Source differences in the components and cytotoxicity of $PM_{2.5}$ from automobile exhaust, coal combustion, and biomass burning contributing to urban aerosol toxicity

Xiao-San Luo[1,#,*], Weijie Huang[1,#], Guofeng Shen[2], Yuting Pang[1], Mingwei Tang[1], Weijun Li[3], Zhen Zhao[1], Hanhan Li[1], Yaqian Wei[1], Longjiao Xie[4], Tariq Mehmood[5]

[1]International Center for Ecology, Meteorology, and Environment, School of Applied Meteorology, Nanjing University of Information Science & Technology, Nanjing 210044, China
[2]Laboratory of Earth Surface Processes, College of Urban and Environmental Sciences, Peking University, Beijing 100871, China
[3]Department of Atmospheric Sciences, School of Earth Sciences, Zhejiang University, Hangzhou 310027, China
[4]Health Science Center, Peking University, Beijing 100871, China
[5]College of Ecology and Environment, Hainan University, Haikou 570228, China

Correspondence: Xiao-San Luo (xsluo@nuist.edu.cn)

[#]Authors contributed equally to this work

There are 19 figures and 3 tables in the Supplement.

Captions of figures and tables

Figure S1. Schematic of a dilution 4-channel sampler used for collecting $PM_{2.5}$ directly from various combustion source emissions.

Figure S2. Samples of $PM_{2.5}$ loaded in quartz filters collected from 30 typical anthropogenic combustion sources (a: automobile exhaust; b: coal combustion; c: biomass burning).

Figure S3. Example of daily urban air $PM_{2.5}$ concentrations (μg m^{-3}) monitored in Nanjing city, eastern China.

Figure S4. Contents (mg kg^{-1}) and ratio of carbon fractions in $PM_{2.5}$ from 10 types of automobile exhaust.

Figure S5. Contents (mg kg^{-1}) and ratio of carbon fractions in $PM_{2.5}$ from 10 types of coal combustion.

Figure S6. Contents (mg kg^{-1}) and ratio of carbon fractions in $PM_{2.5}$ from 10 types of biomass burning.

Figure S7. Contents (mg kg^{-1}) and ratio of carbon fractions in ambient air $PM_{2.5}$ from Nanjing city, eastern China.

Figure S8. Heavy metal contents (mg kg^{-1}) in $PM_{2.5}$ from 10 types of automobile exhaust.

Figure S9. Heavy metal contents (mg kg^{-1}) in $PM_{2.5}$ from 10 types of coal combustion.

Figure S10. Heavy metal contents (mg kg^{-1}) in $PM_{2.5}$ from 10 types of biomass burning.

Figure S11. Heavy metal contents (mg kg^{-1}) in ambient air $PM_{2.5}$ from Nanjing city, eastern China.

Figure S12. Water-soluble ions (WSIs) contents (mg kg^{-1}) in $PM_{2.5}$ from 10 types of automobile exhaust.

Figure S13. Water-soluble ions (WSIs) contents (mg kg^{-1}) in $PM_{2.5}$ from 10 types of coal combustion.

Figure S14. Water-soluble ions (WSIs) contents (mg kg^{-1}) in $PM_{2.5}$ from 10 types of biomass burning.

Figure S15. Water-soluble ions (WSIs) contents (mg kg^{-1}) in monthly ambient air $PM_{2.5}$ from Nanjing city, eastern China.

Figure S16. Cell viability, oxidative stress and inflammation levels exposed to $PM_{2.5}$ from 10 types of automobile exhaust.

Figure S17. Cell viability, oxidative stress and inflammation levels exposed to $PM_{2.5}$ from 10 types of coal combustion.

Figure S18. Cell viability, oxidative stress and inflammation levels exposed to $PM_{2.5}$ from 10 types of biomass burning.

Figure S19. Cell viability, oxidative stress and inflammation levels exposed to various ambient air $PM_{2.5}$ from Nanjing city, eastern China.

Table S1. Characteristics of the investigated typical vehicles.

Table S2. Characteristic analysis of typical coal samples.

Table S3. Characteristic analysis of typical biomass fuel samples.

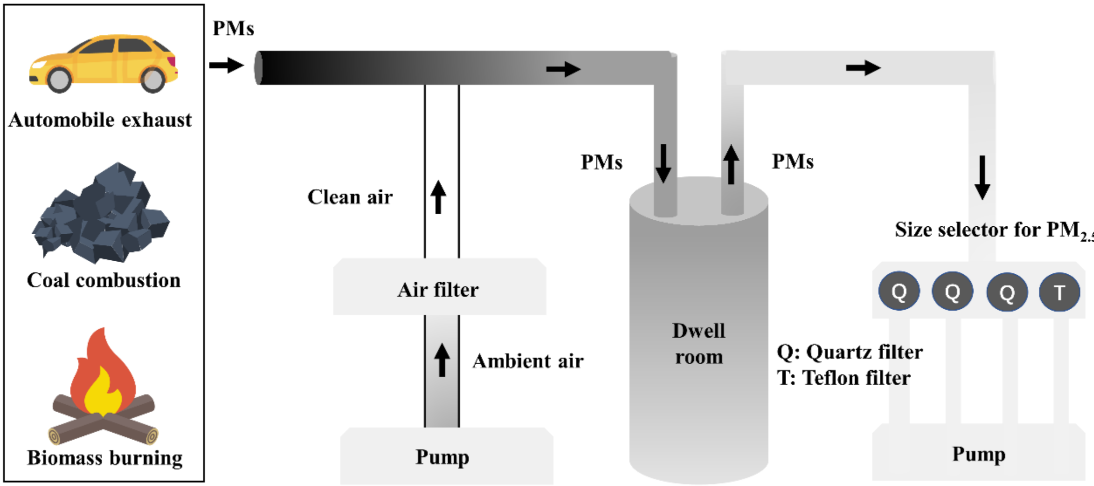


Figure S1. Schematic of a dilution 4-channel sampler used for collecting $PM_{2.5}$ directly from various combustion source emissions.

