Immobilization of Cd, Pb and Zn in soil solution and contaminated soil using biochar to improve soil quality

*Rosa Soria[a], Stephen A. Rolfe[b], Steven F. Thornton[a]

[a]Groundwater Protection and Restoration Group, Dept of Civil and Structural Engineering, University of Sheffield
[b]Department of Animal and Plant Sciences, University of Sheffield

*Corresponding author
E-mail address: r.soria@Sheffield.ac.uk
@IsaSoriap

Introduction

Biochar is a black carbon produced from the pyrolysis of residual biomass; it possess a high specific surface area and is rich in oxygenated functional groups. Because of these properties it can bind heavy metals (HM) present in soils, immobilizing them by different physical and chemical mechanisms (Figure 1). This immobilization may reduce the amount of available heavy metals in soils, potentially decreasing the toxicity.

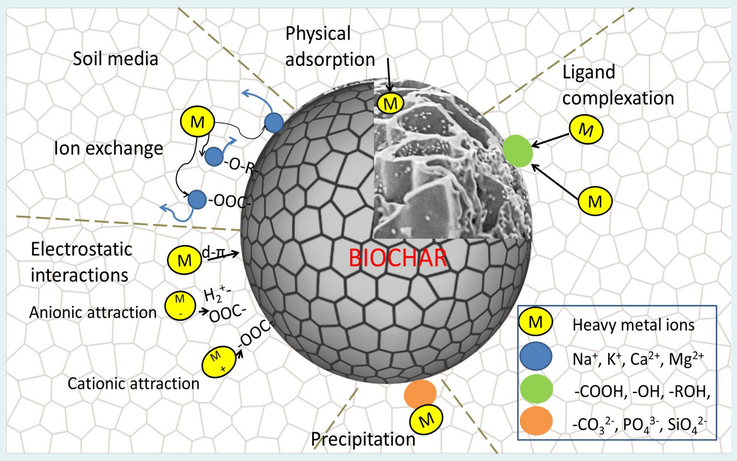

Figure1. *Proposed mechanisms of biochar interaction with heavy metals (M) in soil*

Objectives

The aim of this study is to determine the effect of biochar properties on HM immobilization mechanisms, to provide scientific criteria for its application in soil remediation.

The objectives are to:

1) Select suitable biochar materials and characterize their properties
2) Identify the immobilization mechanisms for Zn, Pb and Cd in the selected biochars
3) Determine the effect of biochar amendments on the reduction of bioavailable HM and plant growth in artificially polluted soils

Methods

The methods proposed in order to achieve the objectives of this study are presented in Figure 2.

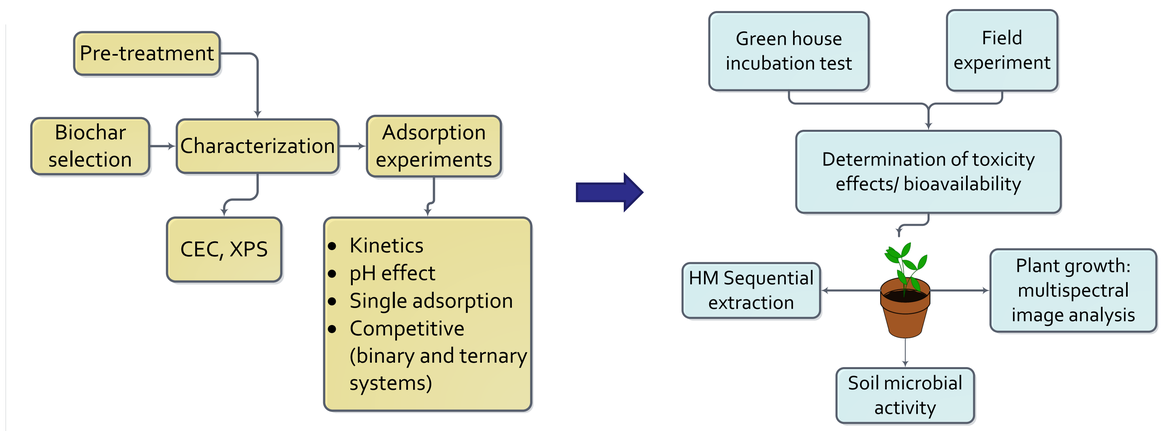

Figure 2*. Diagram of proposed methodology according to objectives*

Results

1. Biochar characterization

Table 1. *Properties of biochars. Cation exchange capacity (CEC) and specific surface area (BET) were analyzed for biochar particles <2 mm*

