The effects of fresh versus aged biochar on the leaching of metals from multi-element contaminated soils

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Effects of “fresh” *versus* “aged” biochar on soil metal leaching

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INTRODUCTION

Biochar* has been proposed as an effective soil amendment for the management of metal(loid)s *via* a number of mechanisms[1]:

- by **direct sorption** on biochar’s surface,
- by the occlusion of soil particles,
- by **indirectly modifying soil chemistry**.

** (solid product from biomass pyrolysis used as soil amendment)*

In particular, an **increase of soil pH** induced by biochar has been shown to reduce metal solubility, while a **release of labile compounds** from biochar has resulted in an increased soil metal leaching [2-4].

Different results may therefore be expected depending on the use of **"fresh" or "aged" biochar**, *i.e.* subject to weathering which can modify the surface and chemical properties of the biochar. Understanding the influence of ageing on biochar ability to immobilize metals in soils is crucial **to assess biochar long-term effects**.

➔ Column leaching experiments were conducted in August 2014 at the James Hutton Institute of Aberdeen (UK), in the frame of a Short Term Scientific Mission supported by COST Action TD1107. This work was done in order to:

- Differentiate **direct sorption** on biochar from **indirect effects** of biochar on soil metal leaching
- Assess the **impact of ageing process** on biochar’s ability to modify soil metal mobility

MATERIALS

- **1 agricultural soil**: contaminated by repeated sewage sludge amendments for 20 years
- **1 biochar:** produced at ~500°C from woody biomass, sieved to <2mm [2]
  - ❖ **Fresh biochar:** untreated
  - ❖ **Aged biochar:** weathered for 3 weeks under outside climatic conditions

	Soil	Biochar
pH	6.4	9.9
Total Cu	240 mg kg^{-1}	-
Total Zn	440 mg kg^{-1}	-

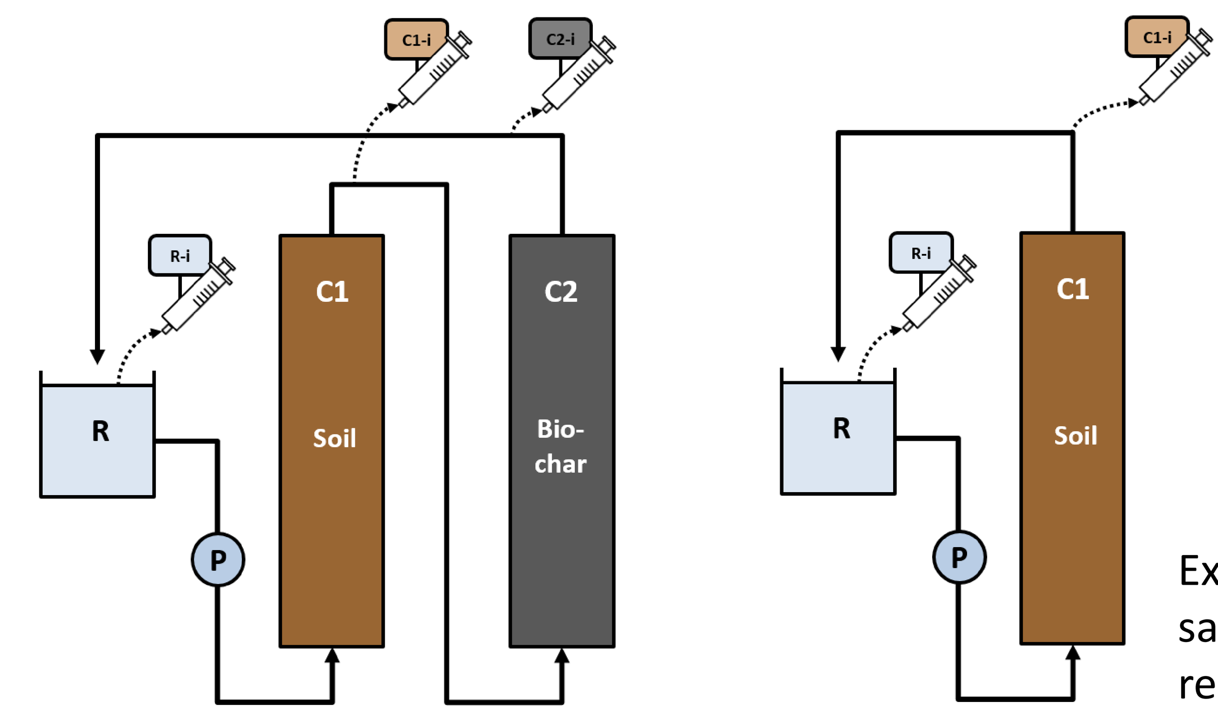
- Glass columns washed with diluted nitric acid were used associated to a multi-channel peristaltic pump.