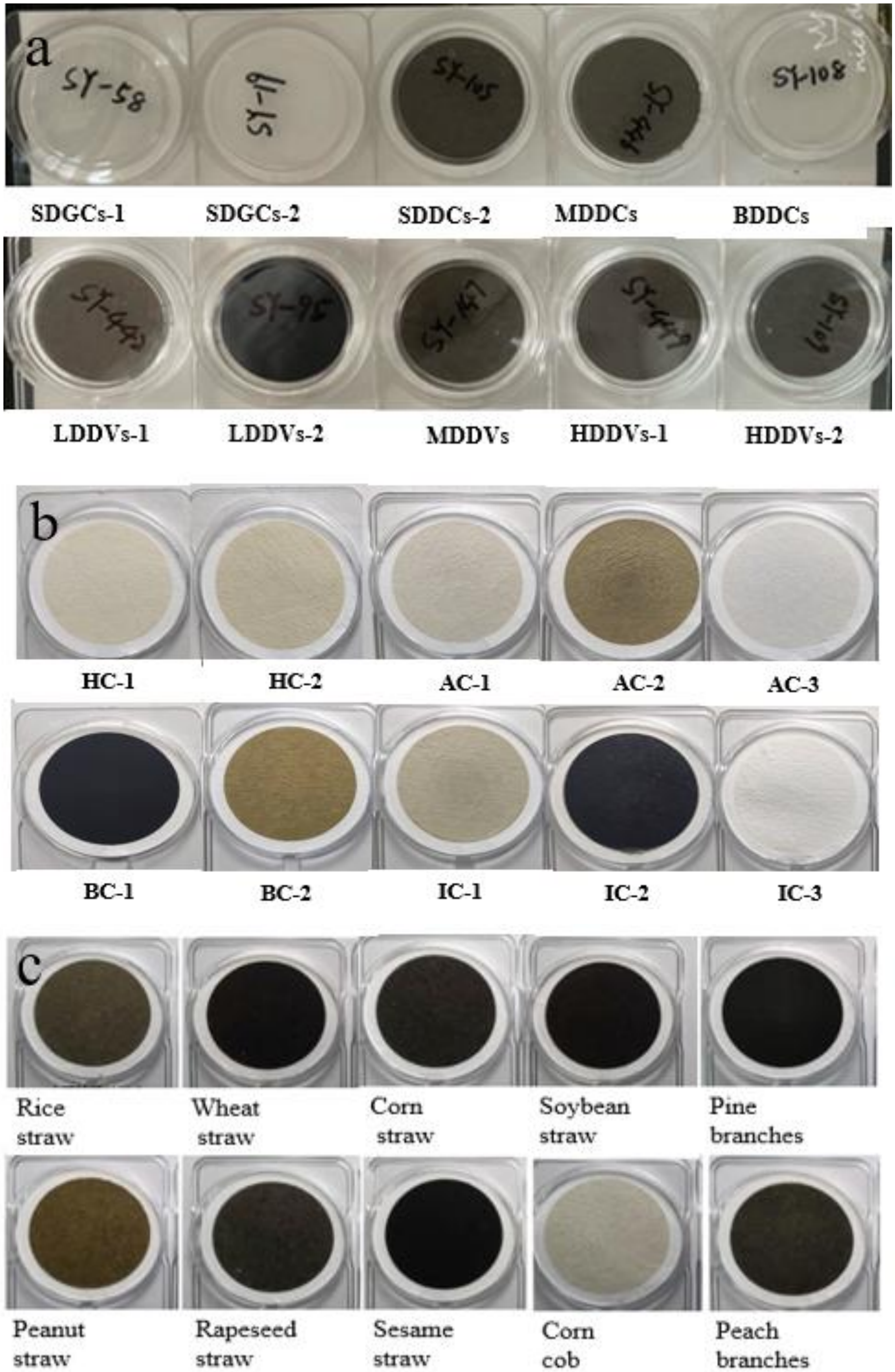


Figure S2. Samples of $PM_{2.5}$ loaded in quartz filters collected from 30 typical anthropogenic combustion sources (a: automobile exhaust; b: coal combustion; c: biomass burning).

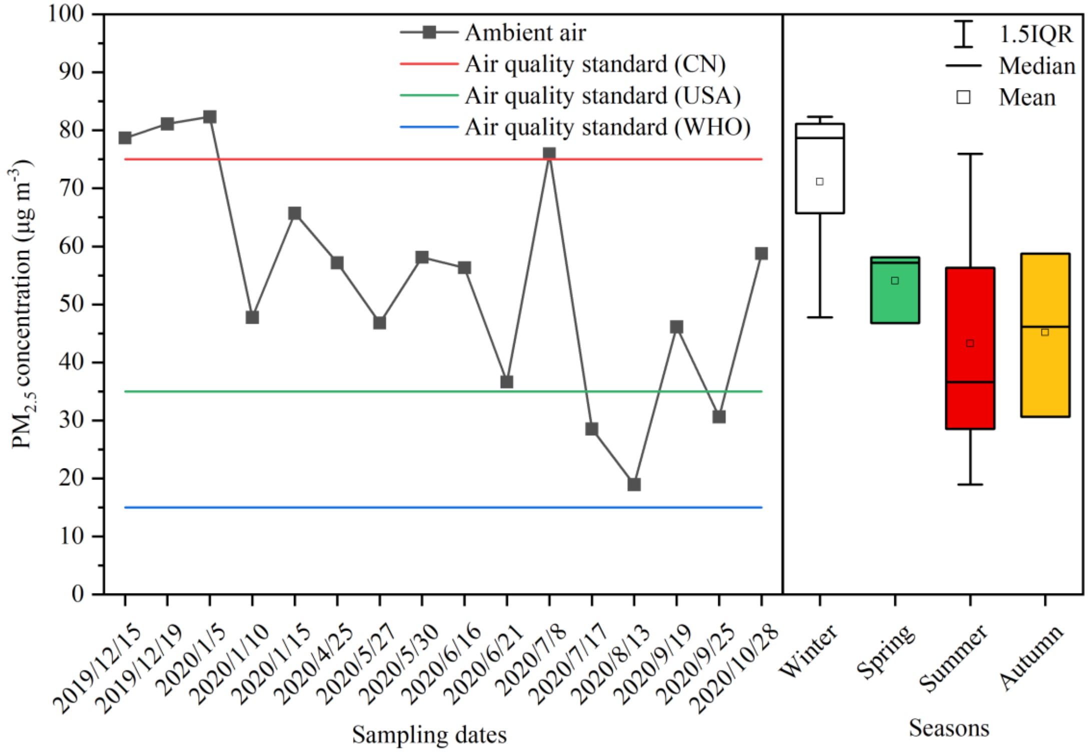


Figure S3. Example of daily urban air $PM_{2.5}$ concentrations (μg m^{-3}) monitored in Nanjing city, eastern China.

