Modified spent coffee grounds and biochar remediation of heavy metal contaminated urban soils in Glasgow

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Introduction

Anthropogenic industrial, agricultural and waste disposal activities have resulted in excessive levels of heavy metals in soils and water globally (Ahsan et al., 2018). Historically, the preferred solution was to excavate these soils, dump them elsewhere, and bring in fresh soils. This study investigates an environmentally friendly alternative that takes advantage of coffee, which is one of the most common beverages in the world. For every tonne of unroasted coffee beans processed, 65% becomes spent coffee grounds (SCG) (Bomfim et al., 2022). Converting SCG to biochar (stable product of anaerobic combustion) is potentially beneficial for climate mitigation through carbon sequestration and immobilisation of contaminants.

This project investigates the potential of SCG in raw and biochar forms to remediate heavy-metal contaminated soils, whilst also mitigating climate change and providing a circular pathway for urban waste.

Heavy Metal Contamination

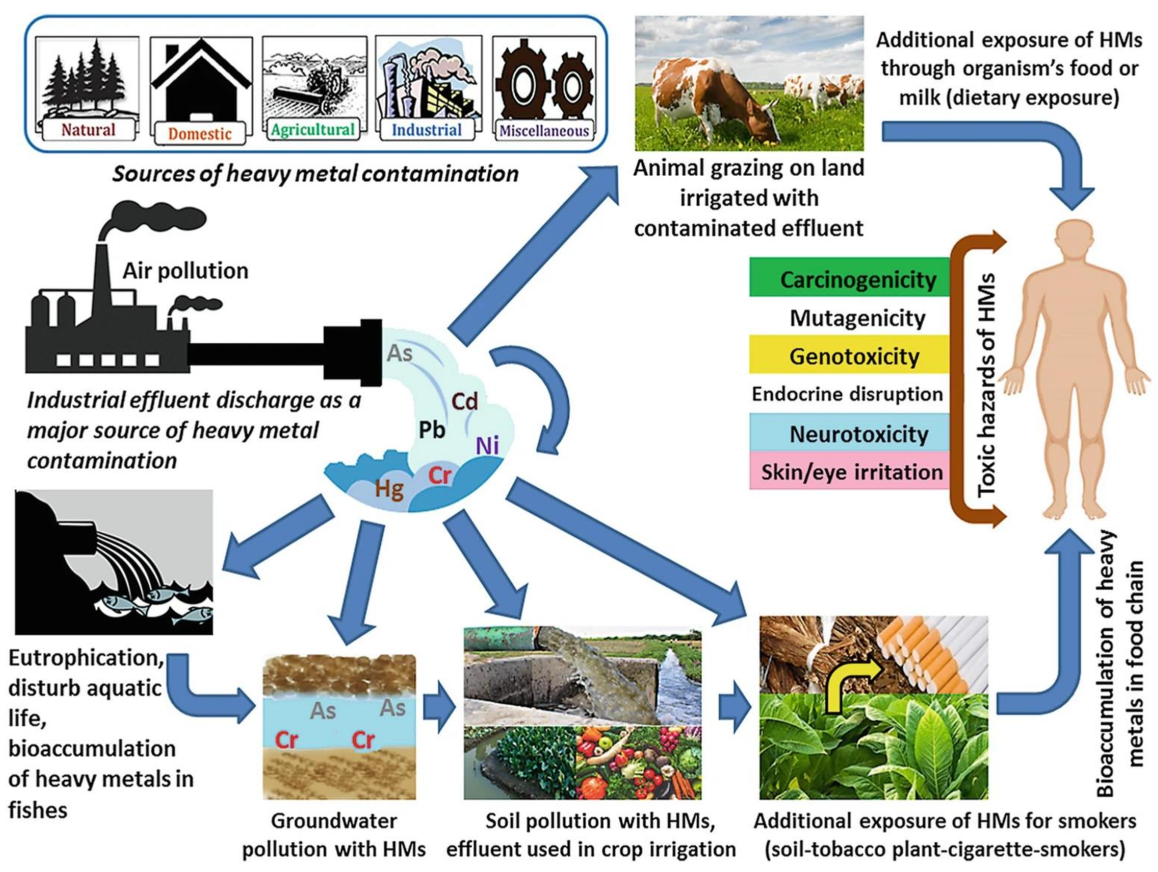

Fig 1. Overview of sources and effects of heavy metals on human health
Source: Saxena et al, 2020