METHODS

➔ A new column leaching protocol was tested **to mimic the new progressive equilibrium which takes place once biochar has been introduced in the soil**, while keeping both materials separated.

« Amendment » experiment (with soil and fresh/aged biochar)

Control experiment (with soil alone)



1. **First column containing pure soil (C1)** is leached by water stored in a **reservoir (R)**
2. **Second column containing either fresh or aged biochar (C2)** is associated in series with column C1, so that the leaching solution for C2 equals the leachate from C1
3. **Loop-circulation** is imposed: leachate from C2 goes back into reservoir R and progressively affects subsequent soil and biochar leaching

Experiments were run in duplicates for 48h. Liquid samples were regularly taken for analysis in the reservoir R, at the outlet of C1 and at the outlet of C2.

RESULTS & DISCUSSION

[Following results are only shown for the first replicate of each leaching run.]

Comparison of chemical analysis of liquid samples taken at different times show that:

- Despite large initial differences, pH of leachates from soil or biochar columns were identical after 24h

➔ Fast equilibration between soil and biochar

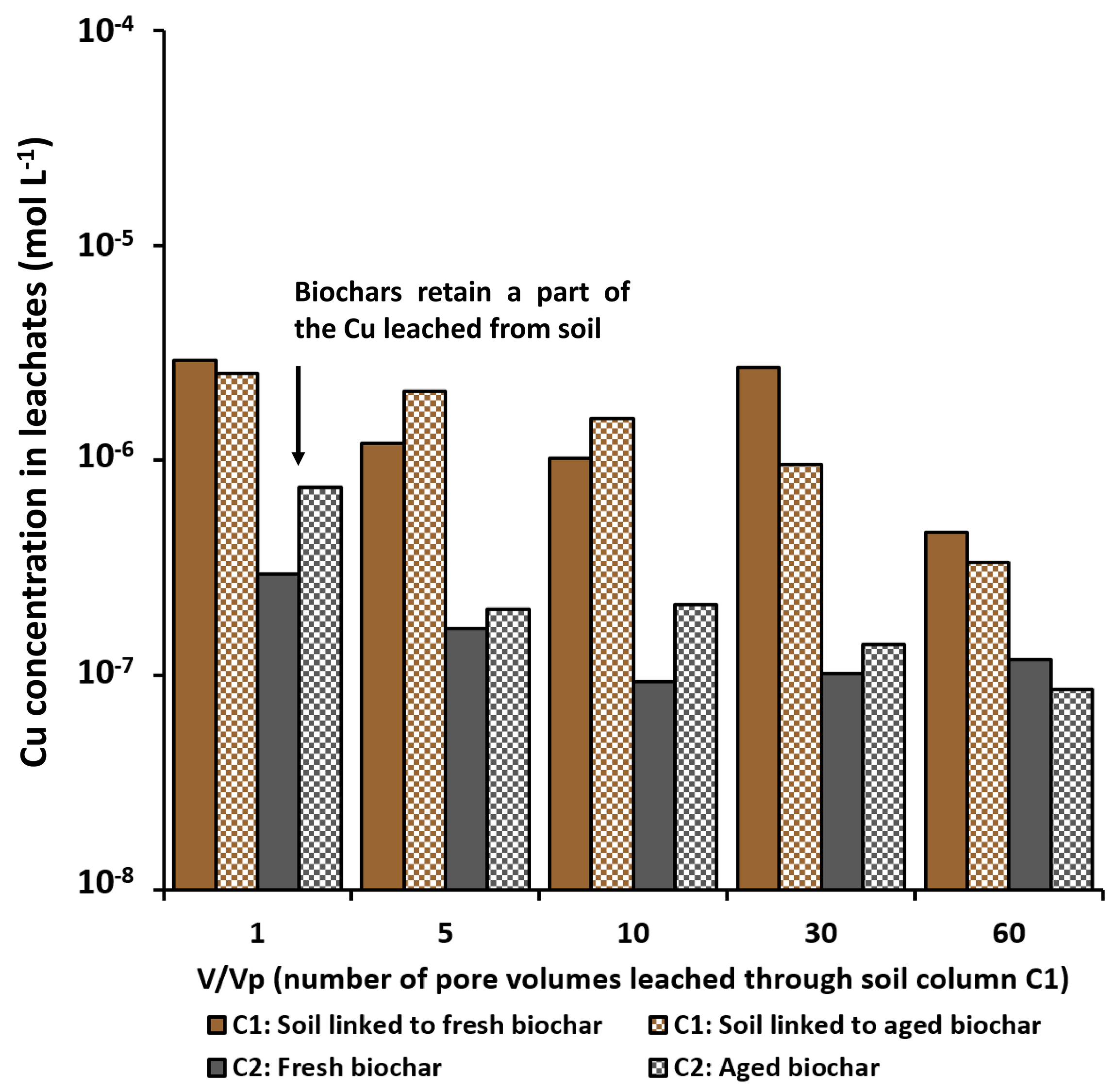
- Both **fresh and aged biochar** enabled to capture the metals released from the soil and to indirectly decrease this metal release **by increasing soil pH**

