Characteristics of Major Particle Types in Emissions from Biomass Combustion - Implications for Health and Climate

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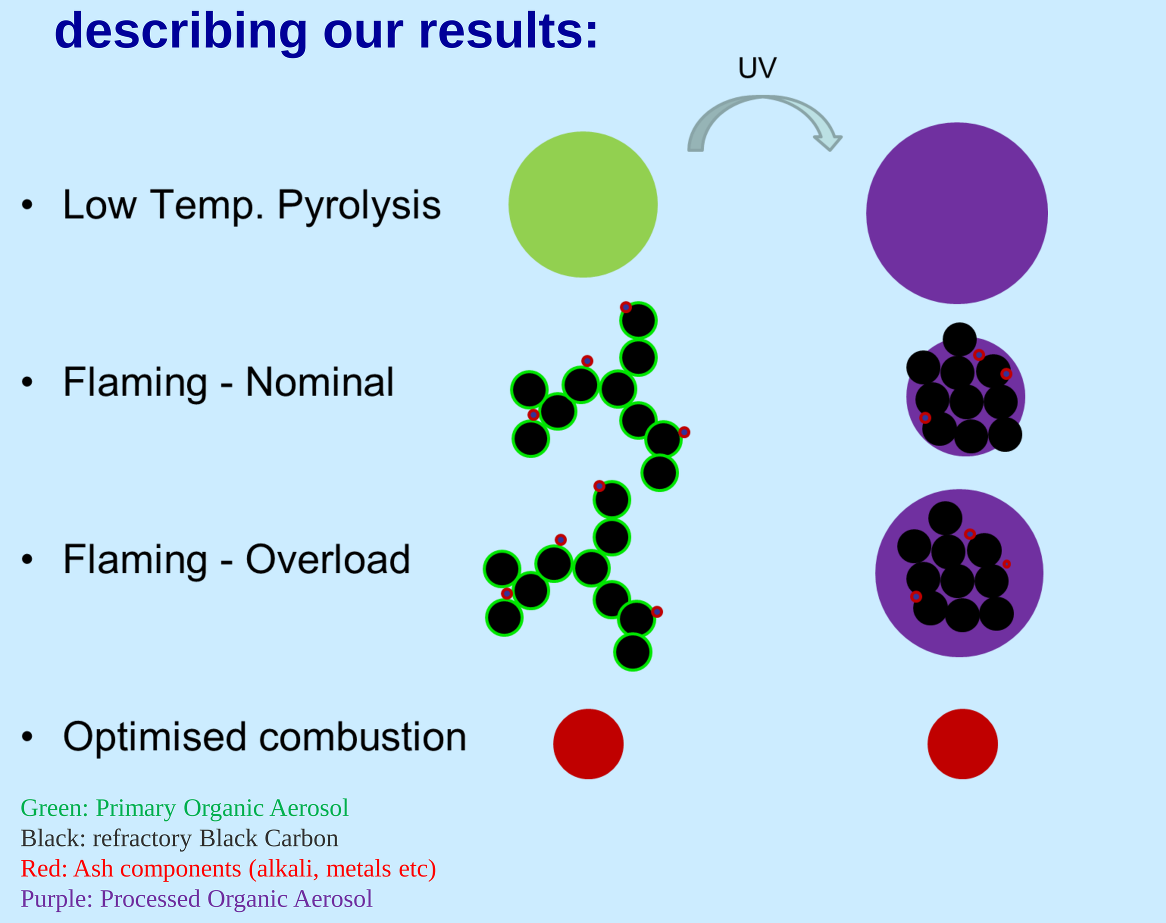
Conclusions

- **Wood stove emissions vary dramatically over the combustion cycle in wood stoves**
- **Variuos techniques were used to classify particles into three major types: Tar-balls, Soot aggregates and Compact ash particles**
- **Soot aggregates from high burn-rate are enriched in PAHs and higher SOA formation**
- **These properties dictates the particle's health and climate impact (e.g. optics, cloud formation, lung deposition and toxicity)**
- **The following is a simple conceptual model describing our results:**



Introduction

By converting energy-production from fossil fuels to biomass net greenhouse gas emissions can be mitigated. At the same time small-scale biomass combustion is responsible for an increasing fraction of ambient air pollution and is estimated to contribute with at least 40.000 pre-mature deaths each year in Europe (Sigsgaard et al. 2015). Additionally, Black Carbon (BC) and Brown Carbon (BrC) 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 of different chemical components within these particle types.

