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Agronomic waste-derived biochar for concurrent stabilization of multiple heavy metals in agricultural soil: Effect of feedstock variety and pyrolysis temperature

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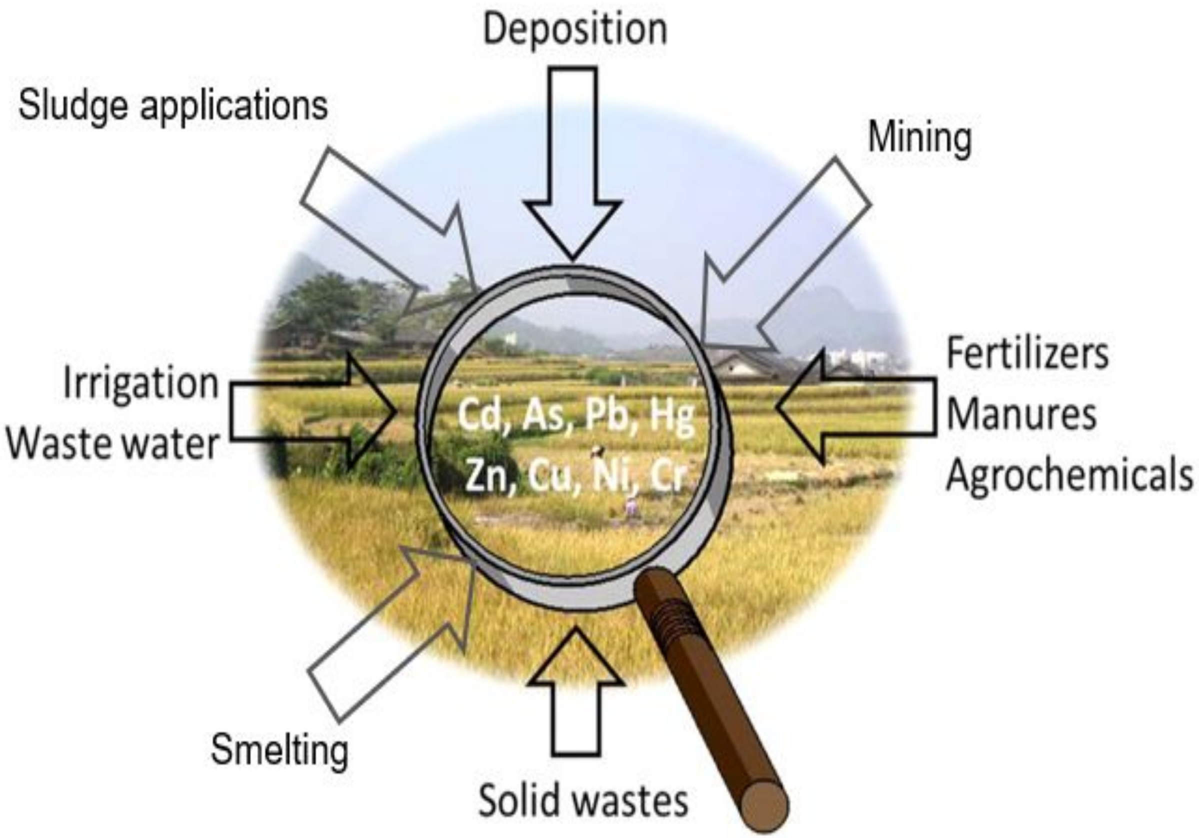
Time: 12:30, UTC+3 (Greece), June 17 2022
Room4

