Electronic Supplementary Material to: Characteristics of $PM_{2.5}$ and Its Reactive Oxygen Species in Heating Energy Transition and Estimation of Its Impact on the Environment and Health in China—A Case Study in the Fenwei Plain

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The Process and Criteria for the Selection of Participants

Through extensive questionnaire surveys and consultations with Shibao village committee leaders and representative villagers in the initial study, resident numbers, clean heating renovation information, the types, habits, and history of household energy use, and other basic information about the village were obtained. There were about 1000 households in Shibao village. 350 households were excluded because they did not live at home all year round or in winter due to work or other reasons; 100 households were excluded due to children who might be hurt during sampling; 100 households without homemakers and 50 households without heating at home were also excluded.

The selection criteria of households and homemakers were: 1) the homemakers used stable solid fuel for at least two years; 2) the households had not been decorated in any way or gained additional furniture in recent years; 3) the living habits and living environments in winter were consistent (Table S2); 4) the homemakers were relatively healthy and free of chronic and genetic diseases; 5) the homemakers fully acknowledged the contents of the survey and agreed to participate.

Therefore, considering the appropriate subjects and experimental design, 18 homemakers (~5% of the available 400 households) using the three most common fuels were selected in this study.

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Table S1. Compositions of domestic solid fuels involved in this study in the Fenwei Plain, China (air dried basis).

Heating energy type	Carbon (%)	Hydrogen (%)	Nitrogen (%)	Sulfur (%)	Moisture (%)	Ash (%)	Volatile matter (%)	Fixed carbon (%)	Heat value (MJ kg^{-1})
Lump coal	59.9	4.59	0.72	2.24	7.98	7.98	33.20	50.84	22.02
Biomass*	45.1	6.97	0.94	0.06	5.12	6.51	71.77	16.59	16.66
Clean coal	72.1	1.50	0.70	0.49	5.20	13.7	18.25	68.27	27.12

*The industrial analysis results of biomass averaged from local wheat straw, corn straw, and corncob.

Table S2. Information on the 18 homemakers and their households in the different solid fuel groups.

	Basic information					Living habits			
	Age (years)	Height (cm)	Weight (kg)	Permanent population	Heating area (m^2)	Heating period	Heating facility	Cooking fuel	Kitchen ventilation equipment
L-1	42	160	64	4	12	All day	Stove	Lump coal	No
L-2	43	161	60	4	8	Daytime	Stove	Lump coal	No
L-3	53	150	63	2	9	Daytime	Stove and "Kang"	Lump coal	No
L-4	46	160	65	4	10	Daytime	Stove	Lump coal	No
L-5	46	165	66	6	12	All day	Stove and "Kang"	Lump coal	Smoke exhaust ventilator
L-6	37	158	50	4	9	Daytime	Stove	Lump coal and wood	No
B-1	51	160	63	4	8	Daytime	Stove	Biomass	Nil
B-2	45	155	47	3	9	Daytime	Stove and "Kang"	Biomass	Nil
B-3	50	165	55	4	8	Daytime	Stove and "Kang"	Wood, straw, and electricity	No
B-4	57	150	50	5	11	Daytime	Stove	Wood and straw	Chimney
B-5	57	Nil	Nil	7	11	Daytime	Stove	Wood	Ventilator
B-6	53	160	50	3	8	Daytime	Stove	Clean coal	No
C-1	41	160	64	4	8	Daytime	Stove	Clean coal	Ventilator
C-2	45	155	47	5	12	Daytime	Stove	Electricity	Ventilator
C-3	45	165	69	5	11	Daytime	Stove and "Kang"	Clean coal	No
C-4	52	164	57	4	9	Daytime	Stove and "Kang"	Clean coal	Ventilator
C-5	53	150	51	2	8	Daytime	Stove	Clean coal	No
C-6	52	160	60	4	8	Daytime	Stove	Clean coal	No

