# A novel set-up for source characterization and human exposures of biomass combustion aerosols

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Emissions from biomass combustion are a major source of indoor and outdoor air pollution, and are estimated to cause millions of premature deaths worldwide annually. Pollution from different biomass combustion sources are a complex and varying mixture of gases and particles, strongly dependent on fuel, technology and operation [Kocbach *et al*, 2009]. Although adverse respiratory effects have been associated with "wood smoke" in epidemiological and controlled exposure studies, important information concerning biomass combustion aerosols is still missing. Examples of such areas are; cardiovascular effects, underlying biological pathways and importance of different aerosol particle properties. A chamber set-up built for controlled human exposures gives unique opportunities to directly relate specific exposure conditions to different short term (acute) respiratory and cardiovascular responses in humans.

The objective of this project was therefore to describe and evaluate a novel chamber set-up for studies of health effects of biomass combustion aerosols using controlled human exposures. In this paper we discuss the biomass combustion aerosol exposure set-up including aspects of; *i)* combustion systems, *ii)* aerosol dilution, *iii)* chamber design and function, and *iv)* exposure data from the first recently performed campaign.

The exposure set-up is located in connection to the combustion laboratory within the Thermochemical Energy Conversion Laboratory (TEC-Lab) at Umeå University. The facility includes several combustion technologies to be used for different aerosol generation purposes such as human exposures and/or other aerosol experimental research. For example, traditional wood log stoves, modern wood pellet boilers using different burner technologies, a fluidized bed reactor and novel grate fired reactors for controlled generation of different kinds of biomass aerosols, are available.

Different flue gas/aerosol dilution systems are available, e.g. ejector dilutors (ED) and porous tube dilutors (PTD). In the first exposure campaign, a three step dilution system with filtered air at ambient temperature was used including a first PTD (~1:10), followed by an ED (~1:6) and a final counter-current flow injection in the main HEPA filtered air flow that enters the chamber.

The chamber is 15.3 $m^3$ (2.7 x 2.4 x 2.4 m) with a small ante-chamber with interior surfaces made of stainless steel/aluminium, except for 2.4 $m^2$ observation glass window facing a control room. The set-up is designed for air exchange rates of 2-10 times per hour. CO, $NO_x$ and total hydrocarbons as well as temperature and relative humidity are continuously monitored. Particle mass concentration is measured by a TEOM equipped with a $PM_1$ pre-cyclone and an integrated filter sampler. Particle mobility size distribution and number concentration are measured with a SMPS system. In addition, several different filter and impactor sampling lines are applied for off-line chemical characterization including, e.g. carbon fractions (OC/EC), PAH/oxy-PAH and inorganic alkali and trace metals, as well as toxicological (*in-vitro*) characterization.

A first human exposure study in the new set-up was performed to elucidate acute airway inflammatory responses and cardiovascular effects after exposure to emissions from incomplete wood log combustion. A common Nordic wood stove was used with a special adjusted combustion approach to generate incomplete (soot-rich) conditions in a repeatable manner for the exposure campaign. The target $PM_1$ mass concentration in the chamber was 300 $\mu g/m^3$ thus in line with a previous experimental wood smoke study [Sehlstedt *et al*, 2011] and several diesel engine exhaust studies performed by the Umeå group and collaborators. Fourteen healthy non-smoking subjects were successfully exposed to diluted wood smoke ($PM_1$ 314±38 $\mu g/m^3$) or filtered air for three hours in a randomized, double-blind crossover study. The EC/TC (total carbon) ratio was 0.72 ± 0.08, and it was estimated that the total PM consisted of approximately 38% soot, 24% organics and 38% inorganics.

Aspects of chamber function (e.g. flow profiles and mixing conditions) as well as aerosol dynamic effects (e.g. coagulation and wall losses) at different chamber conditions are presently under evaluation and will be discussed. Accordingly, the new and novel set-up for biomass combustion aerosol generation, characterization and health effect studies has successfully been established and so far used in one human exposure study and one aerosol ageing and toxicology study (Nordin *et al*., EAC 2013).

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