PAH, PCDD/F and HCB emissions from residential wood combustion

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Incomplete combustion of organic material in the presence of chlorine causes the formation of chlorinated organic by-products, such as polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), polychlorinated biphenyls (PCBs), and hexachlorobenzene (HCB) (Hedman et al., 2006). Residential wood combustion (RWC) in woodstoves and fireplaces is estimated to account for 78% of PAH, 53% of PCDD/F and 70% of HCB emissions in Estonia in 2010 (Kohv et al., 2012). These estimates are subject to large uncertainty as emission factors (EF) used in this inventory are derived from one general study and may not be representative for Estonia and used EF as are not dependent from the type of combustion equipment.

The combination of dispersion modelling and measurement campaigns in different areas is useful tool to validate emission databases for residential heating. Therefore emission and ambient air measurements were performed and EF were validated through combination of ambient measurement campaigns and dispersion modelling.

Emission measurements were conducted at three different combustion facilities: a masonry stove, a cooking stove and a fireplace, as those combustion facilities are typically used in Estonian households. Measurements were carried out in EERC stove test laboratory. Conifer and hardwood logwood with different humidity were used. Each log batch was weighed, heating value was measured and the relative humidity (RH) of each log was measured. PAH, PCDD/F and HCB samples were collected from the hot flue gas, with an Eva dioxin sampler (Metlab) into filter, XAD adsorbent and pre-afterwash liquid. Samples were taken through an insulated, externally heated (180 °C) sample line. Samples were taken during the whole burning process (up to 4 hours, including start-up phase). Samples were analysed with the GC/HRMS. Simultaneously gas samples (O_2, SO_2, NO, NO_2, CO, CO_2, VOCs), temperature (°C), RH (%) and gas flow (m/s) were measured during the whole burning process. Samples for the gas analyses were taken through an insulated, externally heated (180 °C) sample line and through the filter units to the gas analyser (Testo 360, Testo AG).

Ambient air measurements were conducted at the RWC area in Tallinn, Estonia. A high volume sampler DHA-80 (Digitel) was used to collect PM10 and PM2.5 samples for subsequent chemical analysis. PM10 and PM2.5 samples were analysed regarding the PAH, PCDD/F and HCB with the GC/HRMS. Simultaneously gas samples (O_2, SO_2, NO, NO_2, CO, NMVOC, O_3) and meteorological parameters were measured during the whole measurement campaign.

The emission database for RWC for Tallinn was created based on house types from Estonian 2012 census data and EF obtained in current study. The dispersion modelling of emissions of RWC were carried out using ensemble of three local scale dispersion models (two Gaussian and one Eulerian dispersion model). Modelled levels of PAH, PCDD/F and HCB were compared against results of ambient air measurement campaigns.

Results

Highest PAH EF were measured at the cooking stove, which was more than 4 times higher compared to the masonry stove. PCDD/F EF in the fireplace are ca 46 times higher compared to the masonry and the cooking stove. HCB EF are 2 times higher in the cooking stove compared to the other combustion facilities. Taken into account that the combustion equipment type and other relevant flue gas and wood parameters (temperature, RH) play an important role in PAH, PCDD/F, HCB formation, this should be considered in further emission inventories.

The combination of dispersion modelling and measurement technique was used for validation of EF for RWC. Good agreement in certain areas between measured and modelled results was found.

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