Supplement of

Emission factors and light absorption properties of brown carbon from household coal combustion in China

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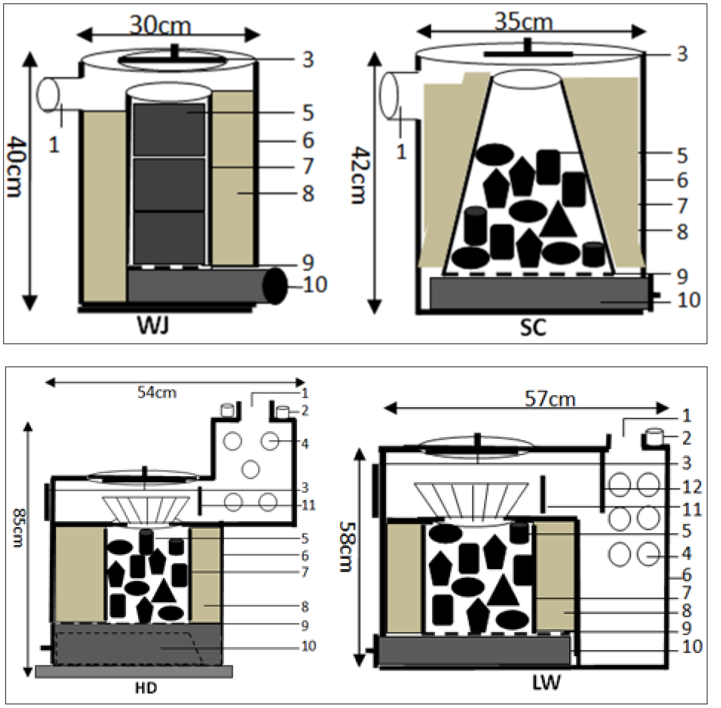

Figure S1. Cross sections of the selected Chinese residential coal-stoves.

Note: WJ, WanJia brand briquette stove; SC, Simple Chunk stove; HD, HuanDing brand chunk stove; LW, LaoWan brand chunk stove. 1, metal chimney; 2, circulation water; 3, removable lid; 4, circulation water; 5, fuel; 6, iron casting; 7, ceramic cylinder; 8, ceramic fiber for heating insulation; 9, steel grates; 10, air inlet and/or dust bin; 11, adjustable iron baffle; 12, fixed iron baffle.

Here are the dimensions of all 4 stoves (Chen et al., 2005; Zhi et al., 2008). Among them, WJ is specifically for honeycomb briquettes and the other three (SC, HD, and LW) are for raw-coal chunks. In addition, the briquette stove WJ and chunk stove SC are of traditional style widely used especially in past decades in China’s households for heating rooms through direct thermal radiation. HD and LW are actually mini-boilers of low pressure type used for heating rooms by heated water circulating through a piping system (2, 4). Compared to HD, the LW stove has an additional iron baffle vertically fixed before the flue pipe so as to lengthen the time of heat exchange between hot flue gas and circulating water.

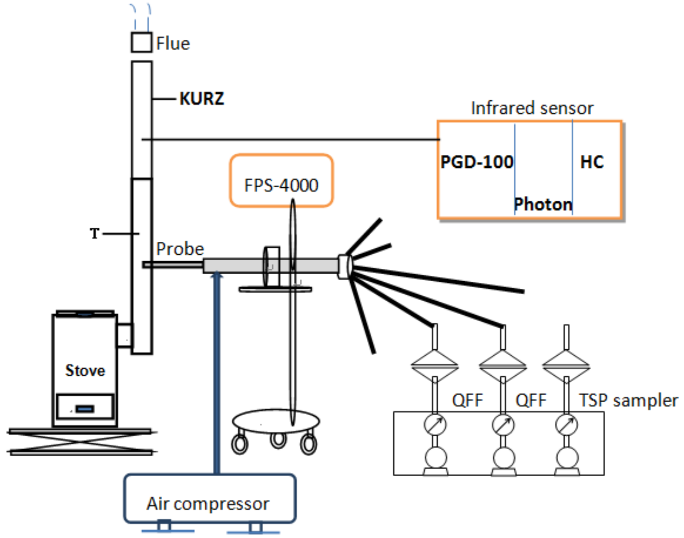

Figure S2. Diversion-dilution-sampling system.

Methods for calculation of EFs (BC and BrC), AAEs, $f_{BrC}(\lambda)$, and F_{BrC}

(A) EFs

Each EF (g/kg) of BC or BrC can be calculated as follows (Chen et al., 2005; Zhi et al., 2008):

$$EF = CF \times \rho \times A \times 10^{-6} / ((M1 - M2) \times f) \quad \text{.....................} (1)$$

Where,

CF—conversion factor from measured equivalent of carbon black (CarB) to BC or from measured equivalent of humic acid sodium salt (HASS) to BrC. As described in our manuscript, CF is 1 for the former and is 0.47 for the latter

ρ—the mass of CarB equivalent or HASS equivalent per unit area of sampling filter ($\mu g/cm^2$)

A—the area of sampling filter (cm^2)

M1—the mass of coal before combustion (kg)

M2—the mass of coal after combustion (kg)

f—the fraction of sampled flue gas in total flue gas

(B) AAEs

Based on the light absorption at the wavelength pair of 365 and 650 nm measured by the IS method, AAEs are calculated as follows(Krivácsy et al., 2001; Chen and Bond, 2010; Sun et al., 2007; Lukács et al., 2007; Lack et al., 2012; Yuan et al., 2015; Forrister et al., 2015):

$$AAE = \frac{-\ln(A650/A365)}{\ln(650/365)} \quad \text{.....................} (2)$$

(C) $f_{BrC}(\lambda)$ and F_{BrC}

The spectrally dependent absorbance by BrC ($ABS_{BrC}(\lambda)$) is obtained by subtracting the BC absorbance from the total absorbance (Kirchstetter et al., 2012; Chakrabarty et al., 2014):

$$ABS_{BrC}(\lambda) = ABS_{sum}(\lambda) - ABS_{BC}(\lambda) \quad \text{.....................} (3)$$

Then, in each wavelength, the fraction of BrC absorbance in total absorbance ($f_{BrC}(\lambda)$) is calculated as:

$$f_{BrC}(\lambda) = ABS_{BrC}(\lambda)/ABS_{sum}(\lambda) \quad \text{.....................} (4)$$

Finally, solar spectrum is considered. The average fraction of absorbed solar radiation by BrC relative to the combined absorption by BrC+BC over the wavelength range from 350 to 850 nm

$$F_{BrC} = \frac{\int_{350}^{850} fBrC(\lambda)\, k(\lambda) d\lambda}{\int_{350}^{850} k(\lambda) d\lambda} \quad \text{.....................} (5)$$

Where k(λ) is the clear sky air mass one global horizontal solar spectrum at the earth's surface (Levinson et al., 2010).

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