Glasgow Vacant and Derelict Land and selected sites

Fig 2. Soil Map of Glasgow based on CLEAR guidelines showing contamination for 5 heavy metals.
Source: Based on BGS OpenReport OR/08/002, 2020.

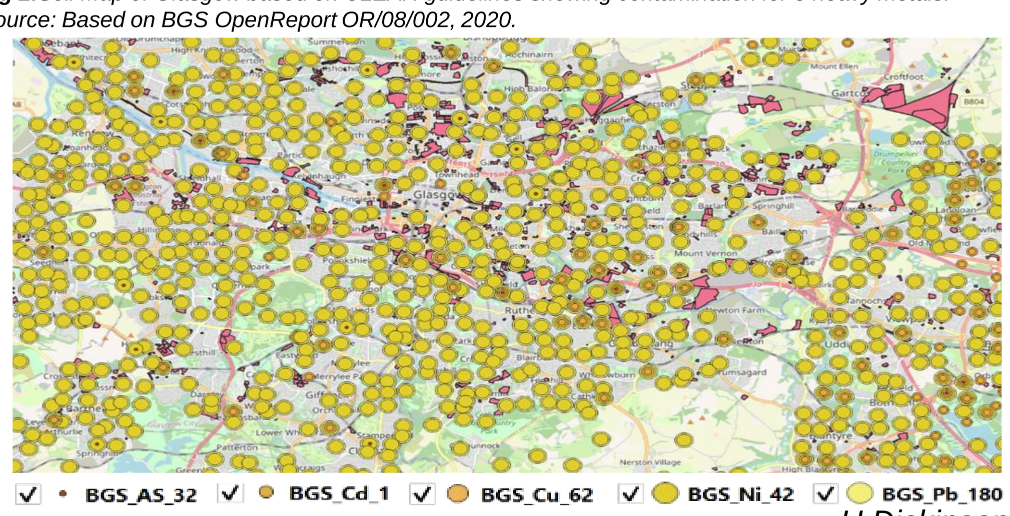

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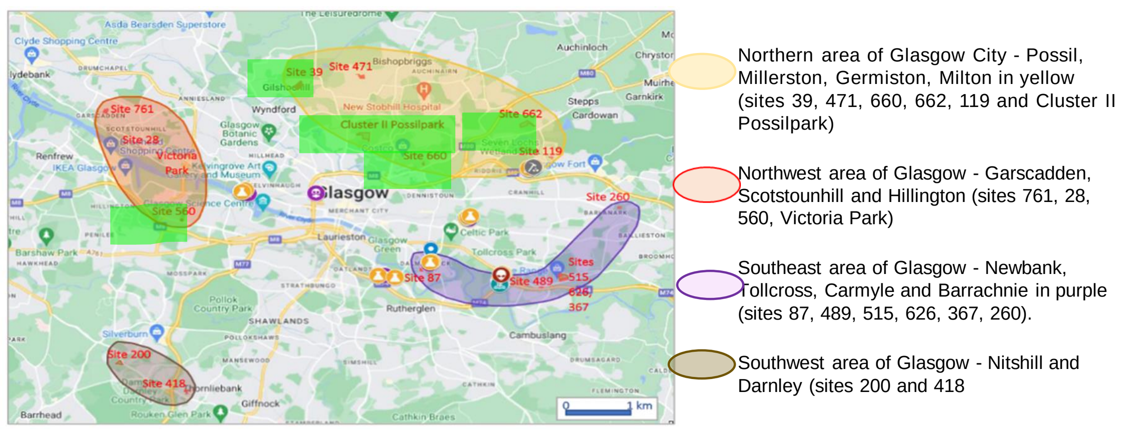
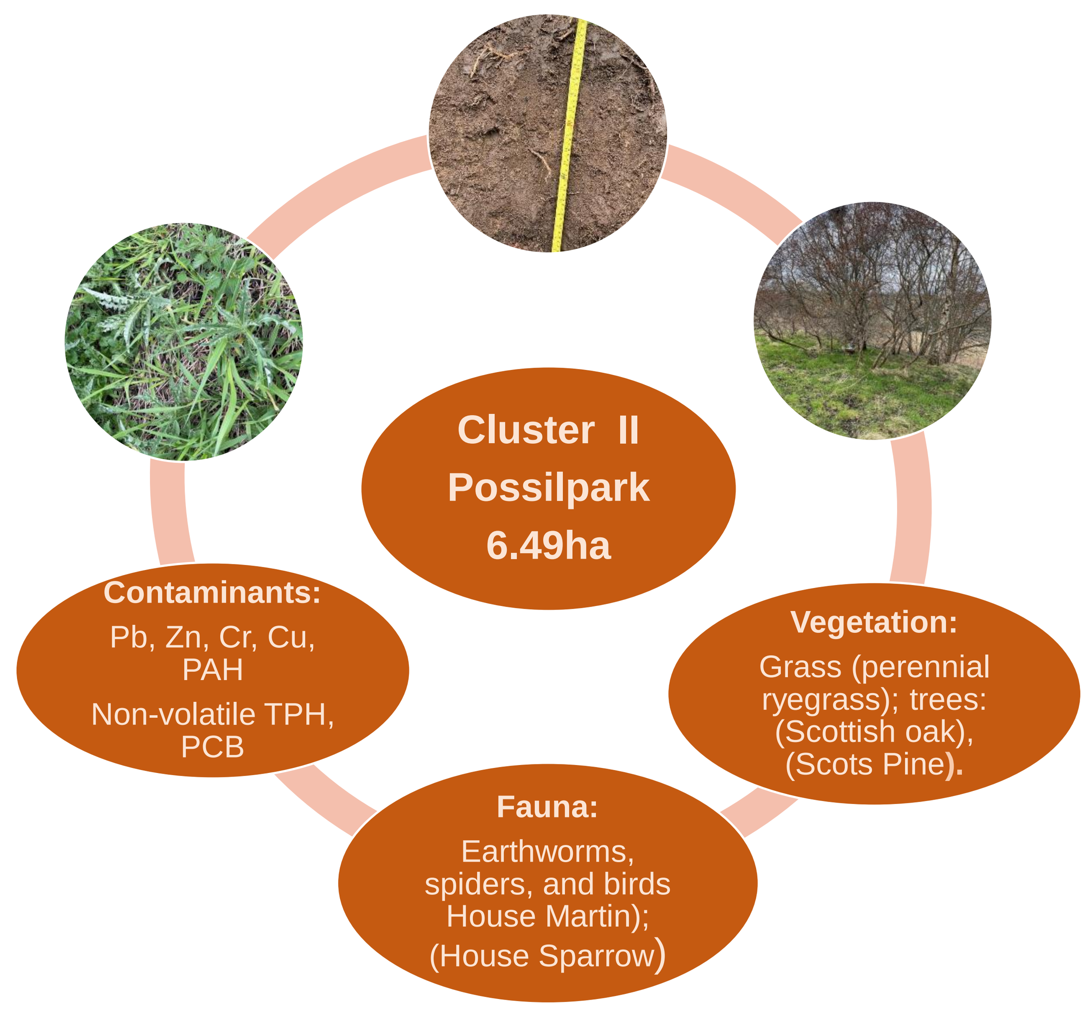
Fig 3. Reconnaissance of 29 sites took place in April and May 2023. Five sites (highlighted in green) were selected for sampling. A single point for Cluster II Possilpark was selected for the experimental soil



Selected Site: Cluster II Possilpark

Fig 4: Cluster II consists of several small sites grouped together, it has a mixture of overgrown rye grass, some bare patches , a small rubbish dumping site to the right. There is a lot of artefacts lying about. Soils are brown ranging in texture from loamy sand to silty clay loam.



