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The water-insoluble organic carbon in $PM_{2.5}$ of typical Chinese urban areas: light-absorbing properties, potential sources, radiative forcing effects, and a possible light-absorbing continuum

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Text S1. Water soluble inorganic ions measurements

3 anions (Cl^-, NO_3^- and SO_4^{2-}) and 4 cations (Na^+, K^+, Ca^{2+} and NH_4^+) were analyzed with ion-chromatography (761 Compact IC, Metrohm, Switzerland). Anions were separated on a Metrohm Metrosep A sup5-250 column with 3.2 mM Na_2CO_3 and 1.0 mM $NaHCO_3$ as the eluent and 35 mM H_2SO_4 for a suppressor. Cations were measured using a Metrohm Metrosep C4-150 column with 2 mM sulfuric acid as the eluent. The injection loop volume for anion and cation was 100 μL. The water-soluble ions analyses were duplicated for several filter samples, and the overall relative standard deviations were generally less than 4%.

Text S2. Calculation of MAC for particulate light-absorbing OC

MAC can be compared with MAE only after considering the particulate effect (ξ) and in the small-particle limit (diameter << λ) (Sun et al., 2007):

$$\mathrm{MAC}(\lambda) = \mathrm{MAE}(\lambda) \times \xi(\lambda) \quad \text{(S1)}$$

$$\xi(\lambda) = \frac{9n}{(n^2 - k(\lambda)^2 + 2) + 4n^2 k(\lambda)^2} \quad \text{(S2)}$$

where n and k represent the real and imaginary parts of the complex refractive index ($m = n + ik$), respectively. In this study, we assume a constant n value of 1.55 (Lu et al., 2015), and the wavelength-dependent k is calculated as:

$$k\,(\lambda) = \frac{\rho \times \lambda \times \mathrm{MAE}(\lambda)}{4\pi \times \left(\frac{OA}{OC}\right)} \quad \text{(S3)}$$

where ρ is the density of particle and was fixed to 1.2 g/cm^3. The OA/OC ratios are 1.51, 1.91, 2.30 for WIOC, HULIS and non-HULIS, respectively (Kiss et al., 2002).

Table S1. Summary of concentration and light absorption of extractble organic carbon components in $PM_{2.5}$ from ten Chinese cities

Component	Unit	Warm seasons rang (avg[a] ± std[b])	Cold seasons rang (avg ± std)	Annual avg ± std
WIOC		1.45−5.25 (2.29 ± 0.95)	1.93−12.9 (4.87 ± 2.89)	3.65 ± 2.53
HULIS-C	$\mu gC/m^3$	1.37−4.31 (2.46 ± 0.77)	2.10−7.64 (4.63 ± 1.49)	3.60 ± 1.62
Non-HULIS-C[c]		1.28−5.61 (2.36 ± 1.16)	1.55−7.96 (4.09 ± 1.51)	3.27 ± 1.60
EX-OC[d]		4.19−12.8 (7.11 ± 2.38)	6.25−25.2 (13.6 ± 5.22)	10.5 ± 5.23
$Abs_{365, WIOC}$		1.27−7.69 (2.76 ± 1.77)	2.78−38.5 (10.4 ± 8.69)	6.80 ± 7.44
$Abs_{365, HULIS}$	Mm^{-1}	1.04−6.05 (2.96 ± 1.4)	2.27−17.2 (8.72 ± 3.75)	5.99 ± 4.08
$Abs_{365, non-HULIS}$		0.53−2.72 (1.25 ± 0.68)	1.11−8.50 (3.76 ± 2.27)	2.57 ± 2.11
$Abs_{365, EX-OC}$		3.24−16.1 (6.98 ± 3.54)	6.42−55.4 (22.9 ± 13.0)	15.4 ± 12.6
WIOC/EX-OC		15.4−48.7 (32.5 ± 6.97)	19.8−57.5 (34.2 ± 8.12)	33.4 ± 7.55
HULIS-C/EX-OC		25.2−45.4 (35.1 ± 5.29)	19.2−47.6 (35.3 ± 6.32)	35.2 ± 5.77
Non-HULIS-C/EX-OC		21.1−43.8 (32.4 ± 5.92)	23.4−36.6 (30.5 ± 4.34)	31.4 ± 5.17
$Abs_{365, WIOC}/Abs_{365, EX-OC}$	%	20.3−50.6 (38.4 ± 9.06)	29.4−69.6 (42.5 ± 10.1)	40.5 ± 9.73
$Abs_{365, HULIS-C}/Abs_{365, EX-OC}$		32.2−55.1 (42.8 ± 6.54)	22.5−57.9 (40.5 ± 7.90)	41.6 ± 7.28
$Abs_{365, non-HULIS-C}$ / $Abs_{365, EX-OC}$		9.51−26.8 (18 ± 4.43)	6.80−30.4 (17.0 ± 5.58)	17.5 ± 5.02

[a] avg: average

[b] std: standard deviation

[c] The concentration of non-HULIS-C is calculated by the difference between WSOC and HULIS-C

[d] The concentration of extractable organic carbon (EX-OC) is the sum of WSOC and WIOC.