Heavy metal (HM) pollution in soil: causes and effects



Zhao et al. (2019) *ES&T*

Affect

Soil property

Soil ecosystem

Crop productivity

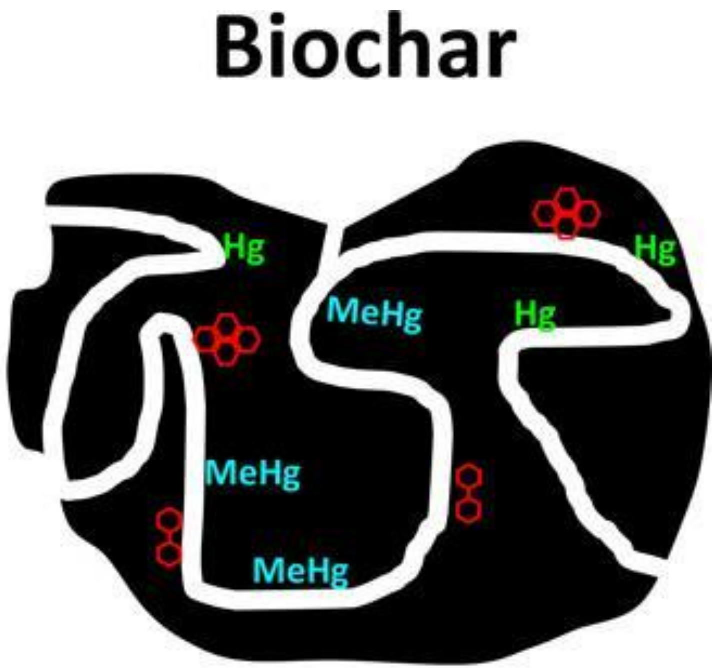
People health

Biochar (BC): a fascinating soil amendment?

A stable carbon-rich porous material

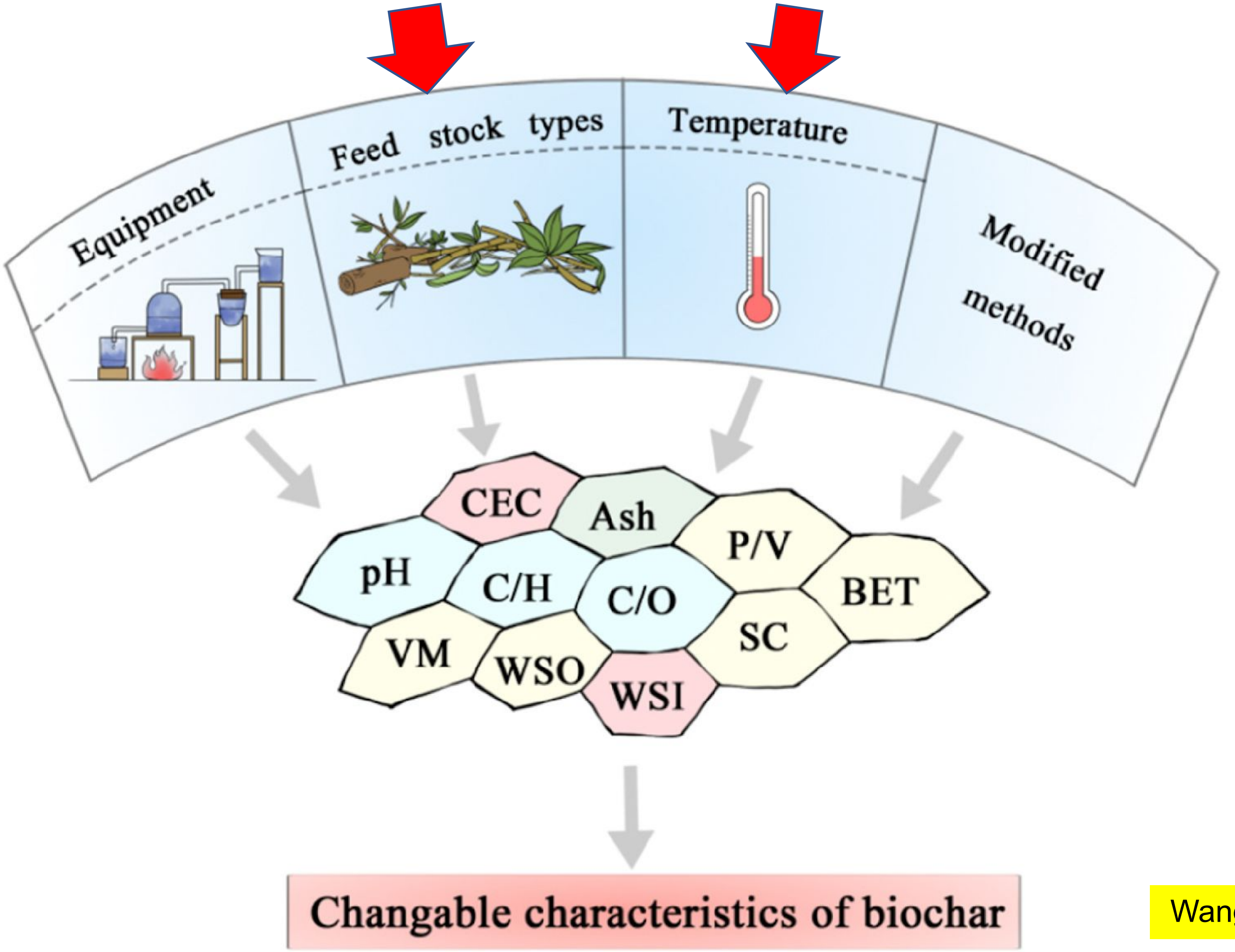
A low-cost, eco-friendly sorbent
- derived from agricultural wastes, including manures

