Linking SOA to precursor VOCs in domestic wood burning systems

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Biomass combustion, which includes residential wood burning, is a major source of gas and particle phase air pollution on urban, regional and global scales. Approximately 3 billion people burn biomass or coal for residential heating and cooking, often using old and highly polluting appliances. The emissions from these appliances are highly variable depending on combustion conditions; fuel type and moisture content, but typically include a complex mixture of non-methane organic gases (NMOGs), primary organic aerosol (POA), and black carbon. NMOGs can undergo further reaction in the atmosphere, producing lower-volatility species that partition to the particle phase as secondary organic aerosol (SOA). These transformations remain poorly understood, and greatly hinder quantification of wood burning SOA in ambient air.

One approach to estimate wood burning SOA is to establish quantitative links with its dominant precursor NMOGs. A recent study combining measured NMOGs with their known SOA yields found that 84-116% of wood burning SOA could be explained by only 22 NMOGs (Bruns *et al*, submitted). Further, non-traditional precursors such as phenol and naphthalene dominated SOA production, while high-volatility precursors such as benzene, toluene and alpha-pinene yielded less than 20%. However, these investigated only a single burner operated under a single combustion protocol. Here we extend this analysis, assessing SOA closure for six wood combustion devices operated under varying combustion conditions. SOA was generated by using two different oxidation systems (a 7 m^3 smog chamber and potential aerosol mass (PAM) flow reactor.

For the smog chamber experiments, emissions were sampled from the stable flaming phase of three different appliances: an old logwood stove (2002), a modern logwood stove (2010) and a pellet stove (2010). Emissions were aged by exposure to OH radicals and monitored by a comprehensive suite of gas and particle instrumentation, including a proton transfer reaction time-of-flight mass spectrometer (PTR-TOF-MS) and a high resolution time-of-flight aerosol mass spectrometer (HR-ToF-AMS). A sample experiment is shown in Fig.1 from the new logwood burner, showing significant SOA formation.

PAM experiments were conducted on the stable flaming phase of three combustion devices: a pellet boiler (burning conditions: optimum, lack and excess of combustion air), an industrial wood chip boiler (30% and 100% load), and an old log wood stove (entire burning cycle). The PAM utilizes OH radical concentrations many times higher than that of the atmosphere to simulate days of atmospheric processing in only a few minutes. Aged emissions were measured by PTR-TOF-MS and HR-ToF-AMS. Fig.2 shows a sample PAM experiment using a pellet boiler at stable flaming condition including direct emissions, and aged aerosol generated at several OH exposures.

Using known SOA yields for the measured precursor NMOGs, we investigate the extent to which SOA mass closure can be attained. We evaluate the effects on SOA closure of the different NMOG emission profiles from different burners, as well as the different oxidation regimes present in the PAM and smog chamber in terms of SOA closure and composition.

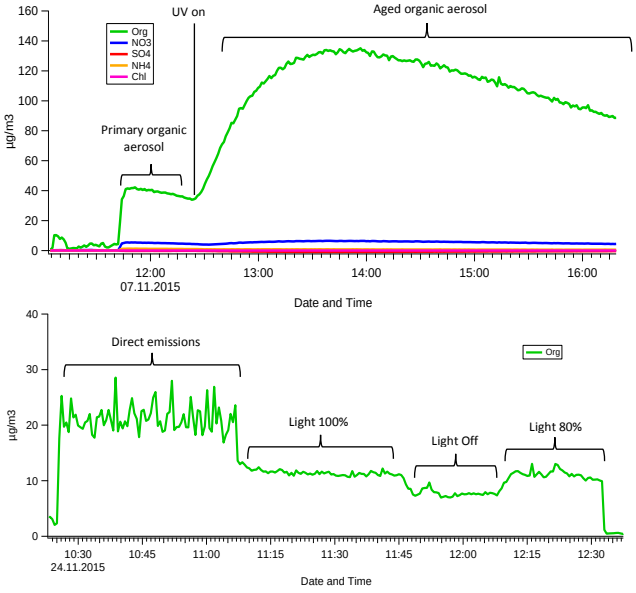

Figure 1. HR-ToF-AMS time series from smog chamber experiment at the Paul Scherrer Institute (PSI) for logwood burner under stable flaming phase. "UV on" denotes the start of aging.
Figure 2. HR-ToF-AMS time series from a sample PAM experiment at Lucerne University of Applied Sciences (LUAS) for pellet boiler under stable flaming phase.

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