Table S2. The person correlation coefficients (r) of concentrations and Abs_{365} of WIOC with water soluble ions in cold and warm seasons.

	Concentrations of WIOC		Abs_{365} of WIOC	
	Warm seasons	Cold seasons	Warm seasons	Cold seasons
K^+	0.04	0.61^{**}	0.25	0.48^{*}
Cl-	0.46	0.92^{**}	0.63^{**}	0.90^{**}
NO_3^-	0.38	0.29	0.53^{*}	0.18
SO_4^{2-}	0.44	0.69^{**}	0.51^{*}	0.63^{**}
NH_4^+	0.51^{*}	0.51^{*}	0.59^{*}	0.49^{*}

* Significance at $p < 0.05$ level

** Significance at $p < 0.01$ level

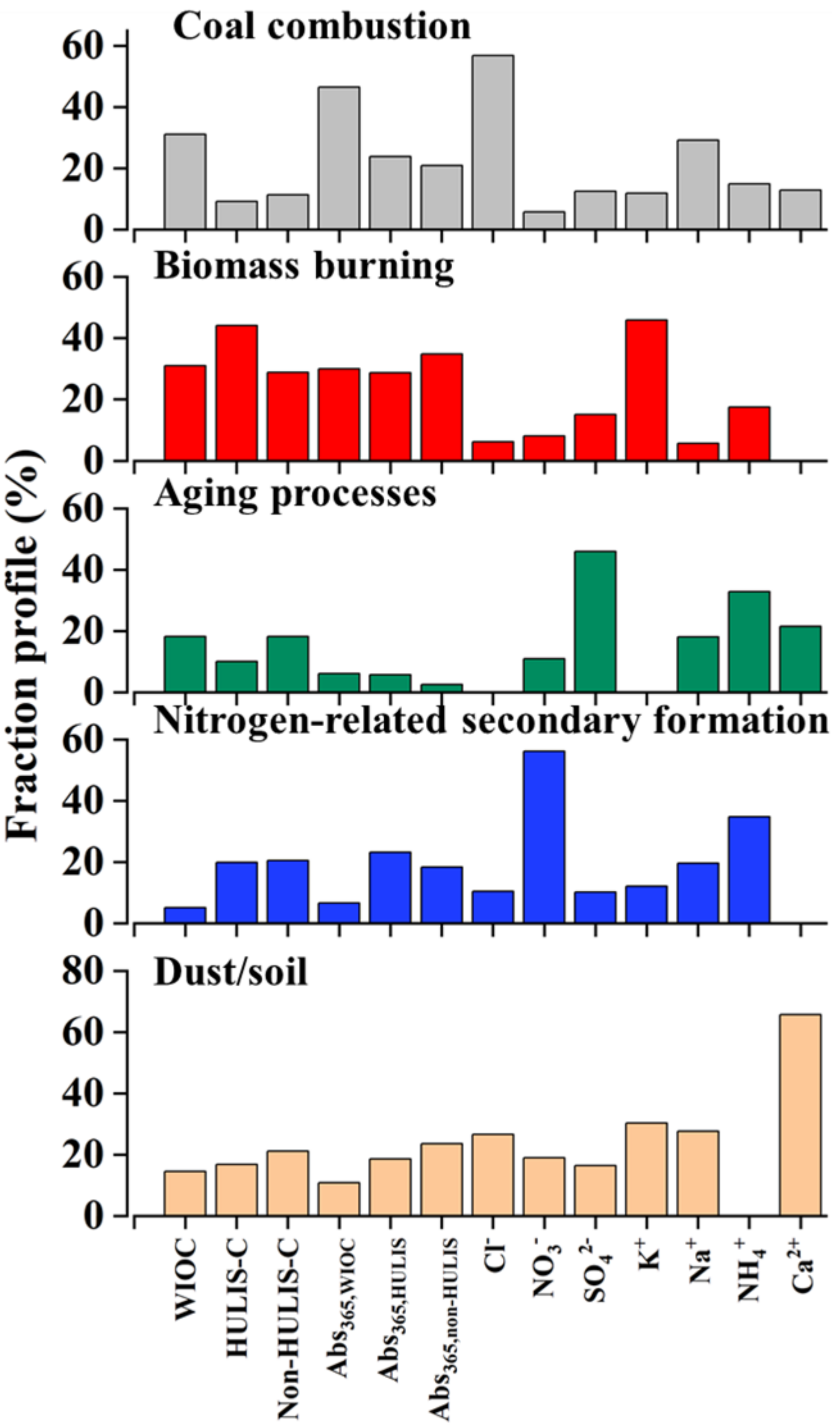

Figure S1. Source profiles for five sources resolved by the positive matrix factorization (PMF) model.

