Characterization of primary and secondary wood emissions for different combustion devices and conditions

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Wood combustion is a renewable and CO_2-neutral source of heat compared to other conventional energy fuels. However, its contribution to high aerosol levels has a negative influence on public health and badly quantified effects on climate change (Alfarra et al., 2007). The global emissions of black carbon (BC) and organic carbon (OC) from solid–fuel combustion is 8 Tg yr^{-1} and 33.9 Tg yr^{-1}, respectively where the contribution of residential wood combustion varies depending on the season, location and technology used (Bond et al., 2004). In addition to particles, biomass burning emits large amounts of volatile organic compounds (VOCs) which may undergo photochemical aging to produce secondary organic aerosol (SOA). The magnitude of SOA production from biomass burning and the impact of combustion conditions thereon remain highly uncertain, which hinders the estimation of the contribution of this source to the ambient air. The quantity and composition (e.g., EC:OC ratio) of the emissions depend on various factors such as type and size of wood (C and moisture content), fuel load and combustion efficiency. Also, the aerosol forming potential of these VOCs depends on their molecular structure, mass yield, vapor pressure of intermediates, and OH reactivity.

We performed a chamber study investigating the primary and secondary emissions of beech wood from three types of combustion devices namely a pellet boiler (combustion conditions: optimum, lack and excess of oxygen), an industrial wood chip grate boiler (30% and 100% power), and an old log wood stove using a potential aerosol mass reactor (PAM) under different OH exposures. We monitored the physical and chemical effects of different OA aging conditions using an SMPS, an Aethalometer, an HR-ToF-AMS, as well as a PTR-ToF-MS and other gas monitors. Emission factors for POA and SOA were determined.

We observed enhanced SOA:POA ratios (~5) at excess O_2 conditions compared to optimum conditions (~1.6) at similar OH exposure (1.2-1.8*10^8 molecules cm^{-3} h) in the pellet boiler. Further, increasing the OH exposure by a ~factor of 1.6 from; 1.1*10^8 to 1.8*10^8 molecules cm^{-3} h) caused a negligible change in SOA mass during optimum combustion conditions (Fig. 1). However, increasing the OH exposure by a factor of 3.6 from 3.3*10^7 to 1.2*10^8 molecules cm^{-3} h) enhanced the SOA mass by a factor of 2.5 under excess O_2 conditions. However, the total POA concentration remained unchanged for both combustion conditions, an enhancement in EF's for POA (3 times) and SOA (18 times) was also observed in the presence of excess O_2 demonstrating the effect of different combustion conditions on emission type (Table 1).

Table 1: Calculated emission factors (mg/kg wood) for primary and secondary particle and gas phase emissions in pellet boiler.

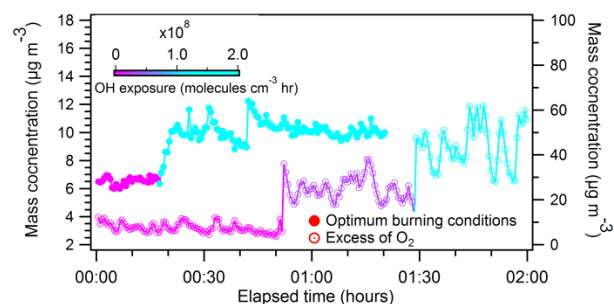| Burning conditions	POA (mg/kg)	SOA (mg/kg)	CO_2 (g/kg)	Carbon content of wood (%)
Optimum	564	356	1686	46.7
Excess O_2	1531	6455		

Figure 1: OA mass concentration at different OH exposure in the PAM chamber for different burning conditions in the pellet boiler (Left axis: Optimum; Right axis: Excess of O_2).

We further present the effect of different combustion conditions on the chemical composition of the gas phase precursors and their oxidation products, their emission factors and the relative SOA forming potential in both gas and particle phase.

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