On-line Characterization of Aerosols from Transient Biomass Combustion

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On-line Characterization of Aerosols from Transient Biomass Combustion

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Combustion of biomass fuels for residential heating is considered to be a climate friendly option and is increasing globally. However, this implies potentially increased emissions of aerosol particles, PM2.5, which is to a large extent comprised by combustion generated particle matter, co-varies with cardio vascular diseases (Kocbach Bølling et al., 2009). The composition of biomass combustion aerosol can be divided into three main components, soot, alkali salts/ash and organic aerosol and is determined by combustion conditions like oxygen supply and temperature as well as the fuel. Soot and organic aerosol are a result of poor combustion conditions and are considered to be more harmful to human health than ash particles produced under optimal combustion conditions (Kocbach Bølling et al., 2009). A combustion cycle for example in a wood stove can emit episodes of poor combustion even when the overall combustion is relatively complete. The start-up phase is very sensitive to flash-over which results in air-starved conditions with emissions of soot and polycyclic hydrocarbons. The aim of this paper is to study the change in aerosol properties due to different combustion conditions and phases using on-line aerosol measurement techniques.

A total of five combustion cases were studied using three residential wood combustion appliances: i) a conventional wood stove operated with high burn rate ii) a conventional wood stove operated with nominal burn rate, iii) a modern pellet burner operated under optimal conditions iv) a novel pellet reactor operating on optimal conditions v) a novel pellet reactor operating under air starved conditions. Mean flue gas and particle characteristics from the combustion cases are shown in table 1.

Table 1: Particle characteristics and gas concentrations.

<table>
<thead>
<tr>
<th>Case</th>
<th>O2 (%)</th>
<th>CO (mg/MJ)</th>
<th>Total conc. (mg/MJ)</th>
<th>Org (mg/MJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>9.3±5.4</td>
<td>3020</td>
<td>2.7±1.1</td>
<td>9.4</td>
</tr>
<tr>
<td>ii</td>
<td>11.8±2.4</td>
<td>2590</td>
<td>1.6±0.8</td>
<td>8.6</td>
</tr>
<tr>
<td>iii</td>
<td>8.2±1.0</td>
<td>110±38</td>
<td>8.4±0.4</td>
<td>0.32</td>
</tr>
<tr>
<td>iv</td>
<td>11.4±1.2</td>
<td>120±67</td>
<td>6.1±0.2</td>
<td>0.45</td>
</tr>
<tr>
<td>v</td>
<td>5.3±2.0</td>
<td>700±1390</td>
<td>3.0±0.8</td>
<td>6.5</td>
</tr>
</tbody>
</table>

The aerosol from the combustion appliances was diluted 1000-3000 times to concentrations relevant for ambient air before sampling. A high resolution aerosol mass spectrometer (HR-TOF-AMS, Aerodyne research Inc.) was used for size resolved composition of compounds vapourised at 600°C. A scanning mobility particle sizer (SMPS) was used for mobility size distributions (10-600 nm) and an aerosol particle mass analyser operated downstream a differential mobility analyser and an optional thermodenuder (DMA-TD-APM) was used to determine the mass mobility relationship and assess the size dependent organic mass fraction. Particles for TEM analysis were collected using an electrostatic precipitator. For highly transient conditions like the start-up phase the time-resolution of the APM is not sufficient. By utilizing a relationship in (DeCarlo et al., 2004) that the effective density is the ratio between the vacuum aerodynamic diameter (AMS) and mobility diameter (SMPS), the effective density can be derived by from SMPS and AMS size distributions. Combining this method with APM measurements will give novel and detailed information about the aerosol composition in all phases of the combustion cycle.

![Figure 1: The effective density](image)

The effective density from DMA-APM measurements (figure 1) gives an indication of the particle shape and composition. Salt aerosols have a relatively high effective density, which does not change with increasing mobility diameter, due to their spherical shape. Soot particles on the other hand have a lower effective density which is decreasing with increased size, due to their agglomerated shape.

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Kocbach Bølling A. et al., (2009) Particle & Fibre Toxicology, 6:29