Indoor PM from residential coal combustion: levels and chemical composition

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Coal is still the dominant fuel contributing to the $PM_{2.5}$ disease burden in several countries (McDuffie et al., 2021). Even though the greatest health losses caused by solid fuels combustion were recorded in Eastern and South-eastern Asia and Sub-Saharan Africa (IEA, IRENA, UNSD, World Bank 2022), coal combustion is still used as a source of heating in several European countries (Kerimray et al., 2017). Thus, considering that quantitative estimates of residential coal combustion for indoor air pollution levels in European countries are limited so far, this study intends to assess household PM levels in a household that relies on coal for wintertime heating. Additionally, the chemical characteristics of PM samples will be evaluated.

The combustion experiments were conducted in a detached house without permanent occupation. Indoors, sampling took place in the kitchen/living area (open space), where a small-scale stand-alone stove was installed. Concurrent outdoor measurements were performed. The study consisted of five days of burning, mimicking similar combustion conditions. The experiments started by lighting newspaper sheets and wood chips. Afterwards, the stove was fuelled with a new batch of wood chips to raise the temperature in the combustion chamber. Then, a total of 6 batches of mineral coal were burned. Two days of background measurements (without indoor sources) were also performed. The airborne samples were collected using high volume samplers (MCV-CAV) and continuously monitored using real time photometric devices (DustTrak). The chemical composition was obtained by ICP-MS/OES (elements), ion chromatography (water-soluble inorganic ions) and thermal-optical analysis (organic and elemental carbon).

During coal combustion, PM_{10} average concentration indoors ranged from 33.3 to 169 μg m^{-3}, which represented increases over background ranging from 1.6 to 8.8 times. The mean I/O PM_{10} ratio was 2.1 ± 1.3 during the coal combustion experiments. From the real time monitoring of particulate mass concentrations indoors, daily fluctuations in the levels and peaks of indoor PM as high as several hundreds of μg m^{-3} were observed. The peaks recorded appeared to result from the refuelling activities. Additionally, the ignition and stove initial pre-heating generated a high peak in the PM concentrations.

Indoors, OC dominated the carbonaceous component of the sampled particles, accounting on average for 14.5–24.9 wt.% of the total PM_{10} mass, except for the last day of burning, during which EC was the most abundant species (17.7 wt.% of the PM_{10} mass). In general, the I/O ratio was larger than 1 for OC (3.4 ± 2.9), highlighting the presence of significant indoor sources. Nevertheless, much higher ratios were observed for EC (10.1 ± 9.2).

The contribution of water-soluble ions to the PM_{10} mass was higher outdoors (27.2 ± 8.20 %wt.), than indoors during coal combustion (5.90 ± 3.70 %wt.). Indoors, the most abundant water-soluble ions were SO_4^{2-} and NO_3^- during coal combustion. Major and trace elements represented 4.37 ± 2.02 wt.% of the PM_{10} mass indoors, while outdoors the average contribution was higher, ranging from 8.04 ± 0.353 wt.% to 11.7 ± 3.44 wt.%. The concentration of toxic and carcinogenic species (such as As, Cr, Pb) increased indoors during coal combustion, which is of particular relevance regarding health effects.

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