➔ Higher impact of direct sorption on biochar than indirect effect on soil metal leaching

- Both direct and indirect effects of biochar on Cu were lower than on Zn; Cu concentration was correlated to the concentration of dissolved organic carbon

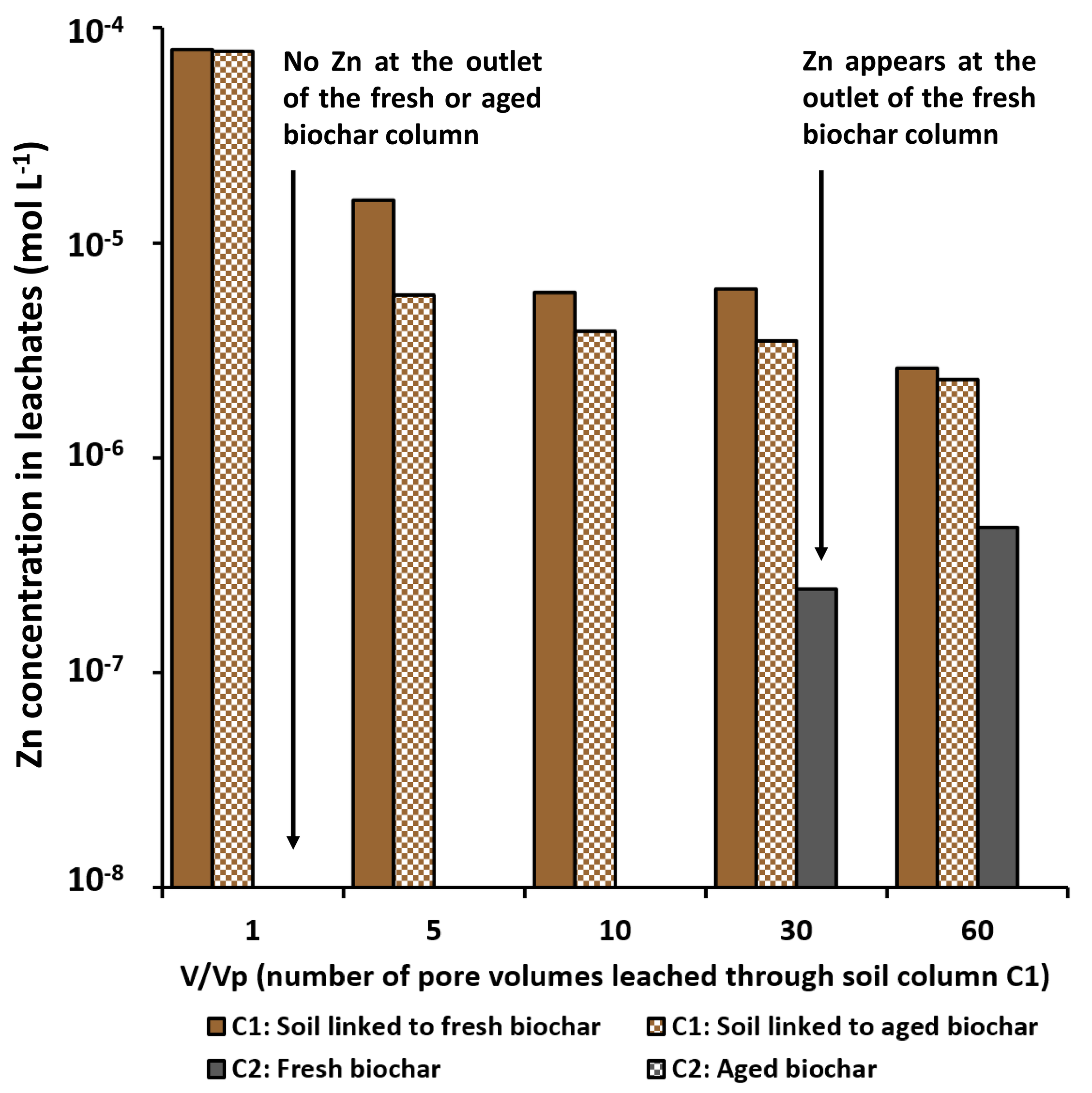
➔ Stabilization of Cu in solution with dissolved organic matter

