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Field application of a novel Mn-oxide modified biochar (AMOchar) and *Betula pubescens* for contaminated soil remediation

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The application of organic amendments to contaminated soils is a widely recognized remediation strategy aimed to immobilize metals and metalloids while improving soil quality. Biochar, a solid product derived from biomass subjected to pyrolysis under low-oxygen conditions, has been extensively studied for its ability to immobilize contaminants due to its alkaline pH, high specific surface area, porosity and elevated carbon content. Surface modification of biochar has the potential to further enhance these properties. In particular, Mn-oxide modified biochars (AMOchar), obtained through the coating with amorphous Mn oxides (AMO), introduces surface charges that facilitate the binding of both anions and cations contaminants. Although laboratory studies have demonstrated of the effectiveness of AMOchar, field-scale evidence remains scarce. Furthermore, the stability of Mn coatings in environmental conditions is uncertain, as Mn leachaing could lead to secondary contamination of soils and water.

In this study, a stable AMOchar was synthesized and initially tested under laboratory conditions. Following laboratory and pot experiments, the material was applied in a field trial to evaluate its capacity for metal(loid) immobilization and its effects on the soil-plant system. The field experiment was conducted in an industrially contaminated site in Asturias, Spain, where AMOchar was combined with *Betula pubescens*, a native specie commonly used for soil phytostabilization. Experimental treatments included not only AMOchar, but also biochar and untreated soil as a control.

Preliminary results indicated that an initial AMOchar application at 2% w/w resulted in high Mn leaching, leading to phytotoxic effects. To mitigate this, a lower AMOchar dose was subsequently applied, optimizing the amendment to minimize toxicity while maintaining its remediation efficiency. This study represents a first step toward improving the stability and effectiveness of AMOchar, aiming to develop a versatile amendment that integrates the beneficial properties of biochar with those of AMO. The optimize AMOchar formulation has the potential to immobilize both anionic and cationic contaminants, enhance soil health, and contribute to long-term carbon sequestration in soils.