The aim of this work was to identify the major emitted particle types and to find relationships between combustion conditions and health and climate relevant particle characteristics of fresh and photo-chemically processed biomass combustion emissions.

Time-resolved Emissions at Different Burn Rates

- **Fuel Addition -> Low Temp. Pyrolysis -> short-lived high OA emissions**
- **Flaming Combustion -> rBC dominated emissions**
- **Burnout: Low Emissions**
- **High Burn-rate -> Elevated PAH and rBC emissions**

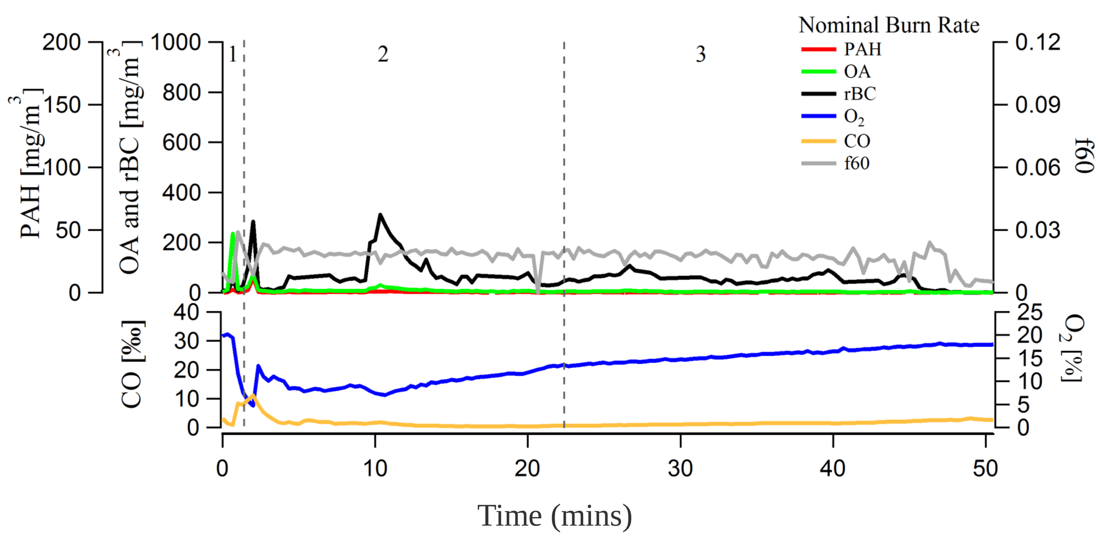


Figure 1. Time-resolved emissions measured with the SP-AMS of a nominal burn rate batch in the wood stove. The batch was initiated by adding fuel on glowing embers. 1. Fuel Addition, 2. Flaming (intermediate), 3. Burnout

