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2014

Link to publication

Citation for published version (APA):

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Time-Resolved Biomass Combustion Emissions – Impacts of Burn Rate and Atmospheric Processing

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Keywords: Biomass Combustion, SP-AMS, Black Carbon, Organic Aerosol, SOA

Particulate matter emissions (PM) from biomass combustion are a concern due to adverse effects on human health and climate. Since any batch-wise operated biomass combustion facility is a highly dynamic system, time resolution is paramount to gain a deeper knowledge on the formation mechanisms and emission characteristics. The Soot Particle Aerosol Mass Spectrometer (SP-AMS; Onasch et al. 2012) is a useful tool allowing time- and size resolved measurements of the aerosol chemical composition including both non-refractory components and Black Carbon (BC) cores. Another important parameter is the light absorption properties of biomass emissions, including BC, brown carbon (BrC) and the potential increases in absorption or bleaching of OA upon aging in the atmosphere. The aim was to determine the time resolved emissions of black carbon (BC) and co-emitted pollutants, and simulate atmospheric processing of the emissions.

A conventional wood stove was operated batch-wise at three different burn rates (nominal, high and very high burn rate). For each case, diluted samples from 3-5 consecutive batches were investigated using a SP-AMS operated in the dual vaporiser mode, a 7-λ Aethalometer and a flue gas analyser. Recorded emissions are quantified in terms of mg/MJ or released mg per combustion phase using the oxygen consumption method (Eriksson et al. 2014). The final batch or a selected combustion phase from that batch was diluted and transferred to a 16 m² stainless steel chamber down to 10-30 µg/m³. Samples from the chamber were passed either directly to the SP-AMS and Aethalometer or through a potential aerosol mass (PAM) flow tube inducing high (UV induced) oxidant concentrations.

Time resolved emissions were investigated for a set of target pollutants that are of importance for effects on health and climate. An example for a high burn rate experiment is given in Fig.1. It can be seen that the organic emissions during a cycle were dominated by a variable burst occurring during a few minutes after fuel addition, presumably before the vaposours emitted from the heating logs ignited. PAHs and refractory BC (rBC) emissions both showed increased emissions at higher burn rates increasing with reduced flue gas excess oxygen concentration.

Particularly, the PAH emissions varied over several orders of magnitude dependent on the combustion conditions. Signal due to Zn was also unambiguously assigned, but is not yet quantified.

The OA enhancement factor found during simulated atmospheric processing in the PAM chamber increased with increasing burn rate. For example at high burn rate the OA mass concentration increased by a factor of ~3 after passing the PAM chamber and the O:C ratio of organic aerosol increased from 0.4 to 0.9.

In conclusion: strongly elevated emissions of rBC, PAHs as well as a high secondary organic aerosol formation potential occur at high burn rates, while POA is primarily emitted during the pyrolysis phase following addition of fuel. These results have important implications for targeted mitigation of emissions from biomass combustion, both from a health and a climate perspective.

Acknowledgements
This work was supported by the Swedish research councils FORMAS and VR.

References
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