	Living environment			
	Distance to main road (m)	Residential floor height (m)	Residential materials	Residential temperature (°C)
L-1	>100	>4	Masonry	13
L-2	<20	3.5–4	Masonry	16
L-3	>100	>4	Masonry	15
L-4	<20	3.5–4	Masonry	15
L-5	<20	<3	Concrete	12
L-6	>100	3.5–4	Masonry	17
B-1	<20	>4	Masonry	15
B-2	<20	3.5–4	Masonry	13
B-3	20–100	3.5–4	Masonry	14
B-4	20–100	3.5–4	Masonry	11
B-5	<20	3.5–4	Masonry	14
B-6	<20	3.5–4	Concrete	14
C-1	20–100	3.5–4	Masonry	13
C-2	<20	3.5–4	Masonry	15
C-3	20–100	<3	Masonry	12
C-4	<20	3.5–4	Masonry	17
C-5	>100	3.5–4	Masonry	12
C-6	>100	3.5–4	Masonry	16

Remarks: L, B, and C represent lump coal, biomass, and clean coal groups, respectively. "Kang" represents "Heated Kang", which is the traditional way of residential heating in rural areas of northern China.

Table S3. Indoor and personal exposure (PE) to $PM_{2.5}$, TC, OC, and EC concentrations of lump coal (L), biomass (B), and clean coal (C) household groups in the Fenwei Plain, China (Mean ± standard deviation in μg m^{-3}).

Sampling site	Heating energy type	Fuel and household ID	$PM_{2.5}$	TC	OC	EC
Indoor	Lump coal	L-1	184.0±5.6	72.50±0.0	64.10±0.3	8.50±0.3
		L-2	368.4±142.7	174.8±84.4	163.2±83.2	11.60±1.2
		L-3	248.5±20.6	130.9±5.8	106.6±12.8	24.30±18.5
		L-4	451.7±229.2	251.4±181.5	230.8±173.7	20.50±7.8
		L-5	202.5±165.9	79.10±81.6	72.80±78.7	6.20±2.9
		L-6	385.7±10.9	196.3±0.2	134.0±33.8	62.30±33.7
		Average	306.8±109.9	150.8±69.9	128.6±62.3	22.20±20.9
	Biomass	B-1	212.1±137.2	99.50±69.5	91.60±65.4	7.90±4.1
		B-2	409.7±322.9	199.9±167.2	143.8±109.3	56.10±57.8
		B-3	253.6±12.8	126.2±5.8	109.3±1.4	16.90±4.4
		B-4	71.90±16.7	17.30±1.7	14.50±1.7	2.80±0.0
		B-5	158.30±24.7	68.40±23.9	59.30±20.1	9.10±3.8
		B-6	193.0±18.4	85.10±9.8	74.30±10.2	10.70±0.6
		Average	216.4±112.8	99.40±61.2	82.10±44.2	17.20±19.6
	Clean coal	C-1	105.3±8.0	50.50±4.2	43.30±5.3	6.10±1.1
		C-2	170.7±144.8	75.20±68.1	64.0±57.0	11.20±11.1
		C-3	136.2±68.2	69.80±40.0	63.90±38.1	5.80±1.9
		C-4	318.1±61.9	173.9±27.7	154.4±28.8	19.50±1.2
		C-5	125.6±6.6	36.90±3.8	32.0±2.8	4.90±1.0
		C-6	182.6±81.7	79.40±52.9	70.20±47.7	9.20±5.1
		Average	173.1±76.6	80.90±48.3	71.30±43.2	9.70±5.3
PE	Lump coal	L-1	151.3±8.3	70.30±4.4	63.20±3.6	7.10±0.7
		L-2	231.0±23.2	107.2±7.3	96.50±8.4	10.70±1.1
		L-3	178.30±0.1	77.0±9.9	62.70±1.1	14.30±8.9
		L-4	304.4±69.4	151.8±66.9	138.2±64.1	13.60±2.7
		L-5	83.80±7.4	18.10±3.2	14.80±2.2	3.20±1.0
		L-6	239.6±96.9	96.10±25.9	78.0±22.7	18.20±3.2
		Average	198.1±77.1	86.80±44.3	75.60±40.9	11.20±5.4
	Biomass	B-1	216.0±8.3	98.70±9.7	90.60±11.5	8.10±1.8
		B-2	336.6±65.4	134.0±29.0	105.7±11.4	28.30±17.6
		B-3	387.0±19.0	161.1±28.0	143.3±26.4	17.90±1.7
		B-4	168.1±62.3	84.40±33.1	74.30±33.6	10.10±0.5
		B-5	64.70±21.8	25.40±20.8	22.50±18.4	2.90±2.5
		B-6	84.60±10.5	34.40±3.0	30.10±2.5	4.30±0.5
		Average	209.5±131.1	89.70±53.6	77.70±46.0	11.90±9.6
	Clean coal	C-1	148.2±11.2	64.10±4.4	49.80±1.2	14.30±3.2
		C-2	209.0±80.8	64.10±13.0	47.50±8.3	16.60±4.7
		C-3	76.50±11.2	35.40±12.6	31.60±12.3	3.70±0.3
		C-4	160.5±31.0	94.50±30.4	82.50±25.0	12.0±5.4
		C-5	255.3±37.8	72.70±8.0	59.30±7.5	13.40±0.4
		C-6	139.1±8.2	62.30±13.3	53.60±13.0	8.70±0.3
		Average	164.8±61.5	65.50±19.1	54.10±16.8	11.50±4.6

