Characterisation of wood combustion ashes - DTU Orbit (17/12/2018)

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The combustion of wood chips and wood pellets for the production of renewable energy in Denmark increased from 5.7 PJ to 16 PJ during the period 2000-2015, and further increases are expected to occur within the coming years. In 2012, about 22,300 tonnes of wood ashes were generated in Denmark. Currently, these ashes are mainly landfilled, despite Danish legislation allowing their application onto forest and agricultural soils for fertilising and/or liming purposes. During this PhD work, 16 wood ash samples generated at ten different Danish combustion plants were collected and characterised for their composition and leaching properties. Despite the relatively large variations in the contents of nutrients and trace metals, the overall levels were comparable to typical ranges reported in the literature for other wood combustion ashes, as well as with regards to leaching. In general, the composition of the ashes complied with Danish ash quality criteria, indicating that they may be applied onto forest soil. However, according to EU landfill waste acceptance criteria, the leachates corresponded to “non-hazardous” or “hazardous” waste, thereby suggesting that recirculation of the same ashes to forestry land may constitute an environmental issue as a result of leaching, especially with regards to Cr and Se.

The release of nutrients and contaminants from two selected wood ash samples (corresponding to one mixed ash sample and one fly ash sample) was estimated based on selected pH conditions and data for both short- and long-term leaching. Acidic conditions relevant for typical forest soils in Denmark indicated considerably higher releases of Cd, Mg, Zn and P compared with releases of the natural ash pH (more than two orders of magnitude difference). The leaching of Cl, K, Na and S was rather pH-independent, high during the initial leaching and most likely governed by the availability of these elements in the ash matrix. On the other hand, the leaching of Al, Ba, Ca, Cr, Mg, Sb, V and Zn was distributed over a wider liquid-to-solid (L/S) interval and differences of at least one order of magnitude were shown between the observed cumulative releases at L/S 10 L/kg and L/S 1000 L/kg. Relatively large fractions of P (i.e. 33 % and 48 % of the fly ash and mixed ash P contents, respectively) were observed to dissolve after extraction with neutral ammonium citrate, which indicated the potential use of wood ashes as a P supplement for the soil.

The release of major elements such as Al, Ba, Ca, Fe, Mg, Si, P and S was governed mainly by mineral solubility. The most likely minerals governing the release of these elements were found to be in general agreement with mineral phases identified in the literature for other wood combustion ashes, but also municipal solid waste incineration ashes. The leaching of trace elements, such as Cu, Cr, Pb and Zn, was described adequately as a combination of mineral solubility, adsorption onto Al/Fe (hydr-) oxides and complexation with dissolved organic matter. The influence of common ash pre-treatments, such as hardening (also known as ageing or maturing) and granulation, on ash chemistry, liming potential and leaching behaviour was investigated through a series of laboratory experiments. Ash granules were relatively hard (barely breakable by finger-pinching) and demonstrated a reduced leaching compared to loose ashes, an effect that appeared to be related to the specific surface area granules. Ash granules may be used in actual field applications to minimise dust generation. Hardening affected the mineralogical structure of the ashes, but their overall acid neutralisation capacity remained practically constant. Column leaching tests showed that hardened ashes presented pH levels about two units lower than fresh ashes and a reduced leaching of alkalinity. The leaching of As, P, Sb and V increased after hardening, while the leaching of Ba, Ca, Pb and Zn was generally reduced to concentration levels below or close to limit of quantitation levels. Ash hardening was observed to be a relatively simple and fast treatment. Preferably, this process should be carried out under controlled conditions, before the ashes are applied, as this will minimise their overall reactivity as well as the leaching of most trace elements. The effects of ash application on the mobility of nutrients and trace elements in soil pore water were evaluated through a series of column experiments. The two uppermost soil horizons of a Danish nutrient-poor forest soil were tested against three ash dosages, namely 3, 9 and 30 tonnes/ha. Ash application promoted the release of nutrients such as K and P during the entire duration of the experiment, corresponding to about eight field-scale years. A short-term release of Cl, K, Mg and S was also observed within the first 500 L/m² of infiltrating water (corresponding to fewer than two years on the field scale). While an overall increase in the leached amounts of As and Cu from the organic soil horizon were observed in the case of ash application (from 2.2 to 5.0-5.8 mg/m² for As and from 2.0 to 4.9-7.6 mg/m² for Cu), their concentration levels in the percolating soil solutions was generally within Danish groundwater quality criteria. Though the effects of both the 3 and 9 tonnes/ha dosages were limited and comparable, the use of 30 tonnes/ha indicated considerably larger amounts of K, Mg, S and Si within the first 500 L/m² (at least five times larger than the soil controls). Furthermore, because of the low mobility of many trace elements, such as Cd, Cr, Ni, Pb and Zn, potential accumulation of these elements on the forest floor should be evaluated. Consequently, such high dosages cannot be recommended based on these experiments.

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