CFPPs	#1	#2	#3	#4	#5	#6	#7	#8
Feed fuel (t/d)	1070[a] 2339[b]	4376	3551	2032	5053	1730	2366	2776
Limestone (t/d)	36	269	140	108	448	384	265	393
Bottom ash (t/d)	563	597	149	101	139	240	141	158
Fly ash (t/d)	1120	1195	841	1054	2056	446	800	909
Gypsum (t/d)	58	462	252	202	815	/	495	824
Stack flue gas (10^4 Nm^3/d)	2213	3279	3367	1420	3995	1087	1571	2335
Actual operating power (MW)	183	360	368	153	448	110	190	262.5
PM content in stack flue gas (mg/Nm^3)	10.59±1.85 (No.=4)	18.28±0.30 (No.=3)	12.92±0.47 (No.=3)	10.15±3.80 (No.=3)	13.90±0.47 (No.=3)	31.26±9.12 (No.=2)	14.58±0.57 (No.=2)	36.42±0.35 (No.=3)

a, Gangue; b, Coal slime

Table S2. Regional information of Pb concentrations in coal and coal ash

Regions	Types	Coal (mg/kg)	Coal ash (mg/kg)	References
World	Brown coal	6.6	38	Ketris and Yudovich[2]
World	Hard coal	9	55	Ketris and Yudovich[2]
World	Coal (Average)	7.8	47	Ketris and Yudovich[2]
China	Coal	15.1	/	Dai et al.[3]
Western Guizhou	Coal	15	/	Dai et al.[4]

Table S3. Relative enrichment factor (REF) of Pb in coal combustion productions (CCPs) of the eight CFPPs in the present study

	Samples	#1	#2	#3	#4	#5	#6	#7	#8
Relative enrichment factor (REF)	Bottom ash	0.87	0.34	0.53	0.23	0.42	0.45	0.33	0.42
	Fly ash	1.20	1.28	1.04	0.99	1.17	1.06	0.90	1.09

Table S4. Comparison of Pb concentrations in solid materials and Pb emissions data from coal-fired power plants (CFPPs)

Region	Boiler type	APCDs	Installed capacity	Coal (mg/kg)	Bottom ash (mg/kg)	Fly ash (mg/kg)	Gypsum (mg/kg)	Stack flue gas (μg/Nm^3)	Emission factors	References
Guizhou, China (No.=6)	PC	SCR+C-ESP(-FF)+WFGD	150-660 MW	16.49±6.69	16.99±6.23	48.00±13.78	1.05±0.93	0.82±0.33	6.41±2.62 mg/t coal 3.04±1.19 μg/(kW·h) 0.28±0.11 g/TJ	This study
Guizhou, China	CFB	SNCR+C-ESP-FF+WFGD	2×300 MW	12.75-14.98	26.41	36.3	0.52	0.37	2.43 mg/t coal 1.88 μg/(kW·h) 0.14 g/TJ	This study
Guizhou, China	CFB	IFD+ESP	2×150 MW	20.67	23.68	55.19	/	1.58	9.93 mg/t coal 6.51 μg/(kW·h) 0.53 g/TJ	This study
Jiangsu, China	PC	SCR+ESP-FF+WFGD	350 MW	2.94-8.56	8.42-14.4	76.7-79.4	6.07-7.09	0.18-0.26	0.07-0.09 g/TJ	Zhao et al. [5]
China	PC	SCR+ESP+FGD	100 MW	23.02	-	-	-	1.42	11.53 mg/t coal	Zhao et al. [6]
Hebei, China	PC	SCR+ESP-FF+WFGD	660 MW	23.4	21.2	155.2	1.5	0.16	1.27 mg/t coal	Zhao et al. [7]
Guizhou, China	PC	C-ESP+WFGD	300 MW	22.44	34.98	71.70	25.54	70.28	-	Deng et al. [8,9]
Guizhou, China	CFB	C-ESP	300 MW	34.90	25.26	92.08	-	154.61	-	Deng et al. [8,9]
Shanghai, China	PC	FF+WFGD	300 MW	13.57	25.35	104.98	38.13	30.17	-	Deng et al. [8,9]
Inner Mongolia, China	PC	FF+WFGD	300 MW	25.76	38.45	123.72	27.50	100.16	-	Deng et al. [8,9]
Inner Mongolia, China	PC	C-ESP+WFGD	600 MW	18.34	37.04	88.74	27.41	138.62	-	Deng et al. [8,9]
Hubei, China	PC	SCR+C-ESP+WFGD	300 MW	58.50	13.27	154.01	16.67	320.15	-	Deng et al. [8,9]
Anhui, China	PC	ESP+FGD	-	13.2-16.7	15.3-17.2	35.3-50.5	-	-	-	Tang et al. [10]
Anhui, China	PC	ESP+FGD	-	20.60	22.2-23.5	62-113	-	-	-	Tang et al. [10]
China	PC	ESP	220 t coal/h	16	7-21	43-55	-	-	-	Huang et al. [11]
Shanxi, China	Unknown	Unknown	Unknown	12.95	17.22	33.13	-	297	-	Wang et al. [12]
China (No.=30)	Unknown	(SCR)+ESP/FF+WFGD	12-1000 MW	8.50±5.68	-	-	-	8.15±10.68	64.34±81.21 mg/t coal	Pei [13]
U.S.	PC	SCR+ESP+WFGD	Unknown	53.00	15.00	41.80	-	-	-	Swanson et al. [14]
U.S.	PC	FF-ESP+FGD	Unknown	46.80	19.20	43.10	-	-	-	Swanson et al. [14]
Western India	Unknown	ESP	220 MW	29.4±8.6	325.6±21.7	266.1±18.9	-	1.3±0.8	0.04-0.06 g/TJ	Reddy et al. [15]
Chhattisgarh, India	Unknown	Unknown	150 MW	10.42	14.24	22.93	-	-	-	Bhangare et al. [16]
Orrisa, India	Unknown	Unknown	3000 MW	20.37	28.28	35.30	-	-	-	Bhangare et al. [16]
Andhra Pradesh, India	Unknown	Unknown	1000 MW	5.03	10.50	27.70	-	-	-	Bhangare et al. [16]
Madhya Pradesh, India	Unknown	Unknown	2250 MW	3.25	8.80	7.60	-	-	-	Bhangare et al. [16]
Andhra Pradesh, India	Unknown	Unknown	90 MW	13.22	19.74	30.38	-	-	-	Bhangare et al. [16]
Uttar Pradesh, India	Unknown	Unknown	1050 MW	5.44	11.7	44.1	-	-	-	Verma et al. [17]
Malaysia	Unknown	ESP+FGD	700 MW	16.2	17.8-22.1	63.7	-	-	-	Mokhtar et al. [18]
Paraná, Brazil	Unknown	FF	10 MW	50-107	66-92	258-627	-	-	-	Flues et al. [19]

