Management of solid residue from sewage sludge conversion in Waste-to-Energy Plants

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The Sewage sludge (SS) is the final output of the wastewater treatment (domestic or industrial effluents) (Melo *et al* 2018). Presently, most SS from wastewater treatment in Europe is landfilled, incinerated or reused in agriculture (Kelessidis *et al* 2011). However, the European Commission has launched a public query about developing a sustainability plan focussed on the efficient conversion of biowaste into heat and power, or as a method for the production of solid, liquid and gaseous fuels (Ferreira *et al* 2016). Due to the need of finding sustainable ways for waste disposal, several authors have studied the recovery of nutrients, energy and chemicals (Tarpani and Azapagic 2018). The thermal valorisation of waste can be done by pyrolysis (Fernández-Akarregi *et al* 2013, Ferreira *et al* 2016), gasification (Gómez-Barea et al 2013, Ayol *et al* 2017) or combustion (Ferreira *et al* 2016). However, they produce solid residue/ash waste with a high load of contaminants and they must be managed in order to ensure the economic and environmental feasibility of the system. These amount and composition of the ash generated depend on the process type and also on the location where the ash is extracted from (bottom, vs fly ash, and the latter can be from cyclone or filter ash). A careful comparison between the ash management from different types of processes is needed for the selection of the most promising technology. However, limited information is available in the literature: although there are many works and reviews on this topic, they are mainly focussed on conversion and economic issues and not on waste management concerns (Ferreira *et al* 2016, Tarpani and Azapagic 2018).

The aim of this work is the evaluation of ash management from different thermal conversion technologies processing sewage sludge. More specifically, the solid residues from various conversion methods are characterized to assess the potential utilization of the ashes, whereas as base material with added-value when the ash properties fulfil certain requirements, or as ash to be landfilled when recovery/reutilization is not possible/feasible. This study is in line with the EU action plan for the Circular Economy.

The main three thermal processes are simulated to quantify and characterize the outlet streams. The inputs for the simulation are based on data from thermochemical experiments in bench-scale reactors (Ronda *et al* 2018) using a SS from an urban wastewater treatment plant in Spain, where the SS is processed in a rotary drier, leaving the plant as dried SS (DSS) in form of granulated particles. The process layout of each thermal process is defined and material and energy balances are formulated to characterize the flowrate and composition (focused on metal content) of the resulting ash streams.

Figure 1 shows the composition (in percentage) of the main output ash (from the bottom of the thermal process) for the various processes (pyrolysis, gasification and combustion) as well as that of the raw SS.

It is observed that heavy metals are concentrated in the residue during thermal processes at elevated temperature. Thus, the concentrations of metals in the residues are higher than those in the untreated SS, and the increase is more significant with the amount of oxygen used in the process (combustion > gasification > pyrolysis). Thus, the bottom ash from the combustion has more than 90% of metals (referred to the residue generated, $g_{metal}/g_{residue}$), whereas the metal content from pyrolysis residue is around 50%. However, the chemical and mineralogical composition of the ash from different thermal conversion methods result in different leaching properties and is not well known. Furthermore, the carbon content in the waste decreases with the amount of oxygen used in the process, being negligible in the ash from combustion, but could be significant for gasification and pyrolysis, particularly for the latter. The high content of carbon in the residue from pyrolysis (char) provides advantage for the reuse of the solid in applications like soil amendment, in some cases probably enhancing soil fertility through improving nutrient retention due to cation adsorption (Kuppusamy *et al* 2016). However, ash with high content of metals could be favourably used as cement replacement in blast furnace briquetting (Mäkelä *et al* 2011). These aspects are investigated in this paper coming up with utilization criteria and recommendation for the management of the ash resulting from different thermochemical processes.

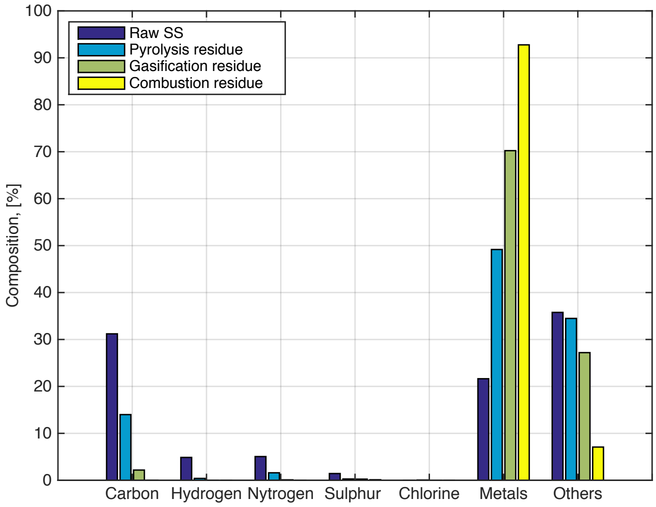

Figure 1: Comparison of the composition of main output ash (bottom ash) from various thermochemical processes (pyrolysis, gasification and combustion) and the raw SS.

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