Fig. S1. Common domestic solid fuels and stoves in Tongchuan of the Fenwei Plain in China (a: lump coal, b: biomass, and c: clean coal).

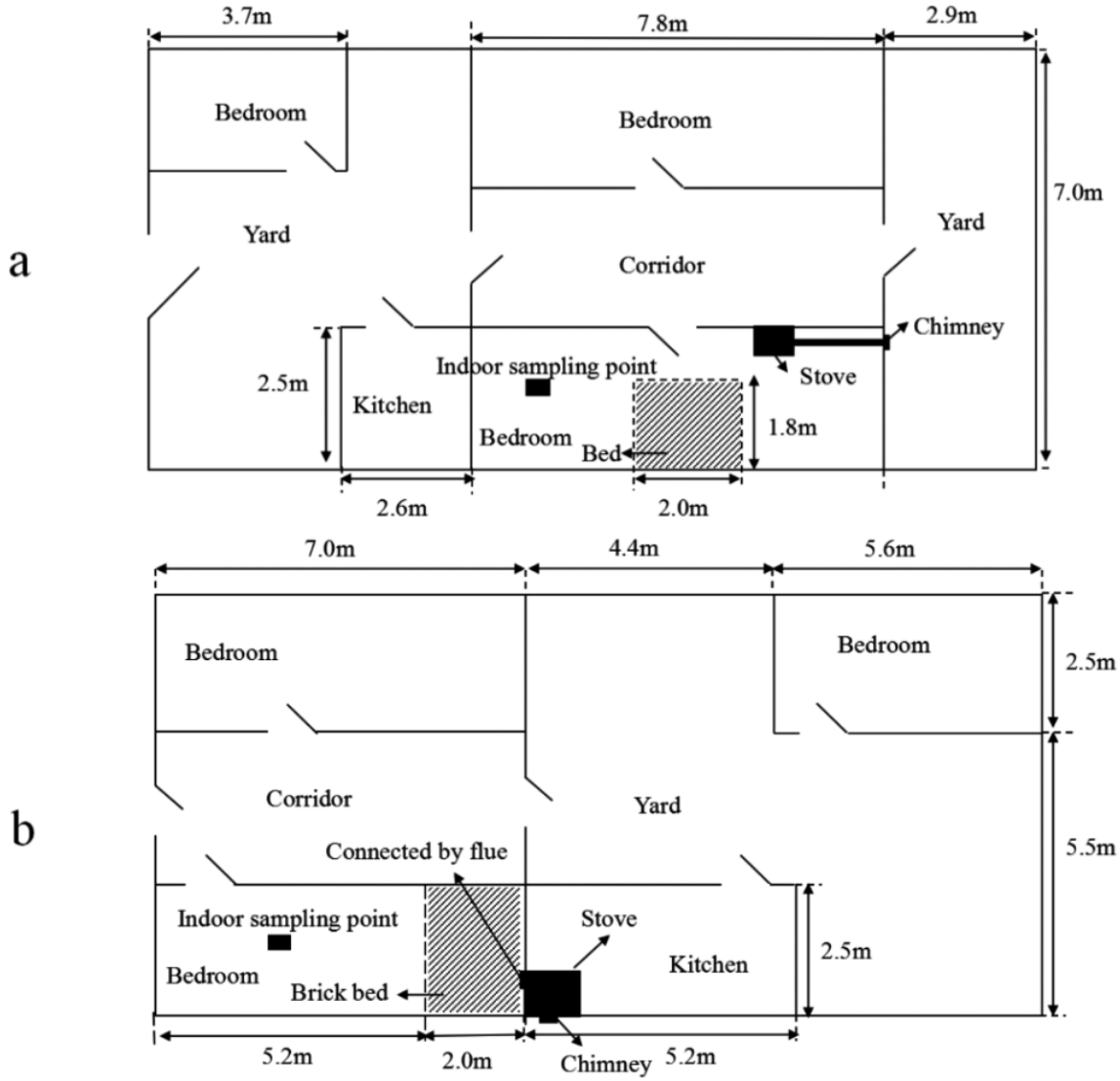

Fig. S2. Typical floorplan of (a) households using a coal stove and (b) households