Why Spent Coffee Grounds and Biochar?

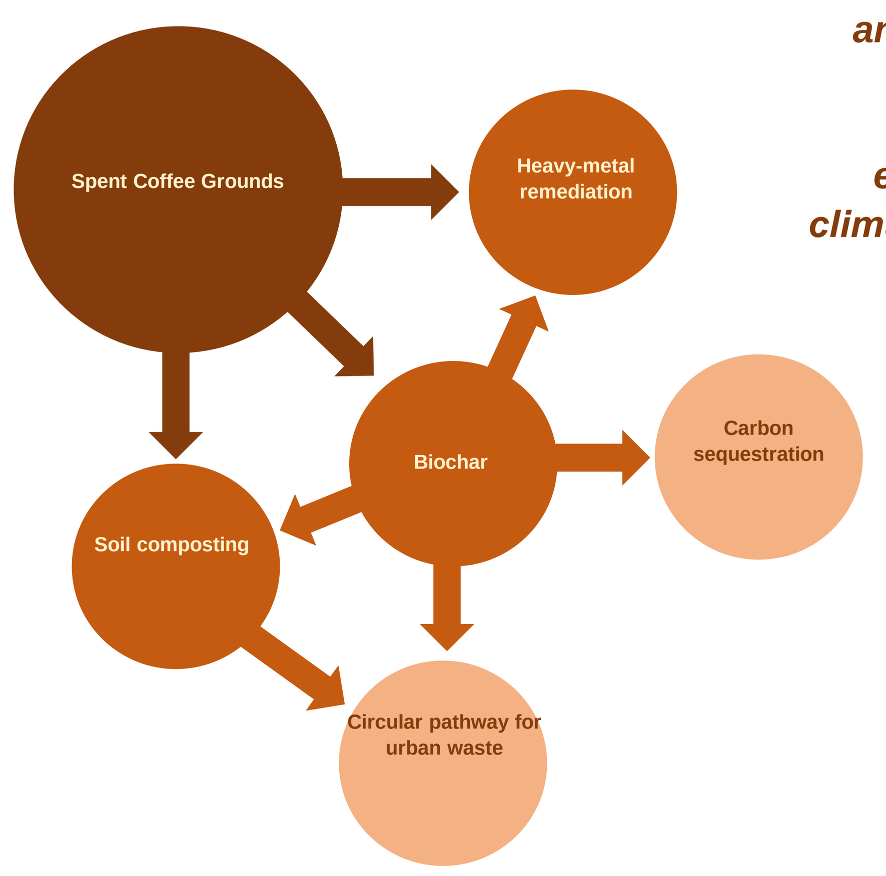


Fig. 5. above shows the opportunities for coffee grounds in soils; the industrial uses are beyond the scope of this article.

"Despite all the differences in assumptions and methodologies adopted, LCA [life cycle analysis] proved that biochar is a very promising way of contributing to carbon-efficient resource circulation, mitigation of climate change, and economic sustainability." (Carvalho et al., 2022)

