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Effects of Softwood Biochar on the Status of Nitrogen Species and Trace Elements in Soils

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Extended Abstract

Application of ammonia-based fertilizers to increase soil nitrogen (N) can lead to acidification and subsequent nitrate leaching [1, 2]. Changes in soil pH can effect trace element mobility which is influenced by environmental conditions [3]. Under inundation conditions reductive dissolution can mobilise trace elements into soil solution, increasing bioavailability [3]. Biochar is a carbonaceous material which has demonstrated potential for soil remediation [4]. However feedstock choice and production parameters can markedly affect physiochemical properties [5], which may explain the inconsistent observations on biochar-driven pollutant immobilization in various studies. Experiments using a wider range of biochar are required to allow generalization of biochar functions in terms of their uses for environmental remediation. This study used softwood pellet biochar (SWP) produced at 550°C and 700°C, to observe the effects on two scenarios: (1) chemical behaviour of added ammonium in a sandy soil, and (2) immobilization of trace elements in a contaminated soil under water inundation conditions.

Results show low concentrations of water-extractable N-species. It is possible the alkaline pH of sandy soil caused a loss of added ammonium via volatilization. Low KCl-extractable NO_3- also occurred. The negatively charged biochar surface and lack of functional groups due to high pyrolysis temperatures (>500°C) disfavours the adsorption of nitrate ions, which is likely to contribute to nitrate leaching from the fertilized sandy soil [6]. Mass balance calculations reveal that the addition of biochar increases N-retention compared to the control. SWP550 increased N-retention by 8% as dose increased and SWP700 increased retention rates by 17%, suggesting a dose-dependent relationship. Results also show production temperature markedly affects N-retention with SWP700 reaching 63% N-retention at the higher dosage compared to 46% for SWP550.

In the water inundation experiment, significant ($p<0.05$) Fe and Mn immobilization was only observed at the end of the experiment using SWP700 at 1% dose, despite an observed decrease in the 240th hour. Significant enhanced immobilization ($p<0.05$) of Zn occurred in by the 240th hour where 59.4% of Zn was immobilized compared to the control with SWP700 1%. Arsenic tended to increase between the 48th and 120th hour; Pb showed no temporal pattern. Dissolved oxygen decreased with incubation time whilst electrical conductivity increased for all treatments. pH remained between 4.9-5.8. The reducing conditions possibly enhanced the anaerobic reduction of iron and manganese oxides, which led to mobilization of trace elements bound to these compounds hence increased concentrations over time for most treatments.

Where enhanced immobilization occurred this may be caused by the observed increased surface area and porosity of SWP700 (162.3m^2/g) compared to SWP550 (26.4m^2/g) increasing the number of active sites on the biochar surface. Increased surface area as a function of pyrolysis temperature has been previously reported [7]. Although past work has shown preferential affinity to other metal species over Zn [8], this work has demonstrated a dose-dependent ability of higher pyrolysis softwood chars to immobilise trace elements in anoxic conditions. An ability to retain N-species in biochar amended sandy soil was also observed. It is suggested that further work should be carried out to explore biochar dynamics in a range of environmental conditions with a wider range of experimental treatments to explore biochar efficacy for pollutant remediation.

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