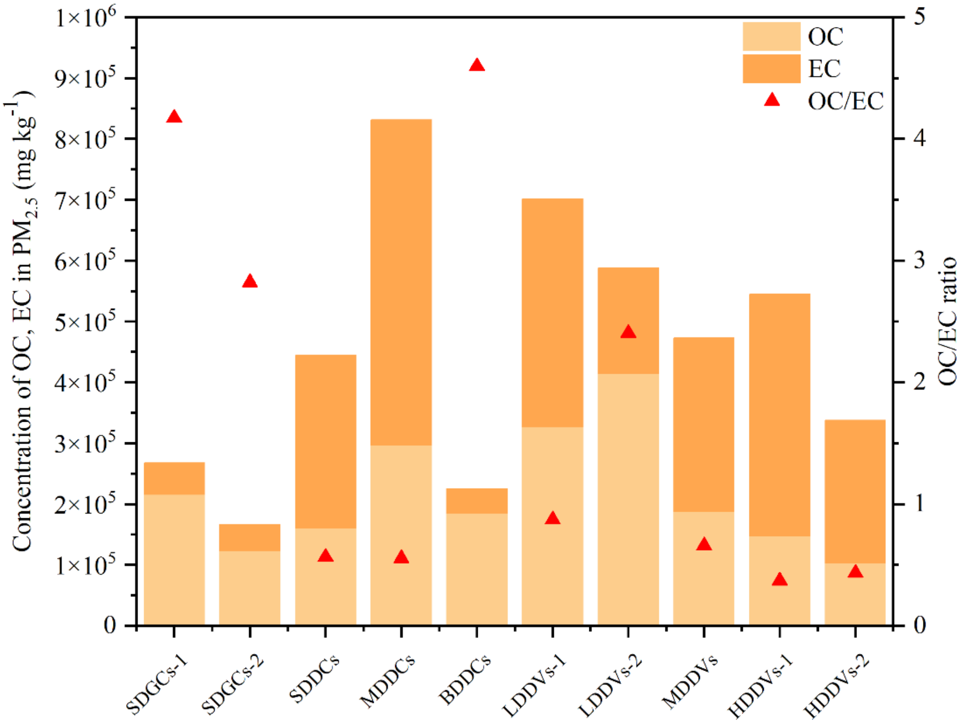
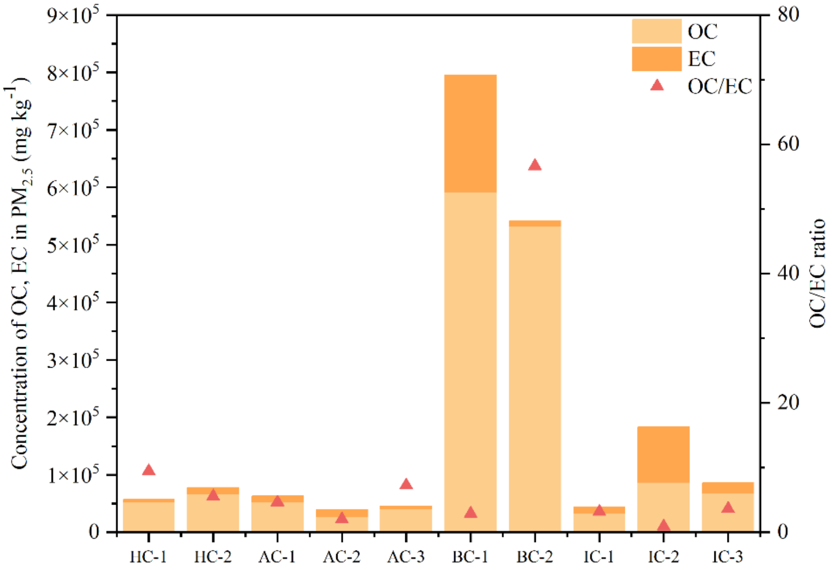


Figure S4. Contents (mg kg^{-1}) and ratio of carbon fractions in $PM_{2.5}$ from 10 types of automobile exhaust.



65 **Figure S5.** Contents (mg kg^{-1}) and ratio of carbon fractions in $PM_{2.5}$ from 10 types of coal combustion.

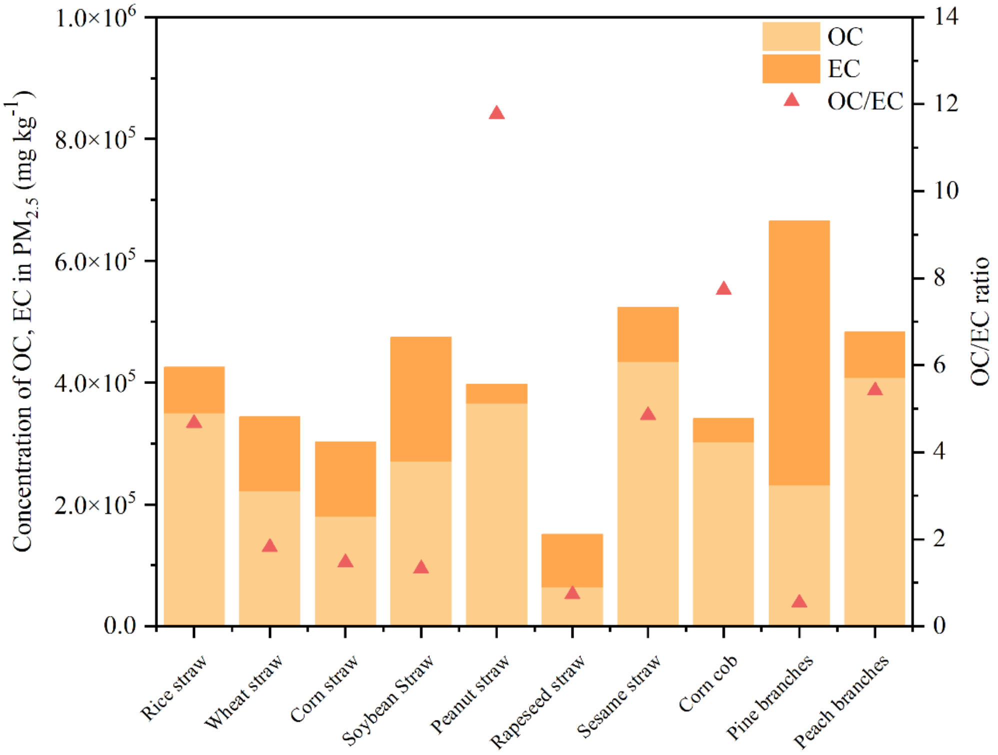


Figure S6. Contents (mg kg^{-1}) and ratio of carbon fractions in $PM_{2.5}$ from 10 types of biomass burning.