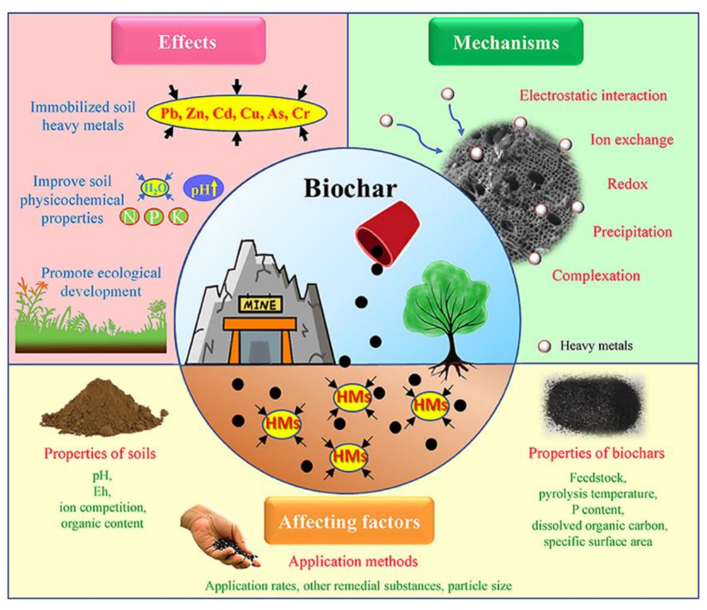


Fig 6: Mechanisms of Biochar and impacts
Source: Gao, Wu et al. 2022

Preliminary Characterisation Data

Fig 7: Images of the main treatments and homogenised soil sample and initial results

	Cluster II P1 M	SCG Raw P	SCG Raw H_2O_2	SCG Char P	SCG Char H_2O_2
pH	6.76	5.92	4.44	9.23	8.87
Carbon(C)	4.62	49.5	49.4	81.1	75.2
Hydrogen (H)	0.63	6.51	7.12	2.19	2.35
Nitrogen (N)	0	2.15	2.08	3.80	3.26

Materials and Methods

Soil samples were collected from the selected sites above and will be analysed be collected/measured**.** Pictures below show the sampling site, the collected SCG and incubation set up. **Fig 9 a) and b)** shows the design and the four main treatments. The soils were mixed with the treatments and incubated at room temperature in the lab for 28 days. 300ml of DI water was added to each column very 7 days and the leachate collected for analysis. Samples were collected for SO_4,NO_3, DIC,DOC and ICP analysis. On Day 28, two Pak Choi seeds were sown in each column.