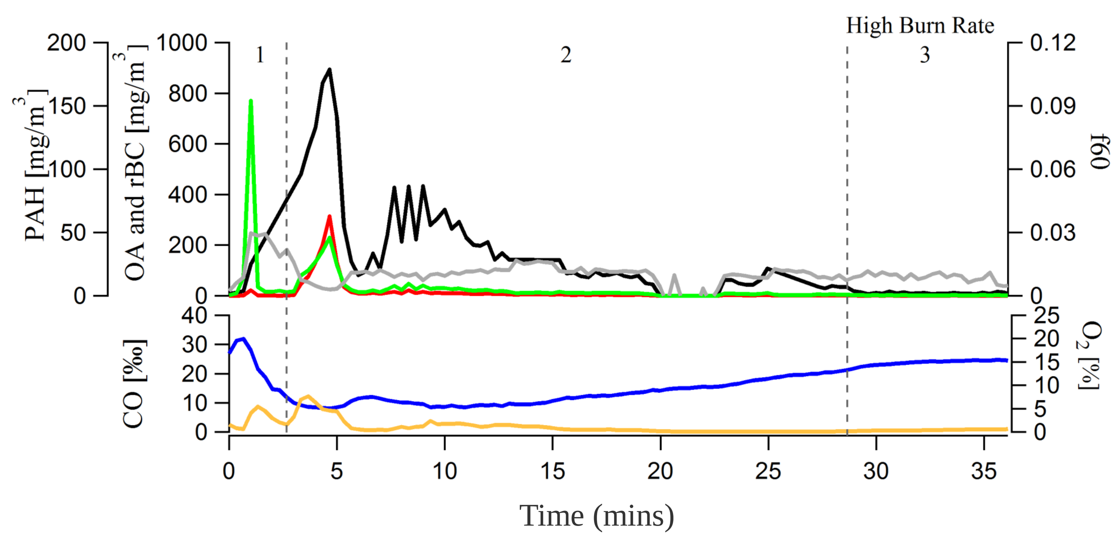


Figure 2. Time-resolved emissions measured with the SP-AMS of a high burn rate batch in the wood stove. The batch was initiated by adding fuel on glowing embers. 1. Fuel Addition, 2. Flaming (intermediate), 3. Burnout

Separation of Particle Types by Physical Properties

- **Three major particle types:**
  - **Low-temp Pyrolysis → Tar Balls**
  - **Flaming Combustion → Soot Aggregates,**
  - **Wood Pellet Combustion → Compact Ash Particles**
- **Separation of particle types by:**
  - **1. Tandem mobility – mass technique (DMA-TD-APM)**
  - **2. Vaccuum Aerodynamic Size (SP-AMS)**
  - **3. Transmission Electron Microscopy**

