Particle Types Occuring in Fresh and Processed Emissions from Biomass Combustion

J Pagels[1], AC Eriksson[1,2], R Lindgren[3], C Andersen[1], IE Nielsen[4], JK Nojgaard[4], J Martinsson[2], E Ahlberg[2], R Nyström[3], E Nordin[1], VB Malmborg[1], WH Brune[5], E Swietlicki[2], B Svenningsson[2], and C Boman[3]

[1]Ergonomics and Aerosol Technology, Lund University, Box 118, SE-22100, Lund, Sweden
[2]Division of Nuclear Physics, Lund University, Lund, Sweden
[3]Thermochemical Energy Conversion Laboratory, Umeå University, Umeå, Sweden
[4]Department of Environmental Science, Aarhus University, Roskilde, Denmark
[5]Department of Meteorology, Pennsylvania State University, University Park, PA, USA
Keywords: Wood Combustion, Mixing State, Black Carbon, Brown Carbon
Presenting author email: joakim.pagels@design.lth.se

Biomass combustion is becoming a major air pollution source in Europe and is estimated to contribute with at least 40.000 pre-mature deaths each year in Europe (Sigsgaard et al. 2015). At the same time Black and Brown carbon emissions lead to short-lived climate forcing at a poorly constrained magnitude. Particle emissions from biomass combustion are heterogeneous and there is a need to provide information of major particles types and the mixing state of different chemical components within these particle types. The aim of this work was to identify relationships between combustion conditions and health and climate relevant particle characteristics of fresh and photo-chemically processed biomass combustion emissions.

Emissions were studied from a conventional log wood stove operated at nominal burn rate (NB) and high burn rate (HB) and from two wood pellet combustion systems. Highly time-resolved measurements, where the dynamics of emissions in individual combustion cycles could be followed, were carried out in diluted flue gas. Additionally, emissions from select burn phases were diluted down to ambient mass loadings and investigated under steady state conditions in a 15 m^3 steel chamber. We used a suit of techniques including a Soot Particle Aerosol Mass Spectrometer (Onasch et al. 2012), Differential Mobility Analyzer – Aerosol Particle Mass Analyzer and Transmission Electron Microscopy to investigate the physical and chemical properties of soot cores and coatings and the occurrence of different particle types in the emissions. The optical properties were investigated with an Aethalometer. Atmospheric processing was simulated with an Oxidation Flow Reactor (PAM; OHexp. ~$3*10^8$ $cm^{-3}h$).

The particle emissions could be grouped into three main classes (table 1). Wood stove emissions from flaming combustion were dominated by Black Carbon (BC) dominated soot aggregates, which were internally mixed with a thin coating of oxidised organic aerosol (OA) and alkali salts. Soot aggregates from biomass combustion are larger than those in diesel exhaust and slightly more dense at a given size. During flaming combustion, the BC, OA and PAH emission factors as well as the OA enhancement (processed OA / fresh OA) increased with increasing burn-rate. Processing of these aggregates led to increased mass at a given mobility size indicative of a gradual conversion towards more compact particle shapes.

Table 1 Combustion conditions and main particle types

	Flaming combustion	**Low temp. pyrolysis**	**Burnout and Pellet comb.**
Main particle type	Soot Aggregates	Tar-Balls	Nucleation mode
GMD (nm)	100-150	100-200	30-60
PM_1 (mg/MJ)	30-100	100-500	5-30
Major components	rBC, minor OA and ash	Oxidised OA	Ash (+OA)
Angstrom Abs. Exp.	1.0-1.2	2-3	Low absorption
OAenh processing	NB 1-3 HB 5-10	1-2.5	Low SOA production

Low-temperature pyrolysis following fuel-addition resulted in tar-ball type particles dominated by organic aerosol with clear fragments in the aerosol mass spectra representing mono-sacharides and methoxy-phenols. Light absorption was primarily in the UV-region (Brown Carbon dominated). For this particle type the OA enhancement and particle density increased and the volatility decreased with increasing organic aerosol O:C ratio. PM_1 mass emission factors were substantially higher for low temp. pyrolysis compared to flaming combustion. However, absorption emission factors (in m^2/MJ) were of similar magnitude.

A third particle type was nucleation mode particles (30-60 nm). Pellet combustion emissions were dominated by water-soluble Potassium salts (ash). Nucleation mode particles also dominated the wood stove burnout emissions, in this case consistent with dense ash-dominated cores onto which varying proportions of less dense OA had condensed.

Emissions from whole combustion batches in the wood stove were externally mixed and contained all three particle types.

This work was supported by the Swedish Research Councils FORMAS and VR.

Onasch, TB et al. (2012) *Aerosol Sci. & Tech.*, 46, 804-817
Sigsgaard, T et al. (2015) *Europ. Resp. J.* ERJ-01865