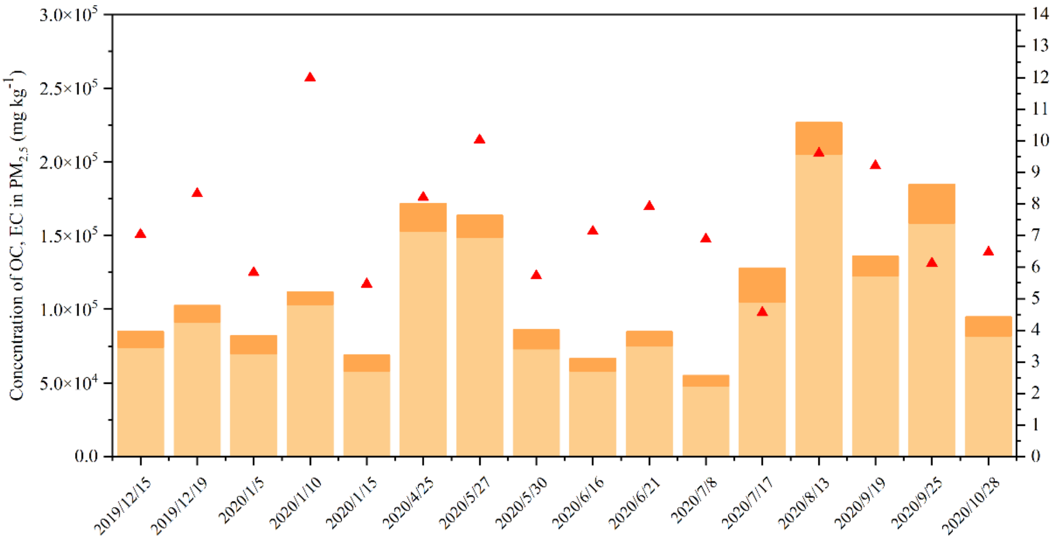


Figure S7. Contents (mg kg^{-1}) and ratio of carbon fractions in ambient air $PM_{2.5}$ from Nanjing city, eastern China.

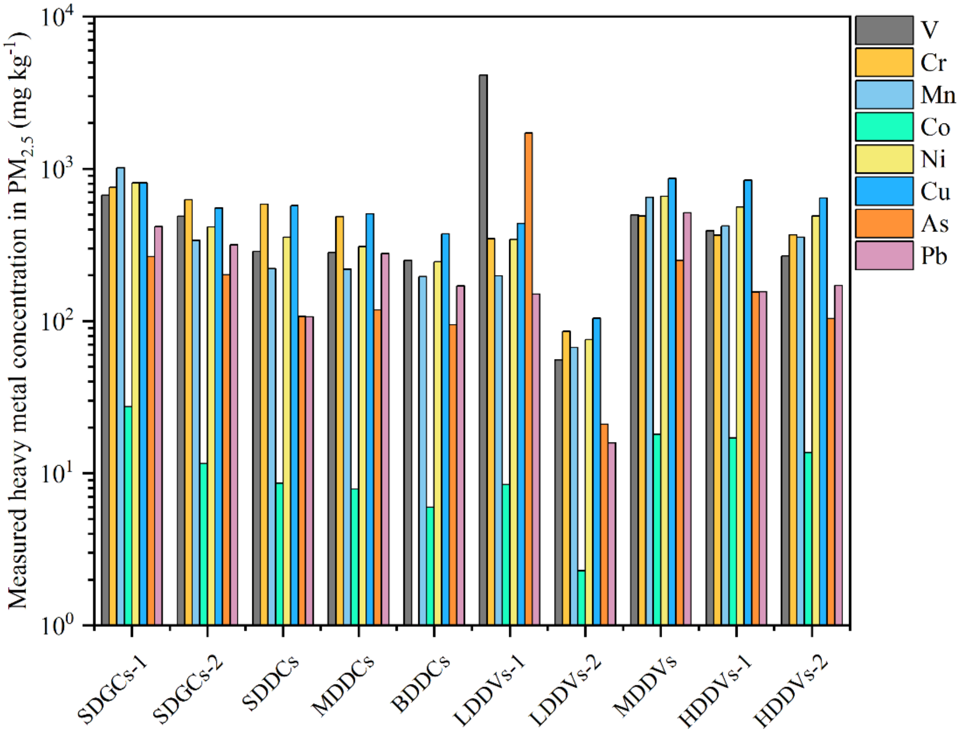


Figure S8. Heavy metal contents (mg kg^{-1}) in $PM_{2.5}$ from 10 types of automobile exhaust.

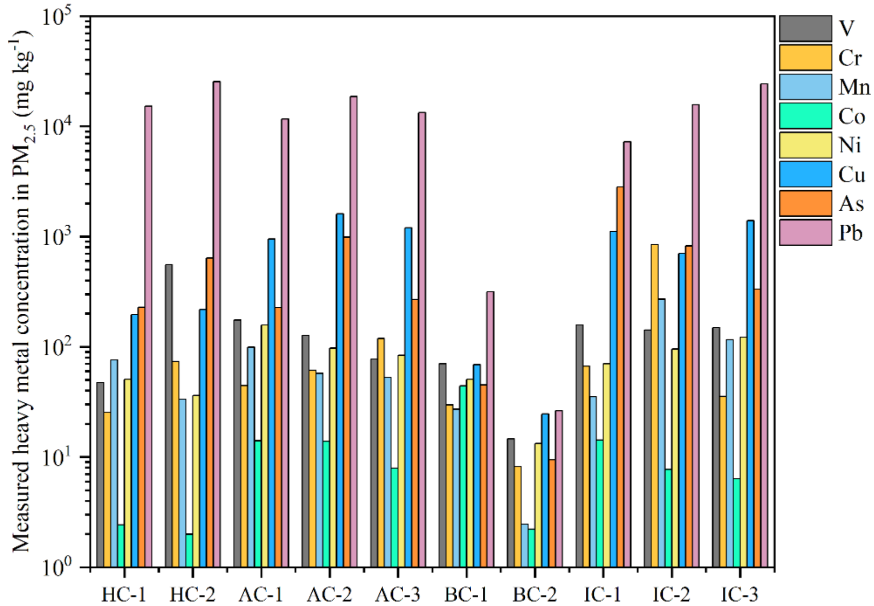


Figure S9. Heavy metal contents (mg kg^{-1}) in $PM_{2.5}$ from 10 types of coal combustion.