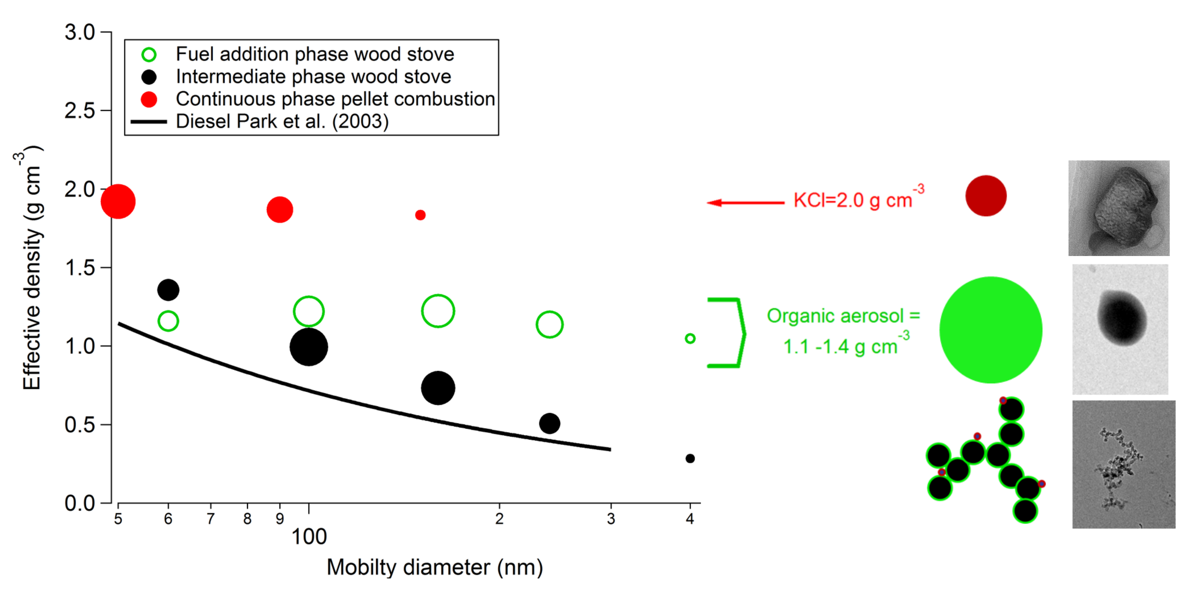


Figure 3. Effective densities derived from tandem mobility-mass measurements of wood stove and pellet boiler emissions. Comparissonwith TEM (right)

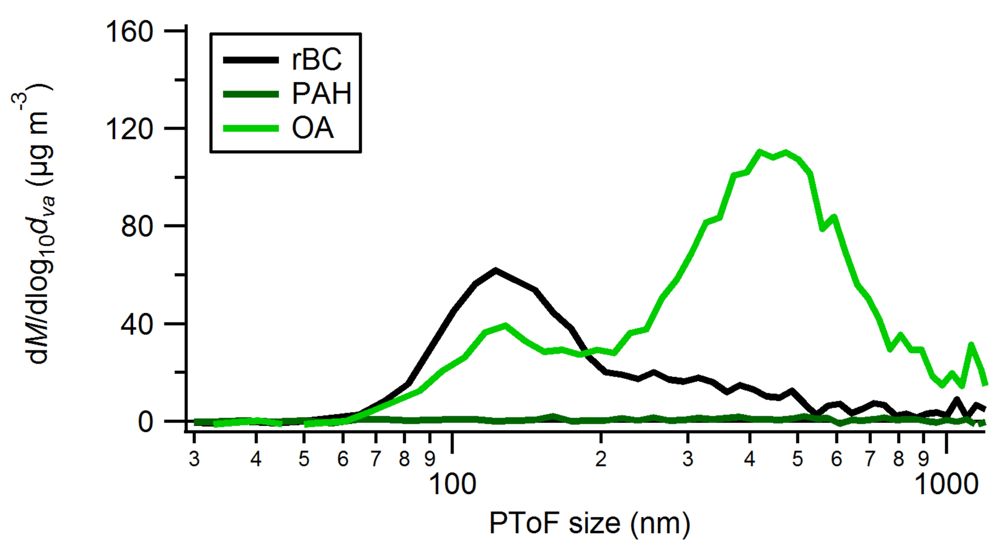


Figure 4. Size-resolved analysis with the SP-AMS, illustrating the separation of tar-balls and soot aggregates from a NB full cycle

Angstrom Exponent (AAE)

- **Tar balls, low temp. pyrolysis → AAE~2.5**
- **Soot Agglomerates from flaming combustion → AAE~1**
- **Full cycles: AAE 1.0-1.2!**

Fresh & Proc. PM1 Emission,

- **PM1 emission factor 5-10 times higher for low temp pyrolysis than flaming combustion**
- **SOA formation variable at low temp. pyrolysis, high for Flaming high burn rate**

LAC Emission Factor

- **LAC emission factors within a factor of ~2 for all cases.**
- **No evidence of BrC formation upon intensive processing**