Biochar	O:C [molar ratio]	CEC cmol kg^{-1}	pH	BET [m2.g^{-1}]
WSP550	0.08	29.86(a)	9.94	290
MSP550	0.09	29.82(a)	9.77	490
OSR700	0.09	30.72(a)	10.41	460
SWP550	0.09	**19.03(b)**	7.91	358
OSR550	0.1	30.27(a)	9.78	416

Biochar SWP550 was shown to have a CEC significantly different from the other biochars. Letters indicate the different group categories according to Tukey post hoc test

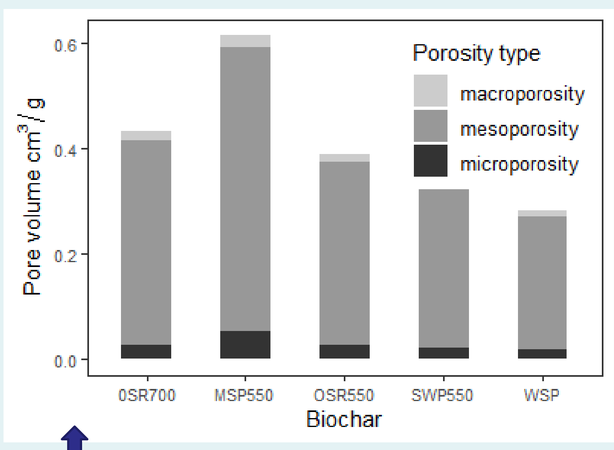

Figure 3*. Biochar porosity distribution according to the BJH analysis*

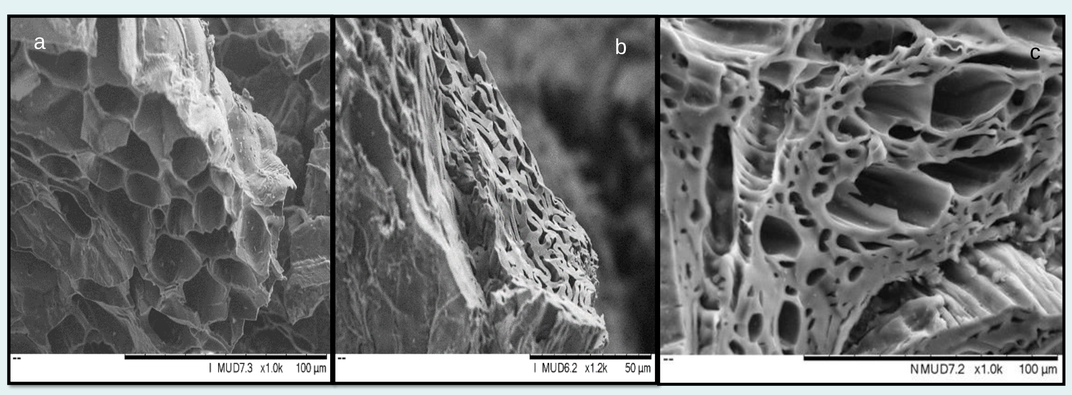

Figure 4*. SEM images of (a) oil seed pellets biochar OSR700, (b) soft wood pellets biochar SWP550, (c) Miscanthus pellets biochar MSP550*