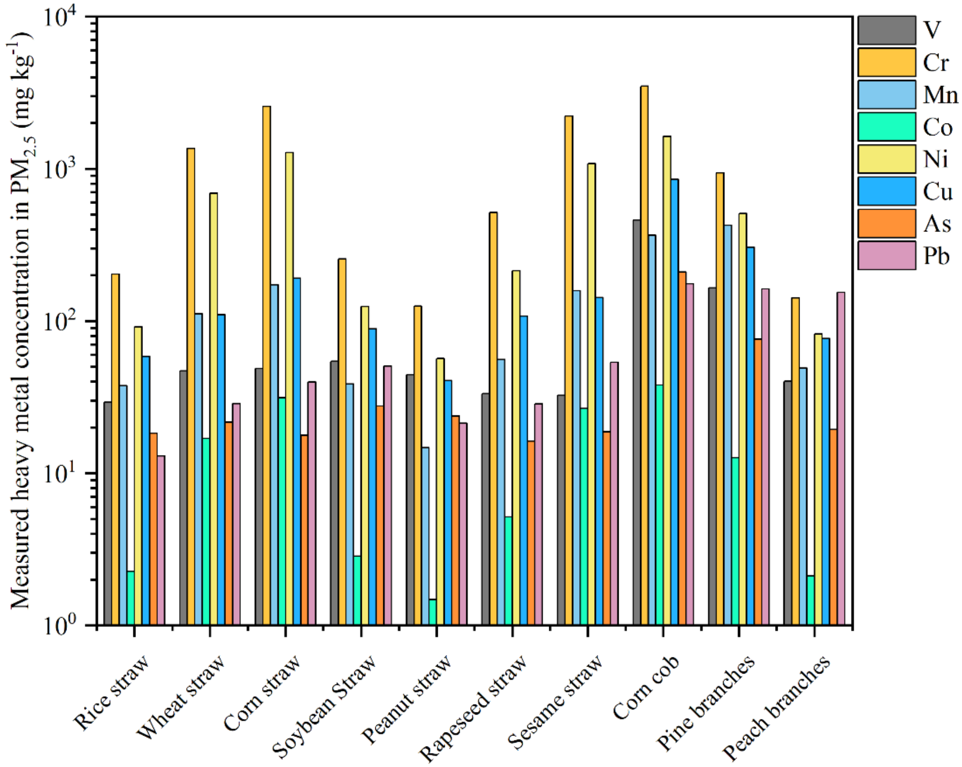


Figure S10. Heavy metal contents (mg kg^{-1}) in $PM_{2.5}$ from 10 types of biomass burning.

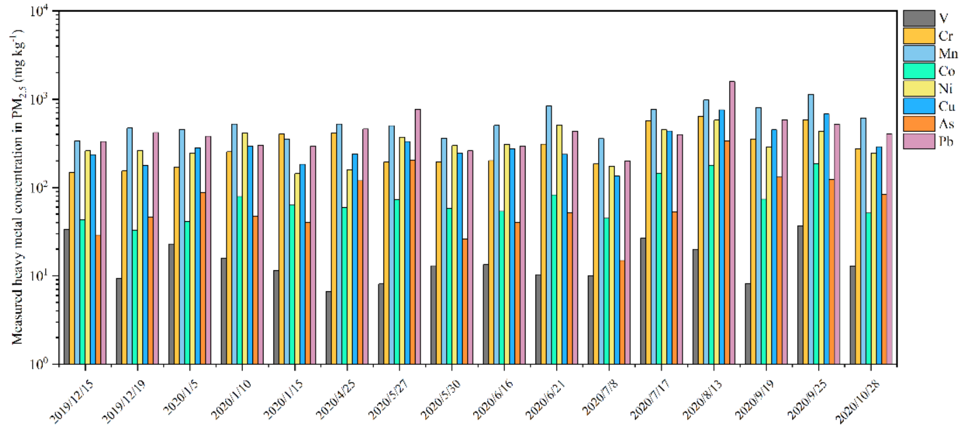


Figure S11. Heavy metal contents (mg kg^{-1}) in monthly ambient air $PM_{2.5}$ from Nanjing city, eastern China.

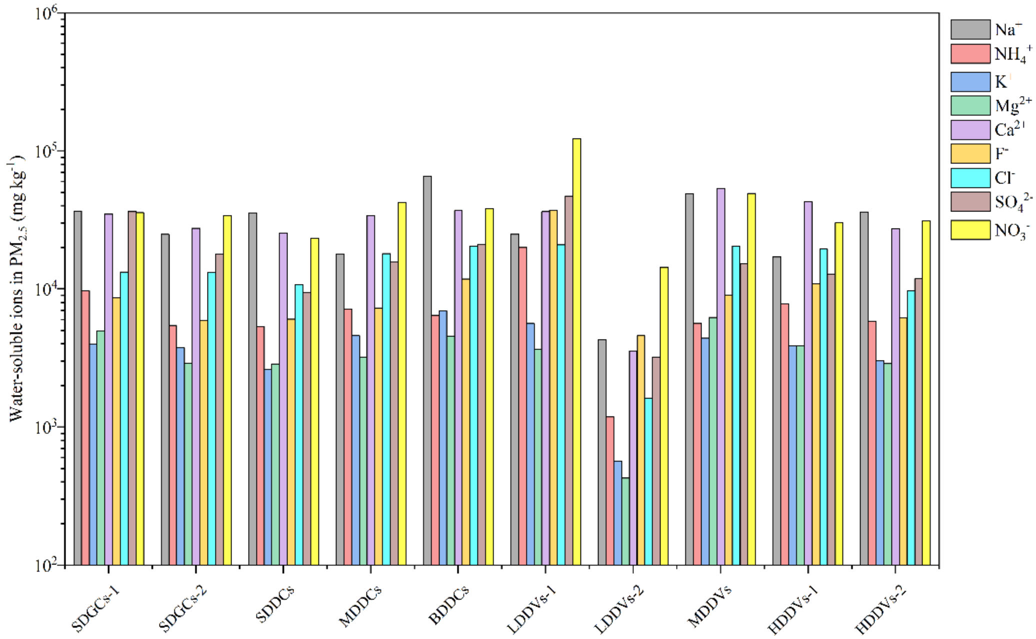


Figure S12. Water-soluble ions (WSIs) contents (mg kg^{-1}) in $PM_{2.5}$ from 10 types of automobile exhaust.