58 **Table S5.** Pb flow and mass balance of the eight tested utility boilers
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CFPPs	#1	#2	#3	#4	#5	#6	#7	#8
Input (g/d)	45852.46	62929.10	46462.07	31417.05	75776.25	36217.42	73427.22	29454.44
Feed fuel	16019.61[a] 29814.05[b]	62732.03	46342.41	31371.84	75613.84	35755.51	73194.25	28244.70
Limestone	18.80	197.08	119.66	45.20	162.41	461.91	232.97	1209.74
Output (g/d)	55570.89	78631.41	40909.00	36251.95	93492.82	30324.95	63068.81	35641.49
Bottom ash	14871.00	9126.95	3333.19	781.75	2201.99	5688.39	3824.88	2133.47
Fly ash	40660.82	69163.82	37223.25	35360.74	90988.05	24619.38	58510.34	31682.24
Gypsum	30.34	305.91	333.19	104.74	278.20	/	716.58	1796.14
Flue gas	8.73	34.73	19.37	4.72	24.58	17.18	17.02	29.63
Output/Input (%)	121.20	124.95	88.05	115.39	123.38	83.73	85.89	121.01

60 a, Gangue; b, Coal slime
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64 **Table S6.** Pb contributions from different input and output materials in the eight tested utility boilers
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Direction	Samples	#1	#2	#3	#4	#5	#6	#7	#8
Input	Feed fuel	34.94%[a] 65.02%[b]	99.69%	99.74%	99.86%	99.79%	98.72%	99.68%	95.89%
	Limestone	0.04%	0.31%	0.26%	0.14%	0.21%	1.28%	0.32%	4.11%
Output	Bottom ash	26.76%	11.61%	8.15%	2.16%	2.36%	18.76%	6.06%	5.99%
	Fly ash	73.17%	87.96%	90.99%	97.54%	97.32%	81.19%	92.77%	88.89%
	Gypsum	0.05%	0.39%	0.81%	0.29%	0.30%	/	1.14%	5.04%
	Flue gas	0.02%	0.04%	0.05%	0.01%	0.03%	0.06%	0.03%	0.08%

66 a, Gangue; b, Coal slime

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