Results

2. Biochar sorption experiments

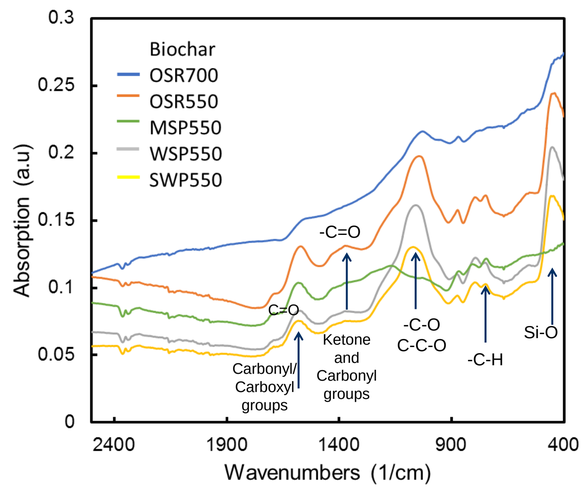

Figure 5*. FTIR spectra of biochar materials, arrows indicate differences in functional groups implicated in heavy metal immobilization*

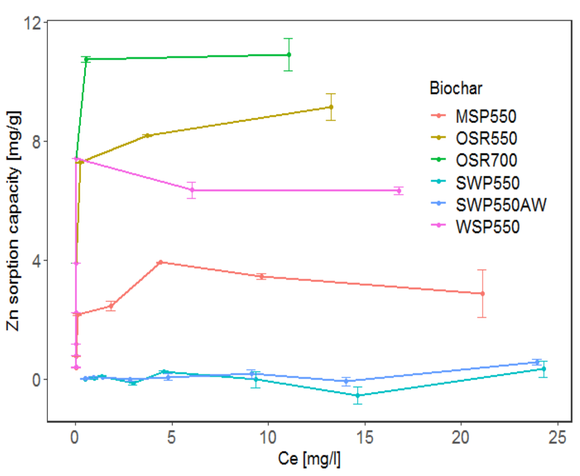

Figure 6*. Zn sorption isotherms of different biochars*

3. Greenhouse incubation with biochar

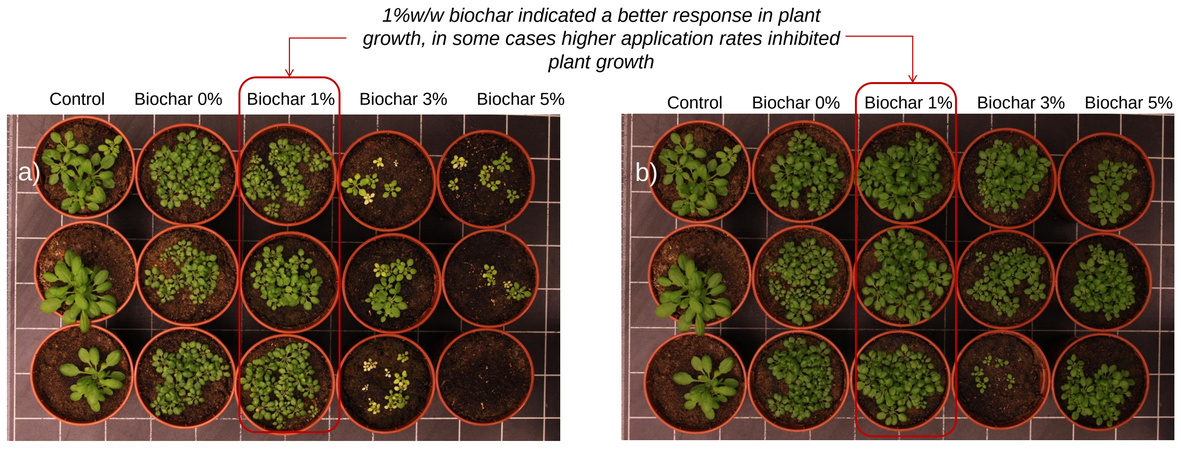

Figure 7*. Greenhouse incubation test: a) Cd artificially contaminated soil amended with OSR550, b) Zn artificially contaminated soil amended with WSP550*

