Impact of wood combustion in an open fireplace on indoor residential air quality: Respirable Fraction

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In Spain, as in many other European countries, mainly in rural areas, open fireplaces are still present. Important quantities of wood are combusted in these domestic devices every year. Some studies have pointed out that wood-burning fireplaces are potential sources of indoor air pollutants, mainly fine particles (Salthammer *et al*., 2014). There are several factors that can have an important influence on pollutant emissions, such as the stove design, operating conditions, combustion conditions (e.g. amount of excess air) and the species of wood and their characteristics.

The present study aims to characterize aerosol size distributions and chemical composition of particles emitted during the combustion of logs of a common Southern and mid-European wood (*Quercus pyrenaica* – oak) in an open fireplace. The wood was cut into logs of 0.25 to 0.30 m in length. A total of 10 combustion experiments were performed. During each experiment, the fireplace was fed with oak logs four times. This methodology tries to reproduce the common procedure carried out in the houses. In the startup phase, 1.5 kg of oak chips, 400 g of branches and two sheets of newspaper were used. For the other three refueling processes, between 11.5 and 12.7 kg of oak were added. The duration of each combustion experiment was about 4-5 hours with a sequential average duration of each phase of 10, 60, 60 and 130 min, respectively.

Wood combustion experiments were carried out using a traditional Spanish brick open fireplace operated manually in batch mode and with no control of combustion air. The fireplace is characterized by a combustion chamber with a volume of 0.09 m^3, corresponding to 0.35 m height, with a trapezoidal base of 0.52 and 0.63 m width and 0.45 m depth. This combustion device is installed in the living room of a typical village house in Báscones de Valdivia (Palencia, Spain). The room volume was 41 m^3. Temperature in the combustion chamber was monitored each 10 min using an infrared thermometer FLUKE.

Two different instruments were used for particle sampling: i) an optical particle counter (PCASP-X), for the continuous monitoring of particle size distributions and ii) a Gent PM_{10} stacked filter unit sampler using quartz filters for later chemical analyses. In two of the 10 experiments, polycarbonate filters (0.2 µm pore size) were used for later microscopic analysis. The morphology and elemental composition of individual aerosol particles were investigated by field emission scanning electron microscopy (FE-SEM).

CO and CO_2 concentrations were monitored each minute using a HERTER meter (indoor and outdoor). Furthermore, a Davis Weather Station was used for continuously registering the temperature and humidity in the room.

After PM_{10} mass determination by gravimetric analysis, small punches from the loaded quartz filters were analyzed by two different techniques: i) a thermal-optical transmission technique for organic and elemental carbon determination and ii) ICP-MS and ICP-AES analysis for trace and major elements.

In addition, ventilation rates were also calculated and the biomass burned was characterized by determining the percentage of volatiles, ash, humidity, carbon, hydrogen, etc., and calorific value.

The evolution of aerosol size distribution and its relationship with temperature and gas concentration throughout the combustion cycle was examined in depth. Furthermore, the contribution to the particle concentration from the removal of ashes when cleaning the fireplace was assessed. The aerosol size fractions associated with health problems were evaluated following the Spanish standard UNE 77213, which is equivalent to the ISO 7708:1995. From the experimental size distributions, first, the inhalable and thoracic fractions, and then the tracheobronchial and respirable fractions were assessed for healthy adults and high-risk groups (children, elderly or infirm people).

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