Evolution of Cu leaching with time



- **Both biochars:** not able to retain all Cu from soil
- **Aged biochar:** less efficient than fresh biochar at the beginning, but not at the end

Evolution of Zn leaching with time

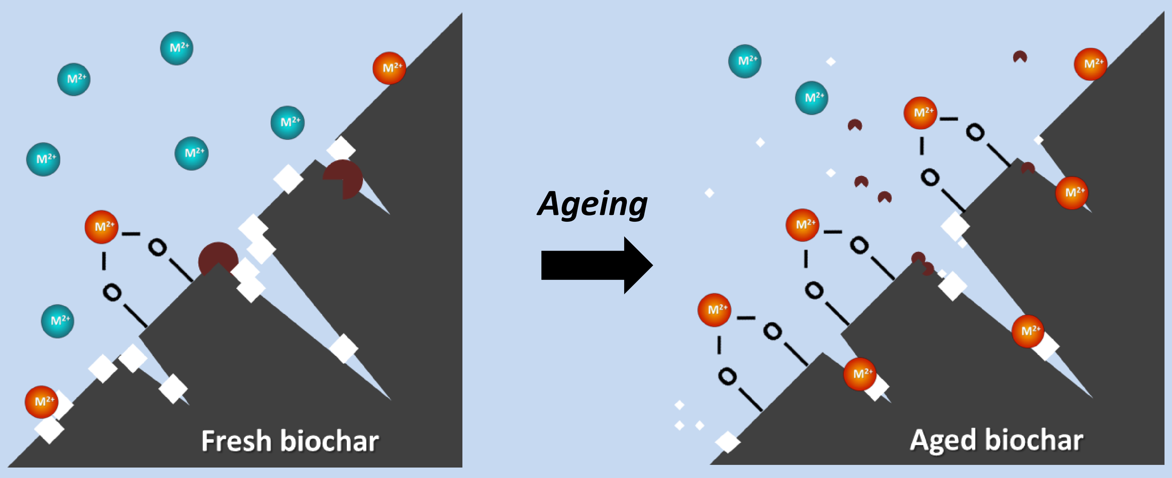


- **Fresh biochar:** (partially) saturated with Zn
- **Aged biochar:** not saturated at the end

➔ Ageing of biochar ↗ Zn retention capacity

CONCLUSIONS

Ageing of biochar can increase its metal retention capacity. **Loss of minerals** (*e.g.* carbonates) and **labile organic matter** associated with **surface oxidation** is likely to **have increased both specific surface area and cationic exchange capacity** of biochars.



PERSPECTIVES

Other processes of ageing should be tested, *e.g.* using litter bags filled with biochar in contact with a real soil environment. The specific design of this multi-column leaching experiment could be **used for other purposes** (*e.g.* nutrients mobility tests with biochar or compost).

[1] Beesley *et al.* (2011.) A review of biochars potential role in the remediation, revegetation and restoration of contaminated soils. *Environmental Pollution*
[2] Beesley & Dickinson (2011). Carbon and trace element fluxes in the pore water of an urban soil following […] amendments […]. *Soil Biology & Biochemistry*
[3] Houben *et al.* (2013) Mobility, bioavailability and pH-dependent leaching of cadmium, zinc and lead in a contaminated soil amended with biochar. *Chemosphere*
[4] Rees *et al.* (2014) Short-term effects of biochar on soil heavy metal mobility are controlled by intra-particle diffusion and soil pH increase. *European Journal of Soil Science*

This work is part of LORVER program and has been funded by Lorraine Region and FEDER program. We thank the STSM Committee of COST Action TD1107, *e.g.* Claudia Kammann. We also thank Samia for her technical assistance.