Chemical, physical and toxicological properties of biomass combustion aerosols

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Combustion emissions from traffic (e.g. Janssen et al. 2002), energy production with coal and oil (e.g. Clancy et al. 2002) and heating with wood (e.g. Schreuder et al. 2006) have emerged as the main sources behind the adverse health effects. The causality between physico-chemical characteristics and toxicological properties of particulate emissions from the heating appliances, engine types and fuels are poorly understood. In search for the key components and properties of biomass combustion emissions that cause the observed health related toxicological responses, we have used multidisciplinary experimental approach. Particulate emissions from modern new and old technology combustion appliances, combustion conditions and fuels were investigated for their physicochemical and health related toxicological properties. PM_1 samples were collected from different modern and old technology heating appliance emissions using Dekati Gravimetric Impactor (DGI) after porous tube diluter (PRD). Thereafter, the samples were weighed and extracted with methanol for subsequent toxicological and chemical analyses.

Gaseous emissions were measured with FTIR (Gasmet technologies) from the stack. PM_1 samples were collected for OC/EC analyses with filter holders (Gelman Sciences 2220) from diluted flue gas. Particle emissions were measured with on-line measurement instruments: ELPI (Dekati), SMPS (TSI) and TEOM (Thermo Scientific).

In *in vivo* studies, healthy C57BL/6J mice were intratracheally exposed dose and time dependent manner. After the exposure, bronchoalveolar lavage fluid (BALF) was assayed for indicators of inflammation, cytotoxicity and genotoxicity. In *in vitro* studies, the mouse RAW 264.7 macrophages or human lung epithelial cell line A549, were exposed to different doses of PM_1 samples for time. Thereafter, inflammatory, cytotoxic and genotoxic markers were detected as well as changes in the cell cycle.

The fine particles from wood-fired combustion were composed mainly of ash (alkali), condensed organic material and soot. The principal factors of ash particle emissions were attributed to combustion temperature affecting the mass of volatilised ash, cooling rate of exhaust gas and composition of fuel affecting on elements released (K, Na, S, Cl, Zn, Pb, Ca…). The organic fraction was low in continuous burning and it can be reduced also in batch combustion by controlling the location of air injection and mixing in the burning chamber.

In general the highest emissions were in incomplete combustions situations like firing phase and smouldering combustion and lowest in the continuous burning of wood chips and pellet. In the batch burning the average PM1 emission was about 100 mg/MJ, in the effective devices about 50 mg/MJ. In the continuous burning PM1 emission was 5 – 30 mg/MJ. The number emissions were 10^{13} – 10^{14} #/MJ and did not correlate with other emission compounds. The particle average size varied between 80 to 200 nm. The size distributions were usually unimodal and shape of particles were agglomerates, covered by organic material in incomplete situations.

Most of the PM samples from the studied appliances caused dose dependent increase in at least some of the toxicological parameters in the exposed cells. Emissions from old technology appliances with incomplete combustion were in most cases more potent inducers of toxicological responses than those from the new technology appliances with more complete combustion. However, the results indicated that also the modern wood combustion appliances and optimal burning conditions may emit particles evoking high cytotoxicity and clear cell cycle arrest. Moreover, all the studied combustion particles caused DNA damage both in the mouse and in the human cell line, but the magnitude of the response was largely different between the samples. These genotoxic responses were associated with increased PAH levels, but there seem to be also other species of organic matter and metals in PM harboring toxicological potential both *in vitro* and *in vivo*. It is noteworthy that the old technology appliances had larger mass emissions than the new technology appliances, which emphasizes the differences. Thus, the promotion and supporting of technologies that ensure efficient and complete combustion and avoid high soot and PAH combustion sequences is motivated of both public health and climate impact reasons.

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