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Biomass burning emissions and influence of combustion variables in the cone-calorimeter

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Emissions from biomass burning are highly variable and depend on combustion conditions as well as fuel properties. Simultaneous emissions from pyrolysis, smouldering, and combustion of the biomass material(s) burning leads to uncertainties in how these processes contribute to emissions of individual or groups of compounds as well as to total particle emissions. These uncertainties are difficult to constrain when analysing real-world emissions but also when performing laboratory studies of e.g., cook-stove emissions in more controlled environments. This study was designed to reduce some of this variability by enabling highly reproducible conditions by controlling combustion via adjustment of a few key factors. The aim of this study was to identify how these factors influenced emissions, and how different pyrolysis and burn conditions in turn contributed to the particle emissions.

In this study, we used a controlled atmosphere cone calorimeter according to ISO 5660-5. We controlled fuel moisture content, the air flow to the combustion and O₂ available for combustion, and the total heat flux (HF) to the fuel to study the independent effect of combustion variables on the aerosol emissions. In each experiment a small 10x10x1 cm piece of Birch-wood was put in a sample holder and combusted under controlled conditions. We conducted over 40 experiments, varying HF and flow conditions while monitoring fuel mass loss to quantify emission yields. An Aerosol Mass Spectrometer (AMS, Aerodyne Billerica, USA), a multi-wavelength aethalometer (AE33, Magee Sci., USA) and a particle size spectrometer (DMS5000, Cambustion, UK) measured time-resolved evolution in particle properties during burns.

Our results showed that pyrolysis conditions in the absence of O₂ resulted in organic aerosol (OA) emissions with mass yields (g/g fuel) from a few percent at the lowest HF and up to ten percent at the highest HF. During combustion in air, equivalent black carbon (eBC) emissions were found to moderately increase with increasing HF. eBC was also found to increase when the O₂ availability or combustion was reduced (O₂ deficient combustion). Polycyclic aromatic hydrocarbon (PAH) was here defined separately from OA in the AMS analysis. PAH emissions were low for pyrolysis and combustion at high air flows (excessive O₂ availability). In contrast, O₂ deficient combustion conditions resulted in dramatically increased PAH emissions, with yields as high as to 0.5%

(g/g fuel). The relationship between PAH emissions and availability of air and O₂ during combustion is illustrated in Figure 1.

Future analyses include a more detailed PAH analysis including off-line GC-MS, thermal-optical carbon analysis, UV-VIS absorption of MeOH soluble OA. We will parameterize emissions based on the initial conditions such as HF, moisture content, air flow rate (cooling) and O₂ availability. A mechanistic understanding of relationships between combustion variables and emissions can aid the development of cleaner biomass combustion technologies and will improve fire emission models.

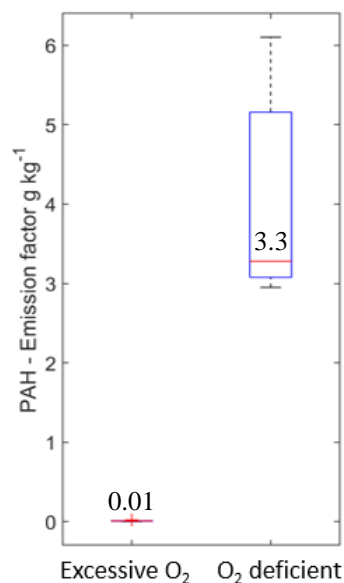


Figure 1. Emission factors for polycyclic aromatic hydrocarbon (PAH) for combustion at excess O₂ and O₂ deficient conditions. PAH were quantified with AMS according to the procedure in Malmborg et al. (2017).

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Malmborg, V. B., Eriksson, A. C., Shen, M., Nilsson, P., Gallo, Y., Waldheim, B., Pagels, J. (2017). *Environmental Science & Technology*, 51, 1876-1885.