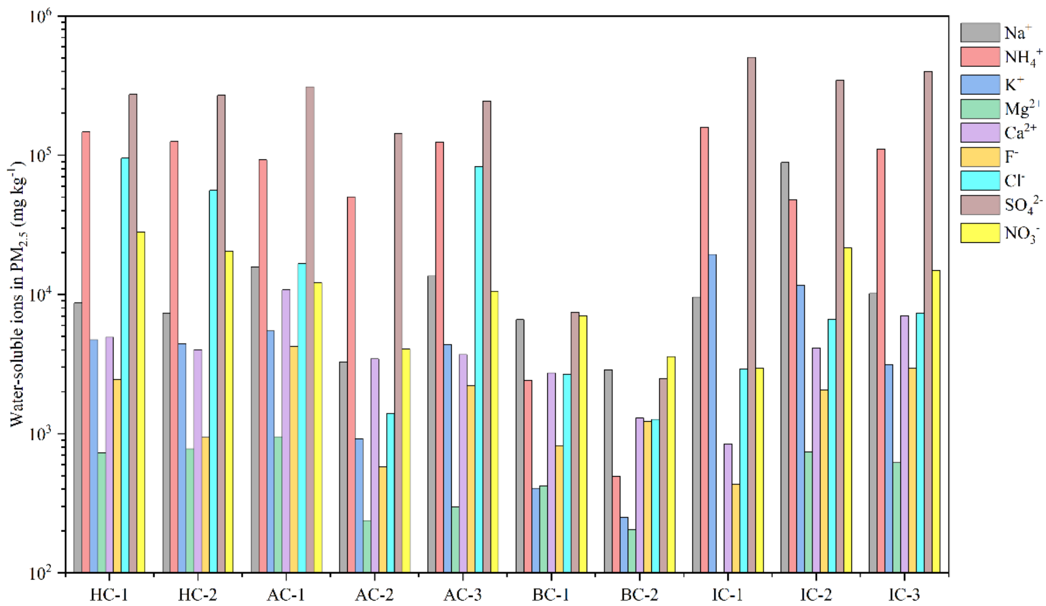


Figure S13. Water-soluble ions (WSIs) contents (mg kg^{-1}) in $PM_{2.5}$ from 10 types of coal combustion.

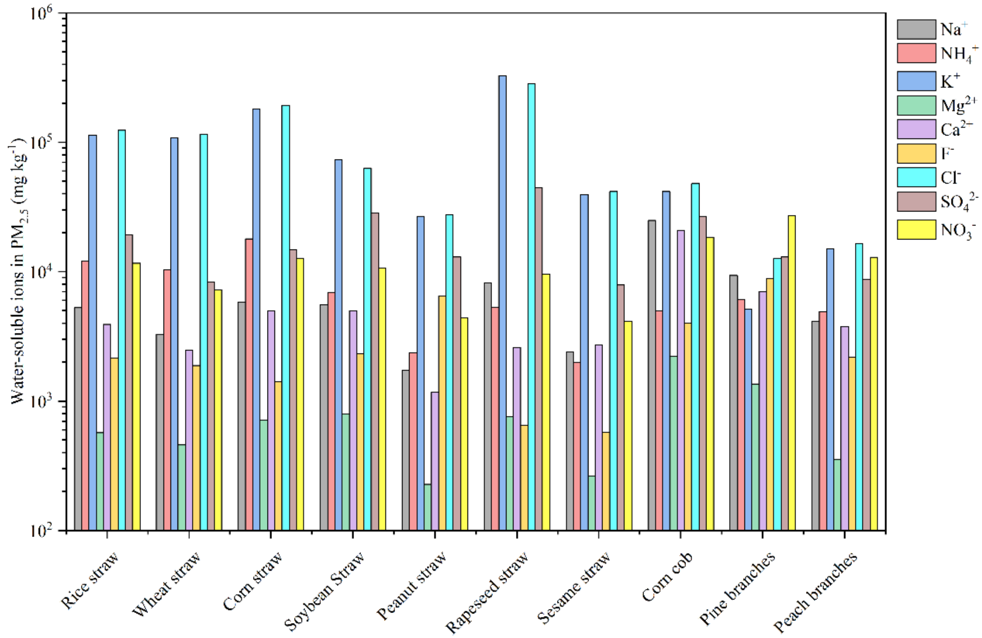


Figure S14. Water-soluble ions (WSIs) contents (mg kg^{-1}) in $PM_{2.5}$ from 10 types of biomass burning.

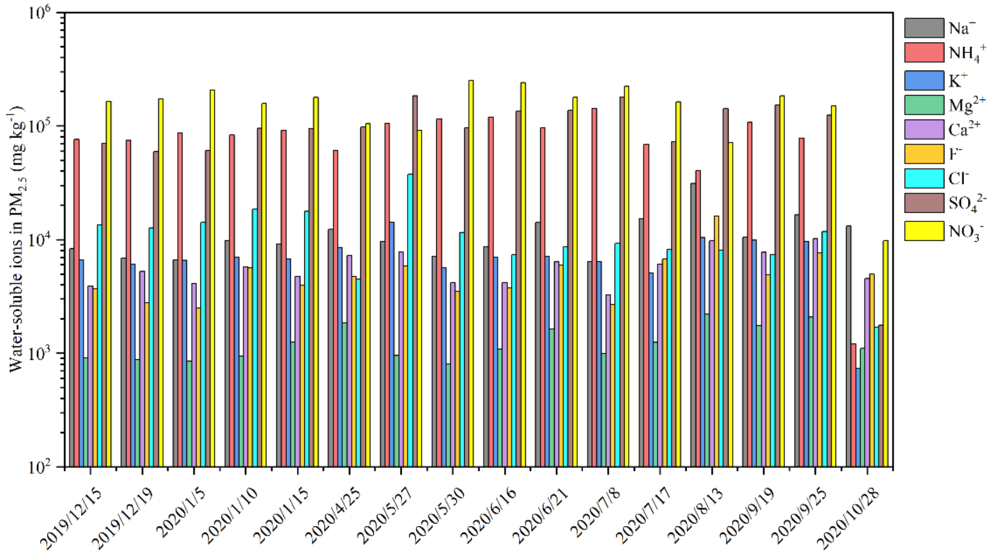


Figure S15. Water-soluble ions (WSIs) contents (mg kg^{-1}) in ambient air $PM_{2.5}$ from Nanjing city, eastern China.