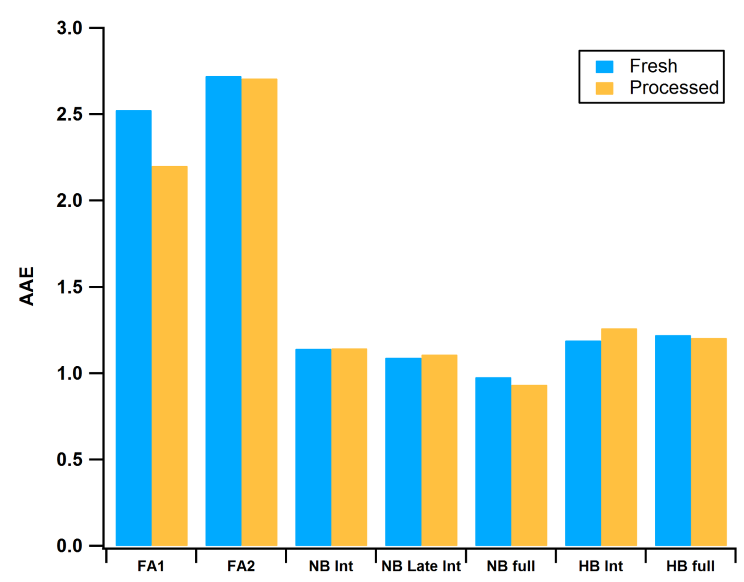


Figure 5. Absorption Ångström Exponents (AAE) derived from aethalometer (AE33) data for fresh aerosol and aerosol processed in the PAM reactor. FA: fuel addition phase, Int: Intermediate Flaming phase. NB: Nominal burn rate and HB: High burn rate. (Martinsson et al. 2015)

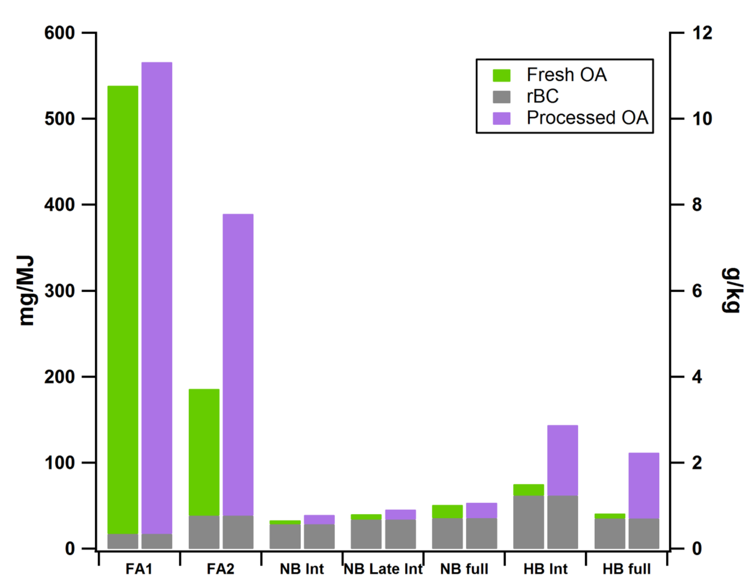


Figure 6. PM 1 mass emission factors divided into refractory BC as derived from the SP-AMS data. Fresh Organic Aerosol (OA) and Processed OA (PAM reactor: 3*10^8 cm-3h). Denotations as in Fig. 5.