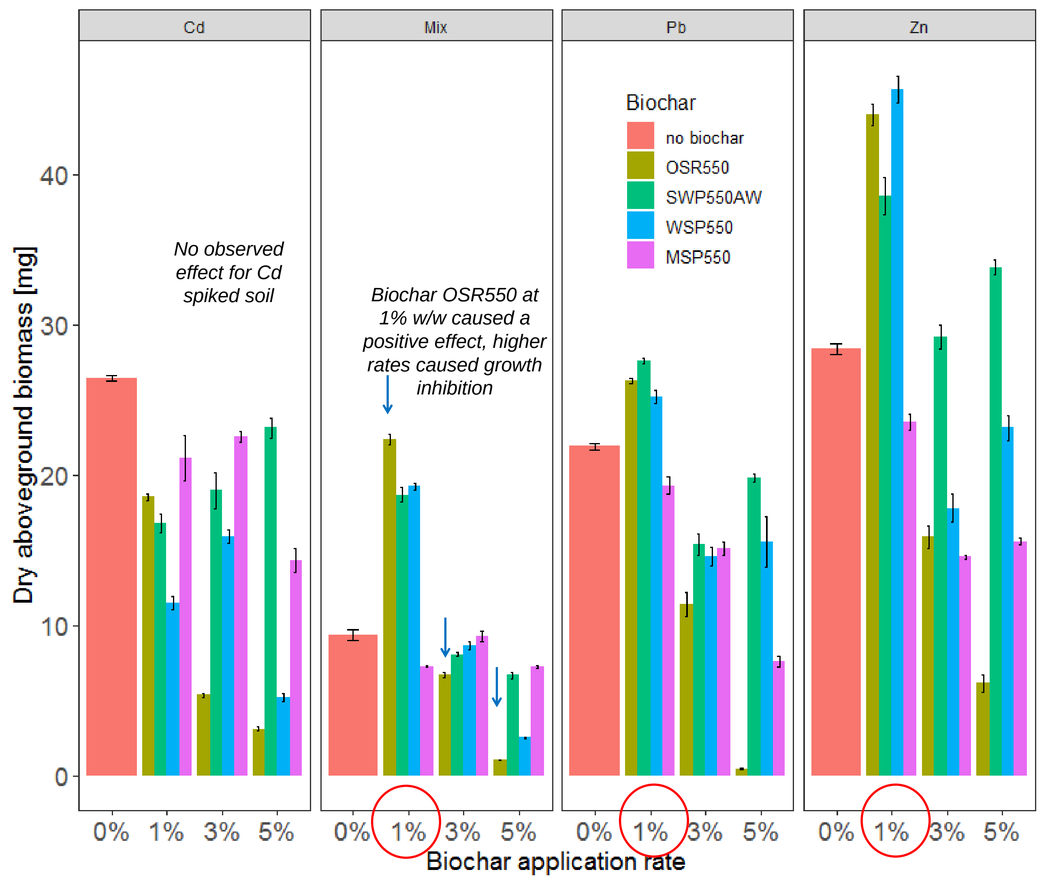

Figure 8*. Dry aboveground biomass from greenhouse incubation test using biochars OSR550, WSP550. MSP550 and SWP550 at application rates of 1, 3 and 5% (w/w). Biomass was harvested after one month of incubation at 25 °C and a photo light period of 12 hours*

Conclusions and Recommendations

- Feedstock and temperature during pyrolysis influence biochar properties CEC, pH and surface area
- Biochar properties determine biochar sorption capacity towards different heavy metals in aqueous solution, with higher immobilization potential for Pb, followed by Cd, followed by Zn
- Biochar at an application rate of 1% (w/w) enhanced plant growth in soils contaminated artificially with Pb, Zn or a mixture of heavy metals
- The roles of elevated pH and K in the deleterious impact of high biochar application rates are being investigated

Acknowledgements

- This research is conducted as part the Marie Skłodowska-Curie Innovative Training Network INSPIRATION - *Managing soil and groundwater impacts from agriculture for sustainable intensification* - funded by the European Comission (Grant agreement no. 675120).
- We acknowledge the UK Biochar Research Centre, University of Edinburgh, for providing the standard biochar materials used in this research.