PAH formation and toxicological responses to fresh and aged aerosol

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PAH and organic emissions from residential wood combustion -investigated with aerosol mass spectrometry

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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 (Bolling et al., 2009). Studies in areas with dense wood combustion have found elevated levels of polycyclic aromatic hydrocarbons (PAHs) in the ambient air (Poulain et al. 2011). Laboratory studies have also found elevated PAHs levels from inefficient combustion, using off line techniques (e.g. Pettersson et al 2011). Several PAHs has been classified as carcinogenic and reduction of PAHs from biomass combustion is of great importance. To further investigate how combustion conditions affect PAH formation, time-resolved measurements on particulate PAHs using the aerosol mass spectrometer (AMS) was performed. The aim of this study was to identify combustion conditions and situations associated with elevated PAH emissions.

The emissions from two biomass combustion appliances were studied, a conventional wood stove and a modern pellet burner. Conventional pellets with 7 % moisture content and birch wood logs 14 % moisture content were used as fuel. The wood stove was operated at two conditions, high (6-7 logs, 2-2.5 kg,~11 kW) and nominal load (2 logs, ~1.8 kg, ~6 kW). The pellet stove was operated at nominal load (O2 9-11%) and hot air starved mode (O2 ~8%). A three stage dilution system (total dilution 1500-2000) was used to dilute the flue gas to atmospheric mass loadings and room temperature before sampling with AMS. O2, CO and NOx were monitored in the undiluted flue gas. A HR-ToF-AMS (Aerodyne inc.) was used to measure the chemical composition of the biomass combustion aerosol. PAHs can be separated from other organic material in the AMS due to their high thermal stability, an algorithm for PAH analysis developed by Dzepina et al. (2007) was used in this study. PAHs were also sampled on filters for GC-MS analysis, during selected episodes, for comparison with the AMS measurement.

Detection of PAHs with the AMS was successful and generally showed good agreement with GC-MS analysis. The highest PAH emissions were found during high load wood stove combustion, both during the start-up and flaming phase. Nominal wood stove combustion had elevated PAH emission mainly during the start-up phase. The PAH emissions from the pellet burner during nominal load were below the detection limit of the AMS, while the emissions during the hot air starved conditions showed PAH emissions that constituted about 10 % of the total organics.

Figure 1 shows time resolved PAH and organic aerosol measurements together with O2 and CO data from the three phases of a wood stove high burn rate experiment. During the start-up phase wood logs are added on glowing embers, which caused elevated organic emissions. During the flaming phase, air starved conditions prevail, which causes elevated PAH and CO emissions.

Figure 1: Time series of PAHs and organic aerosol measured by the AMS together with O2 and CO measured in flue gases from one wood stove high burn rate experiment. Note that CO is given in (%).}

AMS measurements of PAHs and total organics with high time resolution in combination with monitoring of CO and O2 in the flue gases gives valuable information about which combustion conditions that favors PAH formation.


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