using a biomass fuel stove connected to a brick bed in the rural areas of Tongchuan in the Fenwei Plain, China.

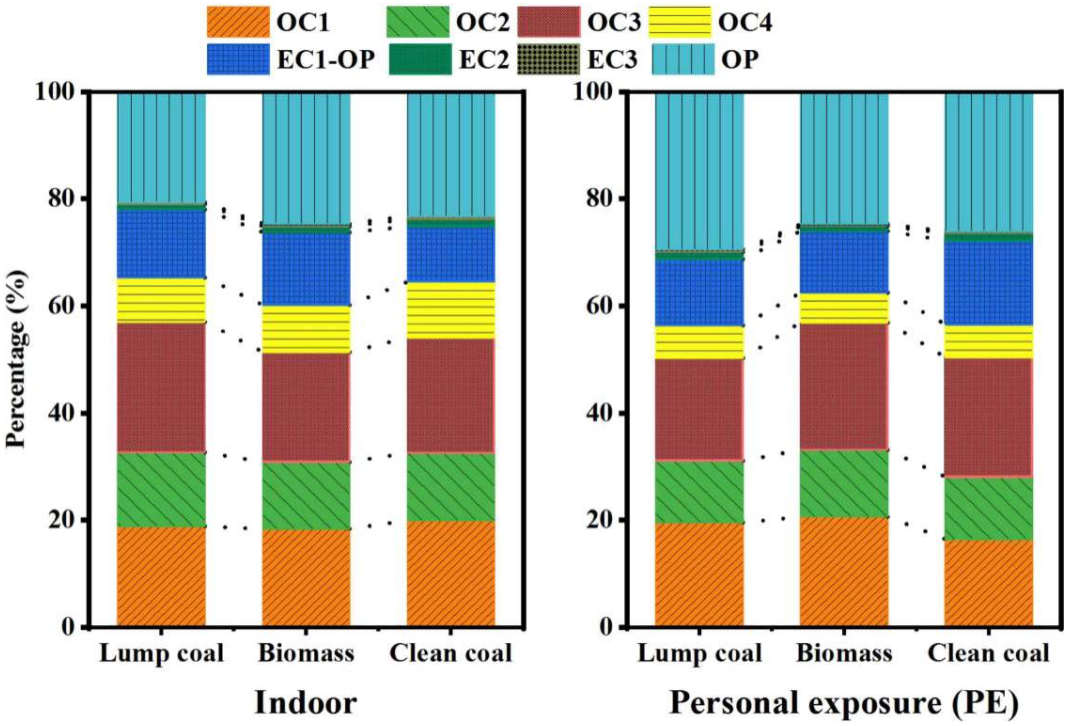

Fig. S3. Percentages of eight carbon fractions in TC in $PM_{2.5}$ for the indoor and PE samples.

