Combustion of forest residues in a bubbling fluidised bed: characterisation of particulate matter emissions

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The use of biomass as fuel is taken an increasing interest regarding industrial heat and power production. Linked to this demand for bioenergy production, the volume of industrial ashes will increase, turning the efficient management of these products into an important challenge. Fluidised bed combustors (FBC) have been identified as one of the most appropriated technologies for converting biomass into thermal energy due to their inherent advantages of low process temperatures, isothermal operating conditions, and fuel flexibility. During biomass combustion in FBC two main types of ashes are produced: the bottom bed ashes and the fly ashes. Knowledge about the characteristics of these ashes is important in order to evaluate appropriate management solutions. However, biomass combustion is a source of particulate matter with a significant impact, not only on public health and on the environment, but also affecting the performance of the heat recovery equipment (economic impact).

In this study, particulate emissions (fly ashes) from the combustion of forest biomass residues resulting from eucalyptus felling for the cellulose industry were studied. These forest biomass residues were air dried, chopped and sieved in order to obtain particles in the size range of 1-5 mm. The combustion experiments were conducted in a pilot-scale bubbling fluidised bed combustor (BFBC) (Tarelho *et al.*, 2011). During biomass combustion in the BFBC, a bottom bed treated (sieved, 0.25-1.00 mm, and water leached) and recycled from an industrial bubbling fluidised bed using forest biomass residues as fuel was taken as bed material. The goal was to evaluate the effect of recycling a fraction of bottom bed in industrial FBC, taking into consideration its particular characteristics (Tarelho *et al.*, 2012). During the biomass combustion experiments in the pilot scale BFBC, the flue gas passed through a cyclone separator to minimise particle emissions into the atmosphere.

In order to characterise the fly ash particles in the flue gas, two different sampling systems were used: i) a low volume instrument to collect $PM_{2.5}$ onto quartz filters directly from the inlet and outlet cyclone ducts and ii) a Venturi system that allows to sample the combustion flue gas directly from the inlet duct of the cyclone by using dry filtered compressed air. Two different instruments used this flue gas flow for particle sampling: i) an optical counter for the continuous monitoring of particle size distributions, and ii) a Gent PM_{10} stacked filter unit sampler using polycarbonate filters (0.2 µm pore size) for later Scanning Electron Microscopy (SEM) analyses.

After $PM_{2.5}$ mass determination by gravimetric analysis, small punches from the loaded quartz filters were analysed by several techniques: i) ion chromatography was used for determining water-soluble inorganic ions, ii) the carbonate mass fractions were obtained by acidification of samples with phosphoric acid, and iii) a thermal-optical transmission technique was used for organic and elemental carbon determination, after removal of carbonates by exposing the filters to HCl vapour and neutralisation of the HCl excess with NaOH.

$PM_{2.5}$ concentrations of 139±5 mg m^{-3} and 105±13 mg m^{-3} were observed before and after de cyclone, respectively. Total carbon (OC+EC) constitutes less than 10% of the $PM_{2.5}$ mass at both sampling points. OC/EC ratios of 1.9±0.6 and 1.1±0.4 were registered before and after the cyclone. K^+ and Cl^- were the dominant water-soluble inorganic ions. Almost 20% (w/w) of the particulate matter emitted is constituted by carbonates. This fact was confirmed by FE-SEM that showed that filters were loaded of submicrometric calcium enriched minerals, salts, and biogenic and soot particles. A bimodal size distribution was found.

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