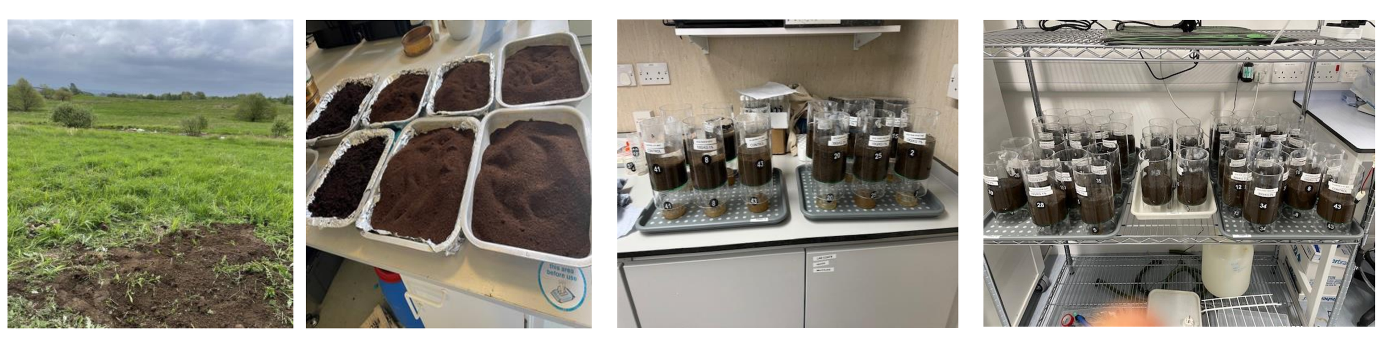
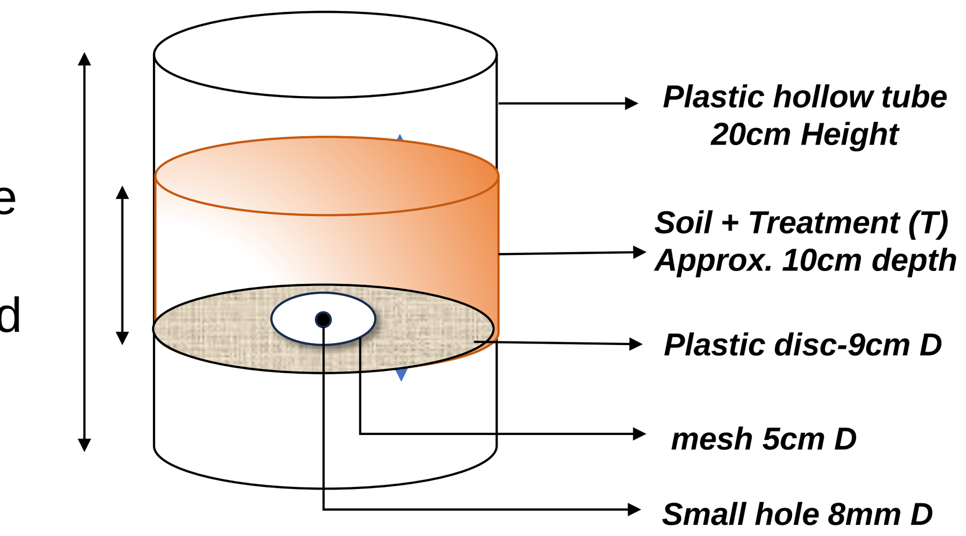
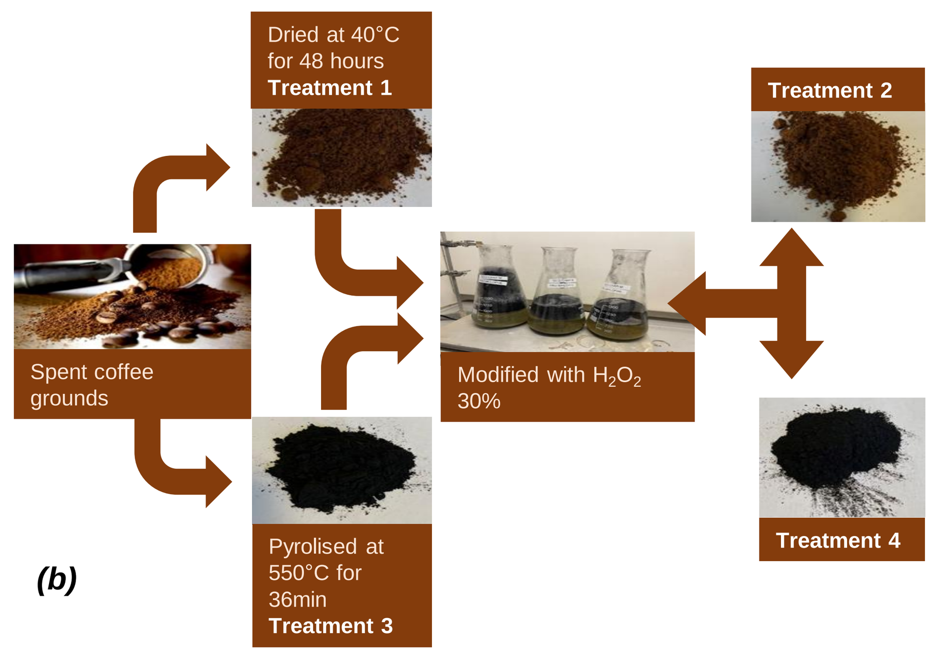


Fig 9: (a) Experimental Design Setup and (b) Overview of Treatments



(a) Leachate collection at the bottom



(b)

Research Questions

- ✓Does the presence of multiple heavy metal contaminants affect the efficacy of either the raw SCG or SCG Biochar?
- ✓Does the green additive H_2O_2, improve removal efficiency in multi-metal contaminated soils?
- ✓Does the modification of SCG into biochar improve its effectiveness in heavy metal immobilisation?
- ✓Does biochar treatment have any effect on other soil properties and nutrient cycling?

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