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Balancing heavy metal release from small-scale biomass combustion systems

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The application of biomass as an energy supplier may reduce the greenhouse gas effect, the shortage of fossil energy sources and the dependency from fossil fuels. Biomass combustion in Europe is widely applied e.g. for residential heating in stoves and boilers and combined heat and power production in industrial boilers. About 14 Million small-scale wood-burning furnaces are currently installed in Germany.

The growing contribution of biomass burning for heat supply may have an adverse influence on its acceptance due to the arising emissions and induced health problems. Especially fine (<1μm) and ultrafine (<0.1μm) particles enter the alveoli of the lung and may trespass into the blood. Elements contained in particles or gaseous molecules are also transferred into the blood. An effective reduction of the emissions is necessary.

To collect the hazardous fly ash an innovative filter holder with a 150mm diameter consisting of PTFE was applied in our study. It guarantees sufficient material for the analysis and assures a low contamination background.

To get a reliable reconstruction of particulate fluxes for input/output balances for wood and straw burning in small-scale combustion systems, we sampled the originating ashes e.g. grate ash, heat exchanger ash and fly ash and compared their combined amounts with the ash content of the burned wood or straw respectively. The recovery rates of seven trials were between 74 and 153%.

The same calculation as for the ashes was done for the combined amounts of element in the ashes with the corresponding element amounts in the burned wood and straw. Some elements such as Al, Zr, Ti, Ca, Fe, Ba and REE have recovering rates larger than 100% indicating contamination e.g. from the refractory lining of the furnaces.

A strongly contrasting behavior can be observed for the environmentally or health relevant elements such as Cd, Zn, Sn, Tl, Pb, Bi, and Sb. Their amount in wood or straw were higher than in their corresponding combined grate ash, flue gas condenser (FGC) ash, electrostatic precipitator (ESP) ash and filtered fly ash. This insufficient retention suggests that portions of these elements are quasi-gaseous (Braun et al. 1983) and can leave the furnaces as gas or as very fine nucleated particles (<0,01μm) (Kennedy, 2006).

The emissions of inorganic elements during combustion of wood and straw depend strongly on the type of the burning system, the completeness of burning, temperature induced release and condensation processes, and ash formation within the furnace. Emissions from furnaces can be diminished e.g. from 76.5 mg/Nm3 without an ESP to 54.6mg/Nm3 with an ESP for a 30kW boiler fuelled with spruce wood-chips. Therefore the amount of risky elements can be diminished if the elements are bound on particles such as Cu, Cs and U rather than in a volatile gaseous form. Similarly a FGC can diminish the dust load in the exhaust gas from e.g. 15.3 mg/Nm3 without FGC to 10.7mg/Nm3 with FGC for the same boiler fuelled with straw-pellets.

Our observations support the assumption that during biomass burning portions of the harmful elements Cd, Zn, Sn, Tl, Pb, Bi, and Sb are volatile because of their gaseous or ultrafine character and therefore make a more effective retention of these elements necessary.

Literature:

Braun et al., 1983: Neue Erkenntnisse über metallische Schadstoffe in der Luft. Fresenius' Journal of Analytical Chemistry, Volume 317, Numbers 3-4, 304-308.

Kennedy, 2006: The Health Effects of Combustion-Generated Aerosols. Proceedings of the Combustion Institute, Volume 31, Issue 2, January 2007, 2757-2770.