World Academy of Science, Engineering and Technology
International Journal of Environmental and Ecological Engineering
Vol:17, No:10, 2023

Towards the Production of Least Contaminant Grade Biosolids and Biochar via Mild Acid Pre-treatment

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Abstract : Biosolids are stabilised sewage sludge produced from wastewater treatment processes. Biosolids contain valuable plant nutrient which facilitates their beneficial reuse in agricultural land. However, the increasing levels of legacy and emerging contaminants such as heavy metals (HMs), PFAS, microplastics, pharmaceuticals, microbial pathogens etc., are restraining the direct land application of biosolids. Pyrolysis of biosolids can effectively degrade microbial and organic contaminants; however, HMs remain a persistent problem with biosolids and their pyrolysis-derived biochar. In this work, we demonstrated the integrated processing of biosolids involving the acid pre-treatment for HMs removal and selective reduction of ash-forming elements followed by the bench-scale pyrolysis of the treated biosolids to produce quality biochar and bio-oil enriched with valuable platform chemicals. The pre-treatment of biosolids using 3% v/v H_2SO_4 at room conditions for 30 min reduced the ash content from 30 wt% in raw biosolids to 15 wt% in the treated sample while removing about 80% of limiting HMs without degrading the organic matter. The preservation of nutrients and reduction of HMs concentration and mobility via the developed hydrometallurgical process improved the grade of the treated biosolids for beneficial land reuse. The co-removal of ash-forming elements from biosolids positively enhanced the fluidised bed pyrolysis of the acid-treated biosolids at 700 ℃. Organic matter devolatilisation was improved by 40%, and the produced biochar had higher surface area (107 m^2/g), heating value (15 MJ/kg), fixed carbon (35 wt%), organic carbon retention (66% dry-ash free) compared to the raw biosolids biochar with surface area (56 m^2/g), heating value (9 MJ/kg), fixed carbon (20 wt%) and organic carbon retention (50%). Pre-treatment also improved microporous structure development of the biochar and substantially decreased the HMs concentration and bioavailability by at least 50% relative to the raw biosolids biochar. The integrated process is a viable approach to enhancing value recovery from biosolids.

Keywords : biosolids, pyrolysis, biochar, heavy metals
Conference Title : ICSWMR 2023 : International Conference on Solid Waste Management and Recycling
Conference Location : Osaka, Japan
Conference Dates : October 30-31, 2023