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Can biochar enhance the immobilisation of heavy metals in historically contaminated soils?

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The location of Arnoldstein in Carinthia, Austria, is an industrial heritage site with mining and smelting activities since about 600 years. Lead and zinc ores were processed for centuries – with impacts on the surrounding soil, being polluted with heavy metals such as Cd, Pb and Zn. Up to now, the concentrations of $NH4NO_3$-extractable heavy metals are far above the trigger values for soils (derived for feed quality according Prüeß, 1994). Cu and Ni concentrations are low and do not contribute to the heavy metal contamination of the soils. The aim of our study was to investigate the effects of various biochar mixtures on immobilisation of heavy metals in this contaminated soil. If biochar successfully immobilises heavy metals, quality of biomass production could be improved. We conducted a pot experiment with ryegrass (Lolium multiflorum) consisting of three different biochar (BC) treatments mixed with compost, a gravel sludge combined with siderite bearing material as well as a lime treatment and an untreated control (n=5). In the analysed treatments, lime significantly lowered the $NH4NO_3$-extractable heavy metal concentrations in the soil compared to the control, except for Cu. Similarly, throughout the study, a combination of gravel sludge and siderite bearing material led to an immobilisation of the heavy metals in the soil. On the contrary, the Miscanthus biochar mixed with compost had no effect on the immobilisation; however, Cu concentration was significantly lower than in all other treatments.
The immobilisation of the heavy metals in the soil was generally not reflected in the plants (Lolium multiflorum), except for Zn, showing a significant decrease after lime, poplar BC and gravel sludge with siderite bearing material. However, Zn as well as Cd and Pb remained above the phytotoxicity level of 200 mg kg-1; lime treatment reduced the Zn concentration in Lolium multiflorum to 513 mg kg-1, gravel sludge to 531 mg kg-1 and poplar BC to 560 mg kg-1 while in the control plot 713 mg kg-1 Zn were measured. While decreased heavy metal concentrations in the plants were recorded after liming (Cu and Zn) and poplar BC treatment (Cd, Ni, Zn), Cd and Pb reacted differently after the lime treatment; the increased pH (between 6 and 7) caused higher plant concentrations of these heavy metals possibly because soluble metal-organic complexes were formed in this pH range.
Overall, the different biochar mixtures showed positive effects on heavy metal immobilisation in the studied soil. While these effects were not all directly reflected in the plant, there was a general qualitative improvement of biomass (except for Pb and Cu).

Keywords: Soil amendment, soil pollutants, Cd, Pb, Zn, Cu, Ni