Potential application in large scale
- to stabilize HMs in soils



Gomez-Eyles et al. (2013) *ES&T*

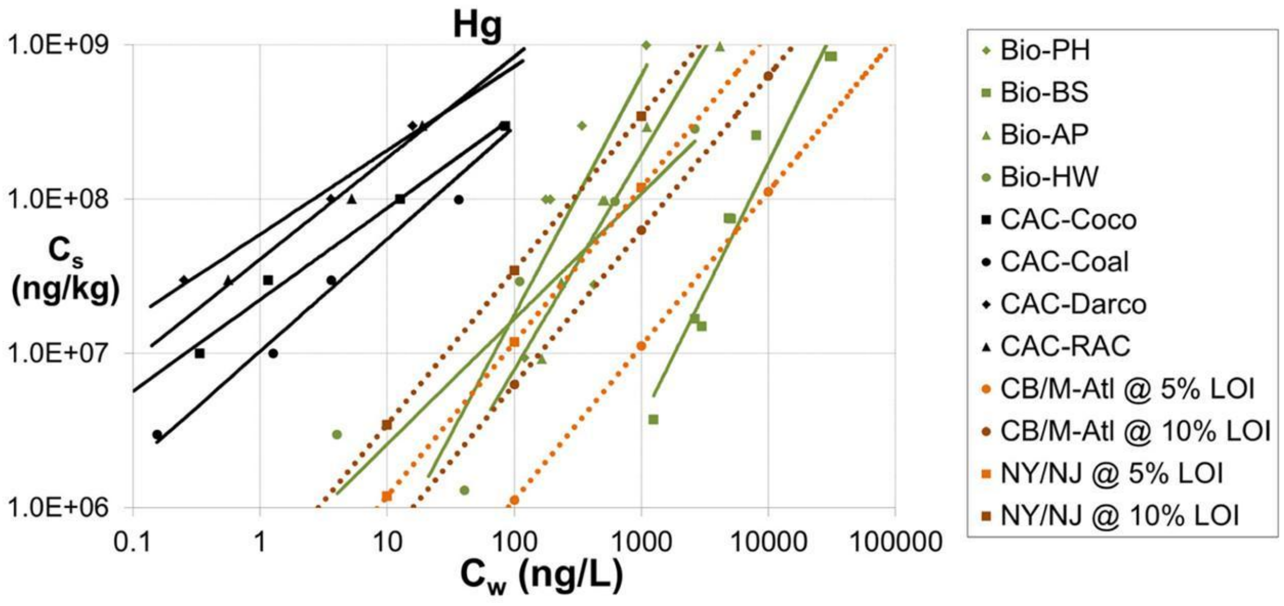
Factors that strongly influence the BC properties