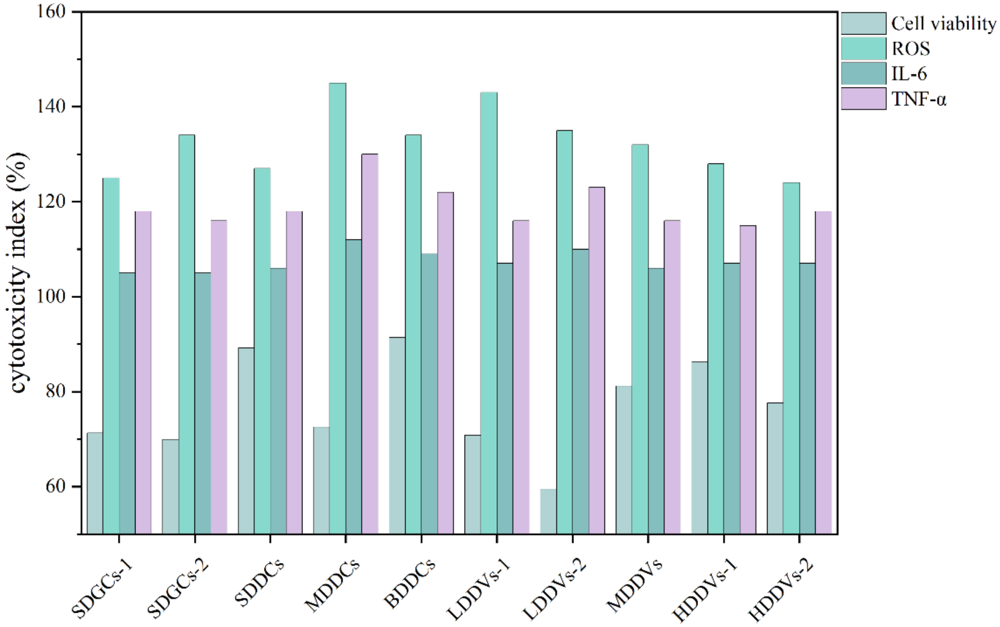


Figure S16. Cell viability, oxidative stress and inflammation levels exposed to $PM_{2.5}$ from 10 types of automobile exhaust.

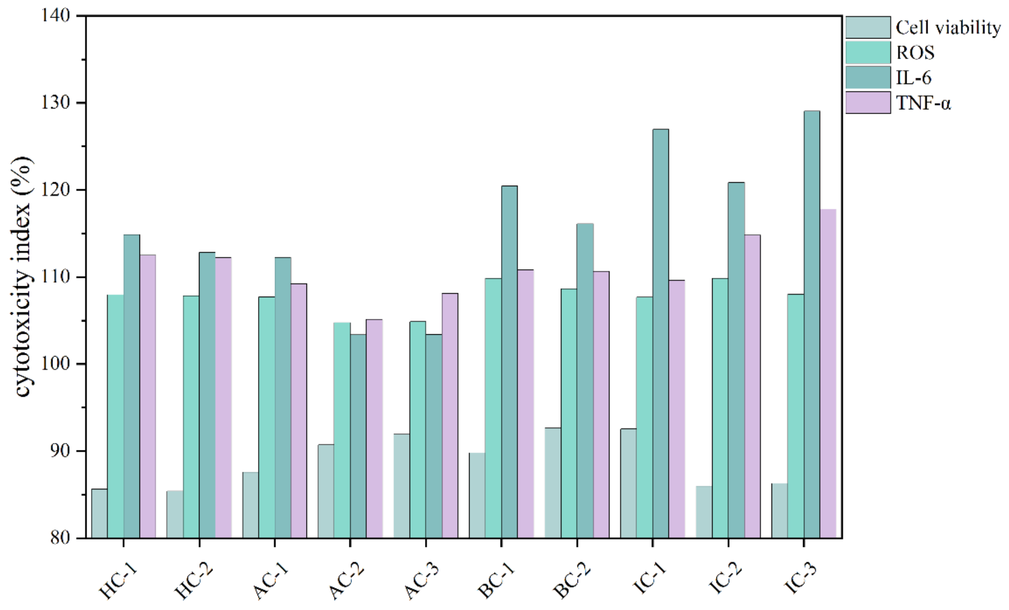


Figure S17. Cell viability, oxidative stress and inflammation levels exposed to $PM_{2.5}$ from 10 types of coal combustion.

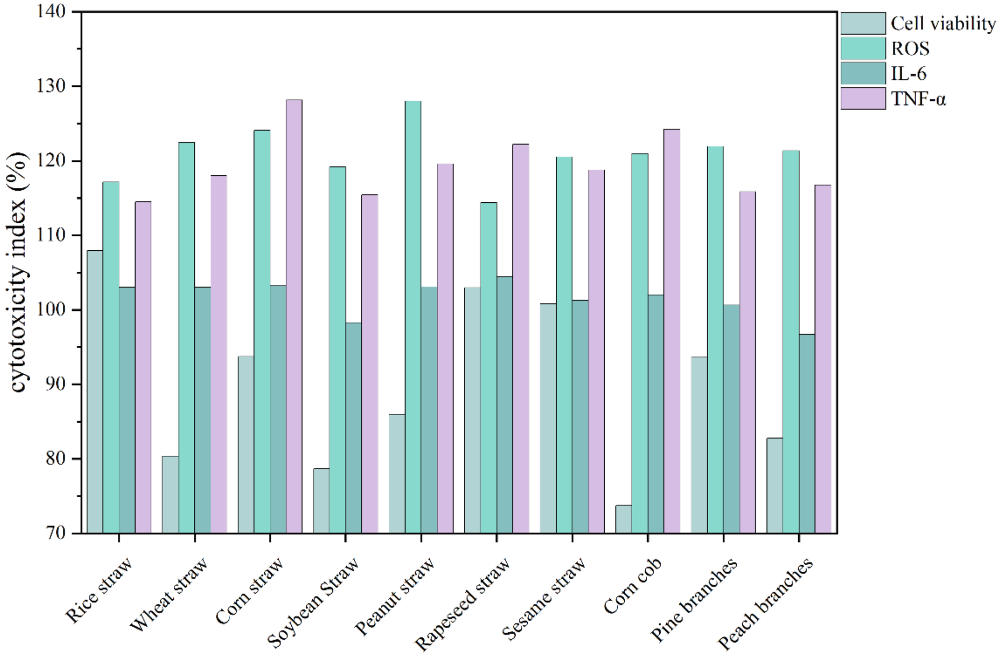


Figure S18. Cell viability, oxidative stress and inflammation levels exposed to $PM_{2.5}$ from 10 types of biomass burning.