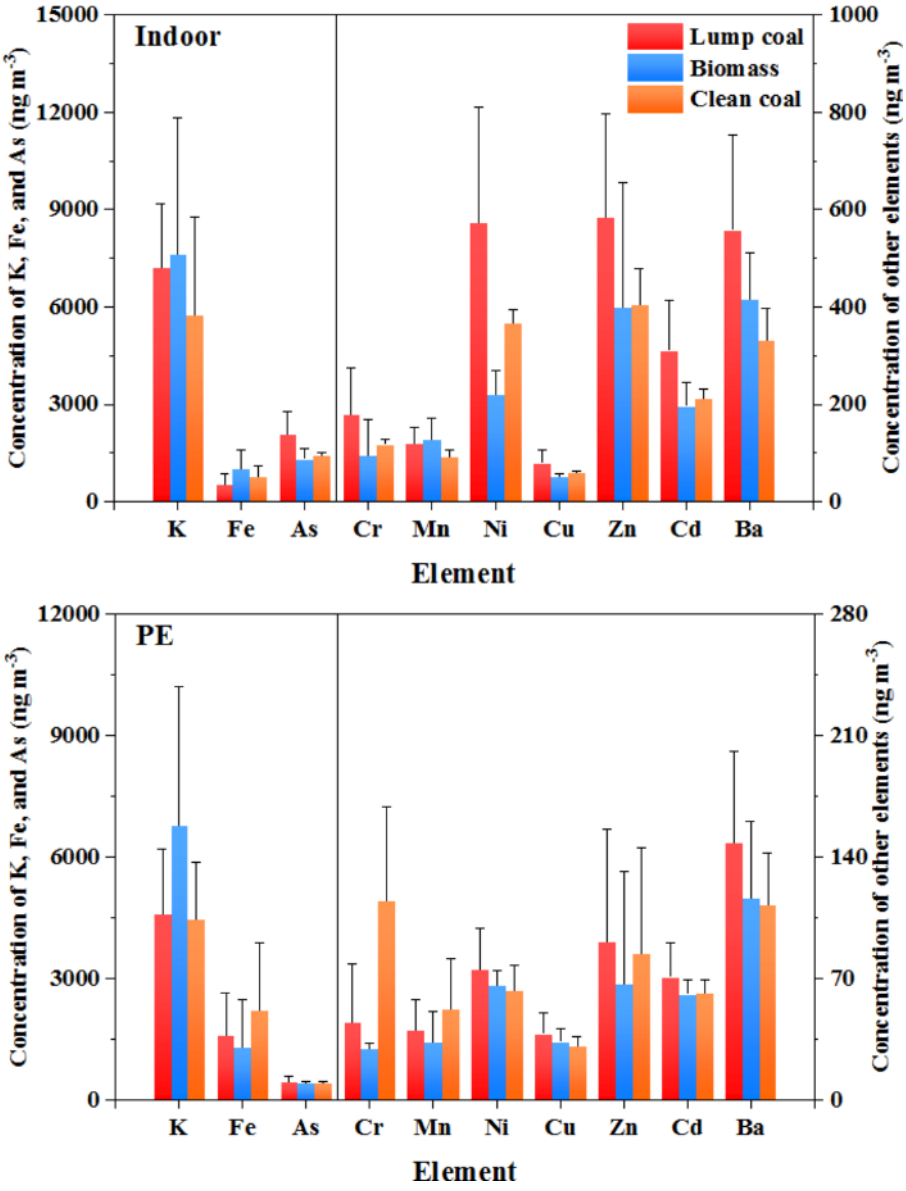

Fig. S4. Concentrations of elements in indoor and PE $PM_{2.5}$ for the three fuel groups.