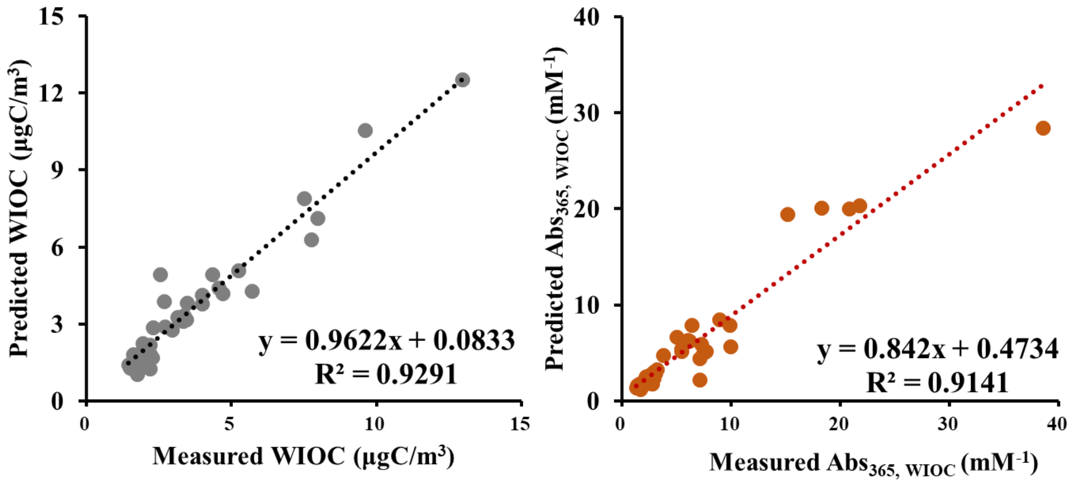

Figure S2. PMF-predicted versus measured values of (a) concentrations and (b) Abs_{365} of WIOC.

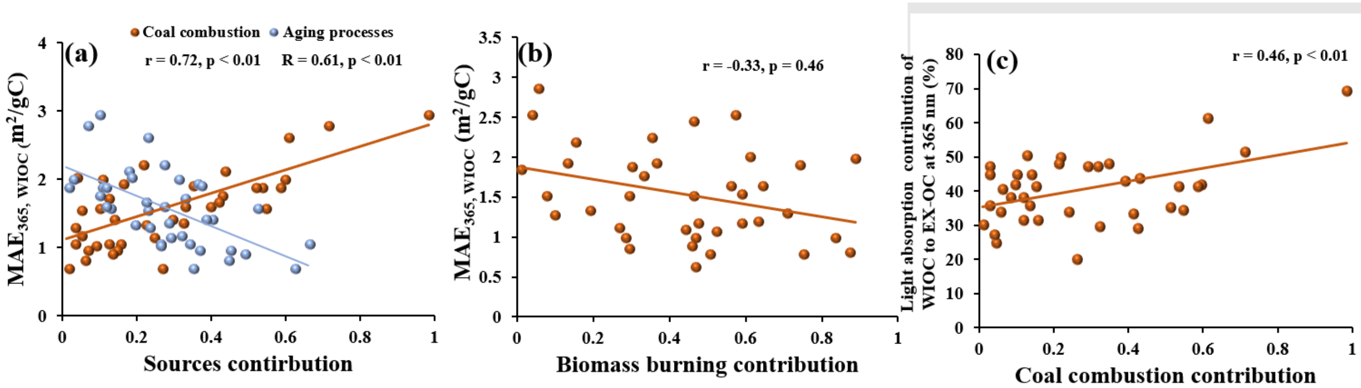

Figure S3. (a) The correlation of mass absorption efficient (MAE_{365}) of WIOC to relative contribution of coal combustion (brown dots) and aging processes (blue dots). (b) The relationship between the MAE_{365} of WIOC and relative contribution of biomass burning. (c) The relationship between relative contribution of coal combustion and light absorption contribution of WIOC to EX-OC at 365 nm.

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