Influencing heavy metal flows in grate-fired biomass combustion plants by means of a new fractionation technology

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Energetic utilization of biomass is considered an environmentally safe way of providing energy, especially for process heat and district heating purposes. The main advantage of energy from biomass is the CO2 - neutrality of this energy production process provided that sustainable forestry is given. However, biomass combustion produces solid by-products, ashes, that have to be considered.

The ashes contain plant nutrients like calcium, potassium and phosphorous that should be recycled to forest or agricultural soils, thus closing not only the carbon cycle but also the mineral material fluxes of the overall energy production process. The problem is however, that besides nutrients, the ashes also contain heavy metals. Especially cadmium poses a risk to the use of wood ash on soils. It pollutes, the fly-ash fractions generated in a biomass combustion plant, especially the filter fly-ash or (where a flue gas condensation is installed) the condensation sludge.

A medium term solution to the recycling of solid residues from biomass combustion is blending cyclone fly-ash and bottom ash and using the mixture in agriculture [1]. Although a large part of nutrients might be recycled in this manner, care has to be taken of the relatively high amount of cadmium in this material. This is especially important in cases when cadmium accumulating species such as *Salix* are used as fuel. *Salix* is an interesting short rotation crop and has been seen to extract and accumulate Cd from soils making it suitable for long term phyto-remediation of contaminated agricultural land [2]. This is however only ecologically feasible if the extracted Cd can be separated from the main part of the ash recycled to the soil.

Due to these circumstances, a new technology has been developed, that takes advantage of the behavior and volatility of environmentally relevant heavy metals in the reducing atmosphere prevailing at the grate and in the primary combustion chamber of modern grate-fired biomass combustion plants. This technology allows to concentrate cadmium (and other volatile heavy metals) in a very small portion of the whole ash flux from the combustion plant (the filter fly-ash) and to keep the remainder of the ash (bottom ash and coarse fly ash fractions) at low concentrations of environmentally relevant substances.

Methodology

Test runs were conducted in a 400 kW_{th} pilot plant, equipped with a horizontally moving grate and a rotating particle separator (RPS) as fly ash precipitator. Two different *Salix* fuels containing elevated Cd concentrations (0.8-2.6 mg/kg dry basis) were investigated with and without the application of the new fractionation technology.

During the test runs the amount of fuels and the ashes produced were measured and analyzed for their chemical composition. Flue dust (amounts of dust emitted with the flue gas) was measured by means of isokinetic dust measurement and Berner type low pressure impactor (BLPI) measurements.

Results

The results from chemical analyses of the BLPI and dust measurements revealed that the concentration of volatile heavy metals (Cd, Pb and Zn) increases with decreasing particle size in grate-fired biomass combustion units and thus accumulate in the finer dust particles.

Moreover, usually 10 to 30 % of the fly ash consist of particles smaller than 1 µm, so called aerosols. Applying conventional combustion technology (reference tests), the aerosol fraction contains about 20-40 % of the Cd in the whole fly ash, which in turn contains 80-95 % of the Cd entering the plant with the fuel. These results underline the importance of an efficient aerosol precipitation in biomass combustion plants, especially when Cd-rich fuels like *Salix* are used.
The pilot plant used in the test runs was not equipped with an aerosol filter, but by using the result from impactor and dust measurements, the precipitation in a fibrous filter for aerosol precipitation was calculated (assuming the dust emission after the filter is reduced to 2 mg/Nm³, 13 Vol% O_2). From this the distribution of metals between the usable ash, ash for disposal (filter fly ash) and flue dust emitted to the air could be calculated (Table 1).

Table 1: Distribution of Cd and the nutrients K and Ca in the usable ash fraction, ash for disposal and the emissions to air via aerosol particles in tests runs combusting *Salix* with and without the new fractionation technology. ***Explanations:*** usable ash…mixture of bottom ash and coarse fly-ash (e.g. furnace ash + cyclone fly ash), ash for disposal…filter fly ash (precipitation in fibrous aerosol filter), emission to air..dust emitted with the flue gas.

Reference test			
	Usable ash	**Ash for disposal**	**Emission to air**
Cd	58 – 63 %	36 – 40 %	1.7 – 1.5 %
K	67 – 77 %	22 – 31 %	0.9 – 1.3 %
Ca	95 – 96 %	4 – 5 %	0.2 %
Total ash	91 – 94 %	6 – 9 %	0.2 – 0.4 %

New fractionation technology			
	Usable ash	**Ash for disposal**	**Emission to air**
Cd	1 – 16 %	80 – 95 %	3.4 - 3.9 %
K	55 – 75 %	24 – 43 %	1.0 – 1.8 %
Ca	86 – 94 %	6 – 13 %	0.2 – 0.5 %
Total ash	80 – 90 %	9 – 19 %	0.4 – 0.8 %

The results from test runs with the new fractionation technology reveal a significant transfer of Cd from the usable ash fraction to the ash for disposal while the amount of usable ash is kept high at about 80- 90 % of the total ash. Following, the usable ash can be gained heavy metal poor (favoring an utilization on soils) while 80 to 95 % of the Cd are upgraded in a very small ash fraction (the filter fly ash)

Also the nutrient K accumulates in dust and is a main contributor to the formation of submicron particles. But only a minor part of K in the biomass fuel is volatile, or the main part reacts with ash-forming elements already at the grate and is therefore found in the usable ash fraction. Ca is generally not volatile during biomass combustion and thus mainly found in the usable ash. The same trends regarding the metal behavior have also been seen and investigated for spruce wood-chips and bark as fuels.

Conclusions

The results show that care has to be taken when heavy metal accumulating crops such as *Salix* are used in small-scale combustion units without proper particulate separation. However, by applying the new fractionation technology and an efficient fly ash precipitation, *Salix* can safely be used for energy production and at the same time contribute to a sustainable long-term remediation of contaminated soils.

References

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