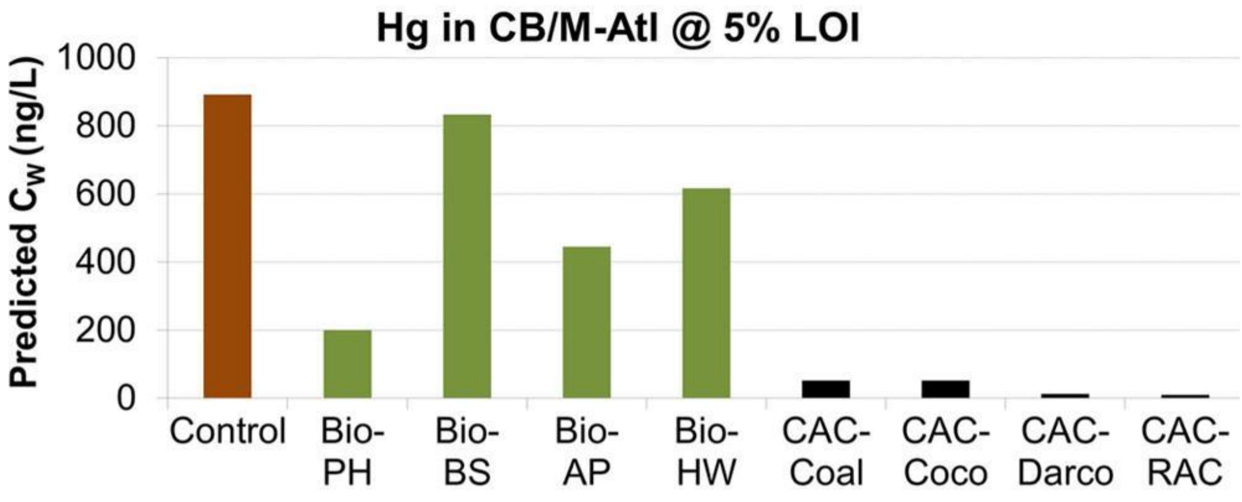


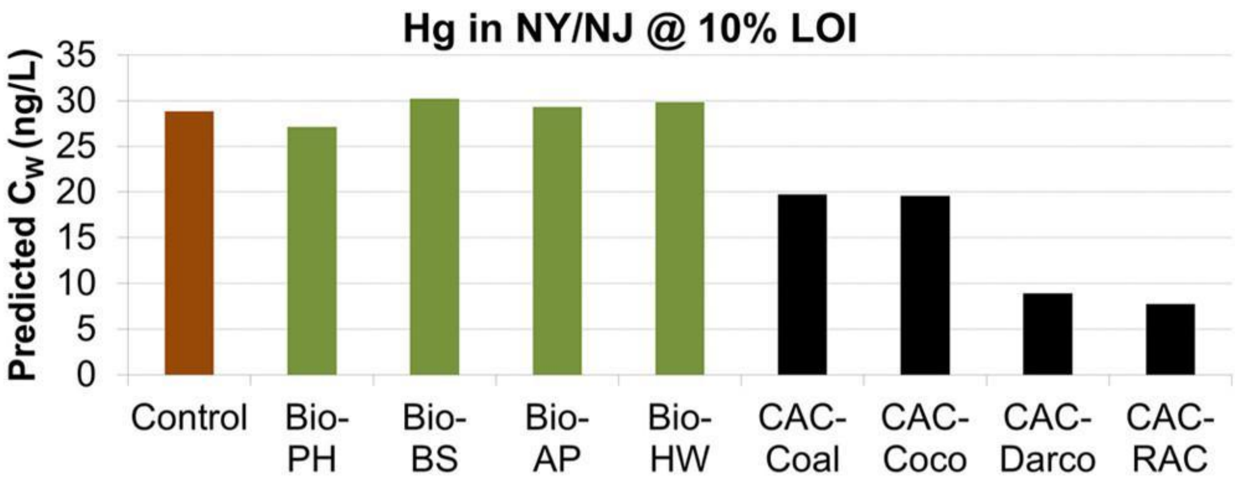
Wang et al. (2020) *Sci Total Environ*

Gomez-Eyles et al. (2013) *ES&T*

Linear model: $C_s = (f_{soil}K_{d\text{-}soil}C_w) + (f_{BC}K_{d\text{-}BC}C_w)$







Questions to be addressed

- How critical is the temperature on the HM adsorption (in the aqueous phase) and immobilization (in the soil matrix) capacity of BC?

- Can this factor be generalized to a variety of feedstock? If so, which type of raw materials originating from agricultural wastes is a better candidate for soil amendment?

- Can a simple partitioning equilibrium-based linear model be developed to effectively and reliably predict the ultimate efficacy of BC for *in situ* sorbent amendment to remediate HM-contaminated soil?

How to achieve the objectives?