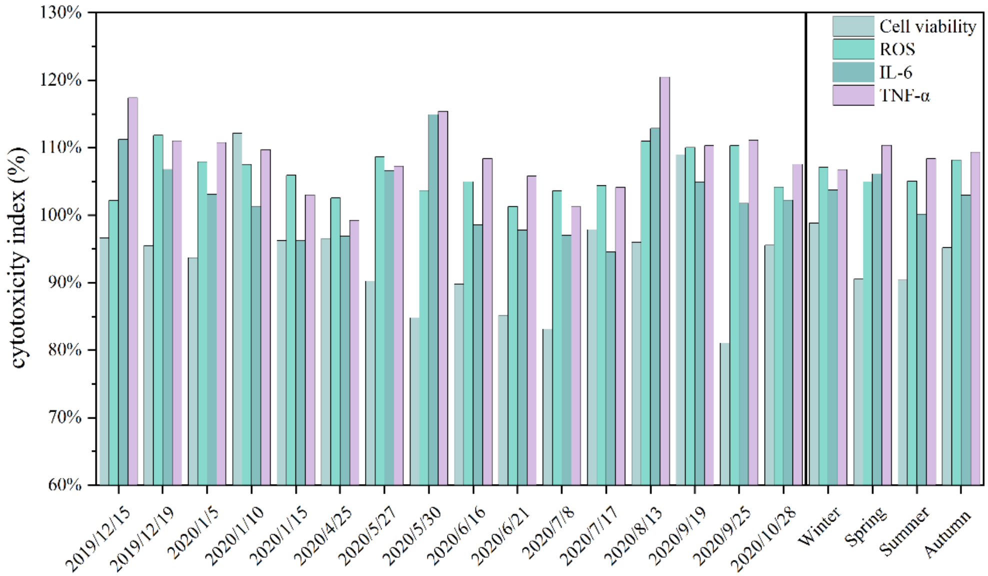


Figure S19. Cell viability, oxidative stress and inflammation levels exposed to various ambient air $PM_{2.5}$ from Nanjing city, eastern China.

Table S1. Characteristics of the investigated typical vehicles.

No.	Abbreviations	Vehicle types	Manufacture year	Emission standards	Fuel type	Weight (kg)
#1	SDGCs-1	Small duty gasoline coach	2015	CN.V	CN.92#	1970
#2	SDGCs-2	Small duty gasoline coach	2019	CN.VI	CN.92#	2110
#3	SDDCs	Small duty diesel coach	lost	CN.IV	CN.5#	1790
#4	MDDCs	Middle duty diesel coach	2009	CN.IV	CN.5#	3600
#5	BDDCs	Big duty diesel coach	2015	CN.V	CN.5#	15800
#6	LDDVs-1	Light duty diesel van	2009	CN.III	CN.5#	3970
#7	LDDVs-2	Light duty diesel van	2015	CN.IV	CN.5#	4500
#8	MDDVs	Middle duty diesel van	2014	CN.IV	CN.5#	7320
#9	HDDVs-1	Heavy duty diesel van	2015	CN.IV	CN.5#	29080
#10	HDDVs-2	Heavy duty diesel van	2019	CN.V	CN.5#	40000

Table S2. Characteristic analysis of typical coal samples.

Coal types	M_{ad} (%)	A_{ad} (%)	V_{ad} (%)	FC_{ad} (%)	Origin
HC-1	1.87	46.2	9.87	42.1	Nanjing city
HC-2	2.15	49.3	9.63	38.9	Nanjing city
AC-1	1.26	10.2	10.6	78.0	Ningxia province
AC-2	1.19	12.5	10.8	75.5	Anhui province
AC-3	1.76	6.78	8.99	82.5	Shanxi province
BC-1	5.23	1.84	41.5	51.5	Inner Mongolia province
BC-2	7.06	5.07	29.8	58.0	Henan province
IC-1	0.43	13.0	1.63	85.0	Nanjing Iron & Steel Co.
IC-2	1.74	11.1	30.3	56.9	China Resources Jiangsu Nanre Power Generation Co.
IC-3	4.37	8.17	30.9	56.5	Huaneng Nanjing Jinling Power Generation Co.

Note: M_{ad} is the moisture mass fraction of the sample on an air-dried basis; A_{ad} is the ash mass fraction of the sample on an air-dried basis; Vd_{ad} is volatile matter mass fraction of sample on dry air-dried basis; FC_{ad} is fixed carbon fraction of the sample on an air-dried basis; $FC_{ad} = 1 - M_{ad} - A_{ad} - Vd_{ad}$.

Table S3. Characteristic analysis of typical biomass fuel samples.

Biomass types	M_{ad} (%)	A_{ad} (%)	V_{ad} (%)	FC_{ad} (%)
Rice straw	10.8	14.6	59.8	14.9
Wheat straw	12.1	5.65	65.5	16.8
Corn straw	11.6	4.22	66.1	18.1
Soybean Straw	11.0	4.62	68.4	16.0
Peanut straw	15.0	10.8	61.4	12.8
Rape straw	11.1	2.95	68.8	17.1
Sesame straw	13.1	7.64	63.7	15.5
Corncob	9.21	0.66	73.5	16.7
Pine branches	13.4	0.33	66.6	19.7
Peach branches	9.94	0.65	73.4	16.0

Note: M_{ad} is the moisture mass fraction of the sample on an air-dried basis; A_{ad} is the ash mass fraction of the sample on an air-dried basis; Vd_{ad} is volatile matter mass fraction of sample on dry air-dried basis; FC_{ad} is fixed carbon fraction of the sample on an air-dried basis; $FC_{ad} = 1 - M_{ad} - A_{ad} - Vd_{ad}$.