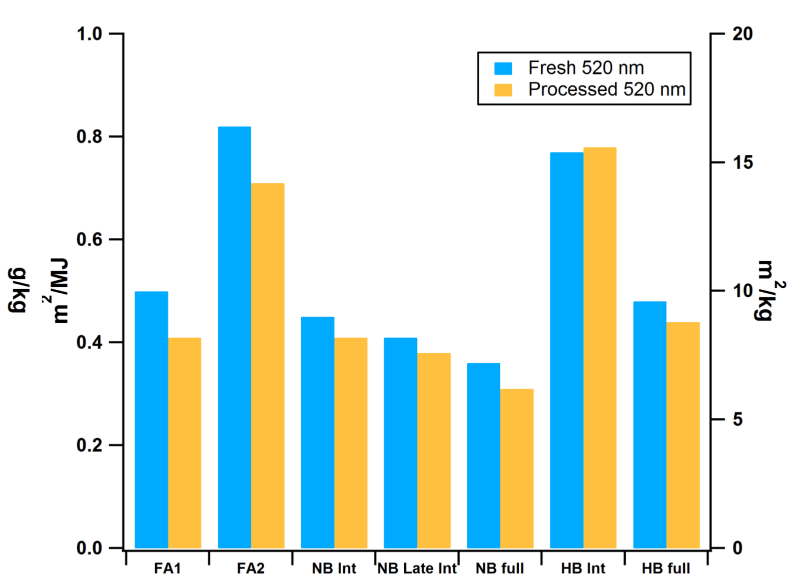


Figure 7. Light Absorbing Carbon (LAC) given as emission factors at 520 nm assessed from the aethalometer (AE33) data for fresh aerosol and aerosol processed in the PAM reactor. Denotations as in Fig. 5.

Methods

Particle Sources

- Conventional wood stove and modern wood pellet boilers (Eriksson et al. 2014) using birch fuels
- Nominal,and high burn rate established by varying log size, batch size and fuel humidity
- Emissions divided into three phases based on O_2 conc

Approach

- Transient measurements directly from ejector dilution system (DR: 1:200)
- Filling 15 m^3 steel chamber with emissions from select phases. Stationary measurements at 10-50 μg/m^3

Particle Aging

- Oxidation Flow Reactor (PAM) 3*10^8 cm^{-3}h

Characterisation Techniques

- Soot Particle – Aerosol Mass Spectrometer (Aerodyne Inc.)
- Differential Mobility Analyser – Aerosol Particle Mass Analyzer (model 3600, Kanomax)
- 7λ Aethalometer (model AE 33, Magee Scientific)
- Scanning Mobility Particle Sizer (model 3071, TSI)

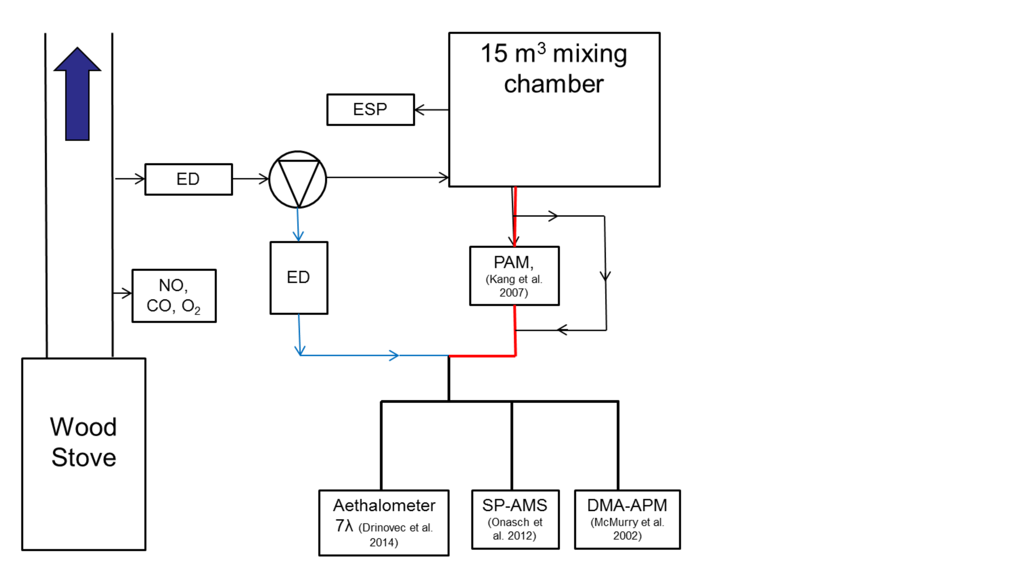


Figure 8. Schematic of the set-up used to characterise fresh and processed biomass combustion emissions.

References
Eriksson, A. C., et al. (2014) Environmental science & technology, 48(12), 7143-7150
Martinsson, J., et al. (2015). Environmental science & technology, 49(24), 14663-14671.
Sigsgaard, T. et al. (2015) Eur. Respir. J. 2015, 46, 1577-1588.

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