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Sewage sludge hydrochars: properties and agronomic impact as related to different production conditions

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The huge amount of sewage sludge (SS) generated in wastewater treatment plants all over the world represents an environmental problem. Due to the high concentration of phosphorus and nitrogen in SS as well as other macro and micro nutrients it has been considered a suitable soil amendment. However, before being applied to soil a complete sterilization and elimination of pollutants should be carried out [1]. In this context, thermal treatments appear as a convenient methodology for producing SS byproducts useful for agronomic purposes. Hydrothermal carbonization (HTC) is a kind of pyrolysis characterized by the heating of the biomass in presence of water. This process shows an advantage compared to other thermal treatments for wet residues since dryness of the biomass prior to the thermal transformation is not necessary. The solid product which results from HTC is called hydrochar and it has been suggested to increase soil productivity [2]. However, the agronomic potential of hydrochars depends on the feedstock and production conditions. Additionally, possible toxic and risks have to be carefully evaluated. Thus, SS hydrochars appear as a potential soil amendment but further scientific research is needed to find its real capacity, optimal production conditions as well as possible environmental harmful effects.

The aim of this study was to evaluate which are the most suitable production conditions, to transform SS into hydrochar. An additional goal of this work was to relate the hydrochars properties to its agronomic response. Therefore, hydrochars were produced from SS collected from the Experimental Wastewater Treatment plant of CENTA (http://www.centa.es/), located in Carrion de los Cespedes (Seville), under two different temperatures (200 and 260˚C) and residence times (30 min and 1h).

With the hydrochars obtained, a greenhouse pot incubation study was carried out for 80 days. The pots contained 250 g of a Calcic Cambisol (IUSS Working Group WRB, 2007) and an amount of hydrochar equivalent to 5 and 25 t ha-1 were prepared in quadruplicate for each hydrochar using Lolium perenne as test plant (25 seeds per pot). Hydrochars were not washed before this experiment. Control pots, without hydrochar amendment, were also settled for comparison purposes (n=6). After adjusting the soil humidity to 60% of the maximum WHC, the pots were placed into a greenhouse under similar conditions than those reported by [3]. In this experiment germination, survival rates and biomass production per pot were measured periodically.

Elemental analysis and the determination of several chemical properties of hydrochars such as pH, electrical conductivity and ash content were performed. Additionally, 13C solid-state nuclear magnetic resonance (NMR) was applied to elucidate the main chemical groups whereas fast field cycling (FFC) NMR relaxometry was valuable for investigating the porous structure and water dynamic in the different hydrochars.

This work confirmed that production conditions of hydrochars vary their chemical properties and hence their agronomic effect. Biomass production raised significantly in presence of all hydrochars, being the response in presence of hydrochars produced at 200˚C significantly higher than the response in presence of hydrochars produced at 260˚C, whereas the residence time of the hydrochars in the reactor did not affect biomass productivity.

Concerning the characterization data, hydrochars which showed the highest biomass production were those which contain the highest mineralized nitrogen content (NH4, NO_2 and NO_3) and a greater presence of alkyl carbons and carboxyl groups. Hydrochars FFC NMR relaxometry results show a lower T1 (longitudinal relaxation time) compared to the pure sewage sludge, which suggests that HTC processes reduced the average pore size of the system. This has further implications in the water and nutrient retention capacity of the hydrochars compared to the pure sewage sludge.

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