Air-dried at 80 ^{o}C

Agro-wastes
(rice husk & camphor tree leaf)

0.27 mm sieve (50 mesh)

Pyrolysis (10 ^{o}C/min)

300 or 600 ^{o}C for 1 hr

Synthetic Biochar

(SEM-EDS, FTIR, XRD)

Biochar Characterization

(XPS, ASAP, elemental analysis)

Aqueous adsorption experiments

Application

Soil incubation experiments

Characteristics of synthetic biochar


Rice-husk Biochar 300℃ (RB300)


Rice-husk Biochar 600℃ (RB600)

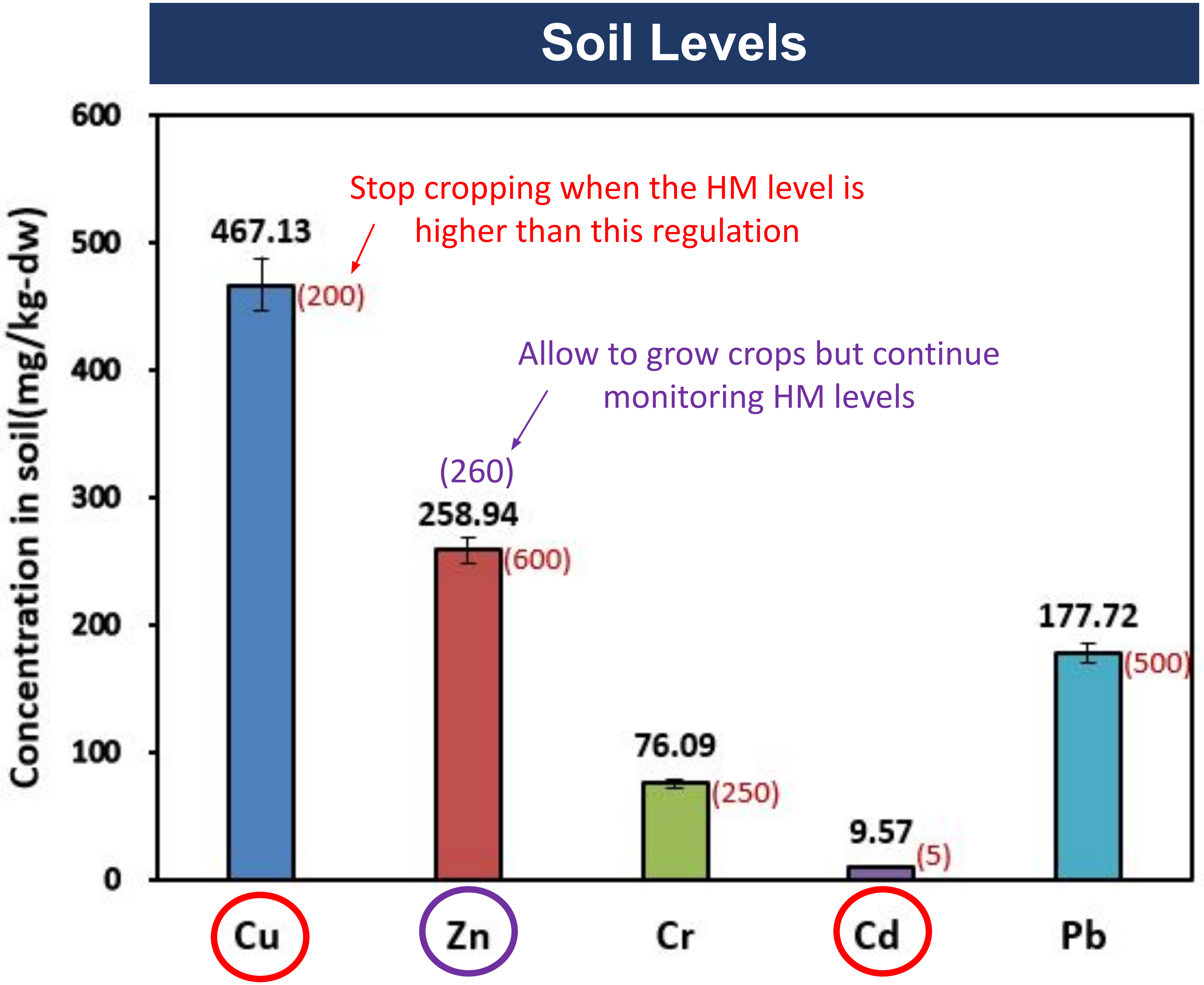

Leaf Biochar 300℃ (LB300)

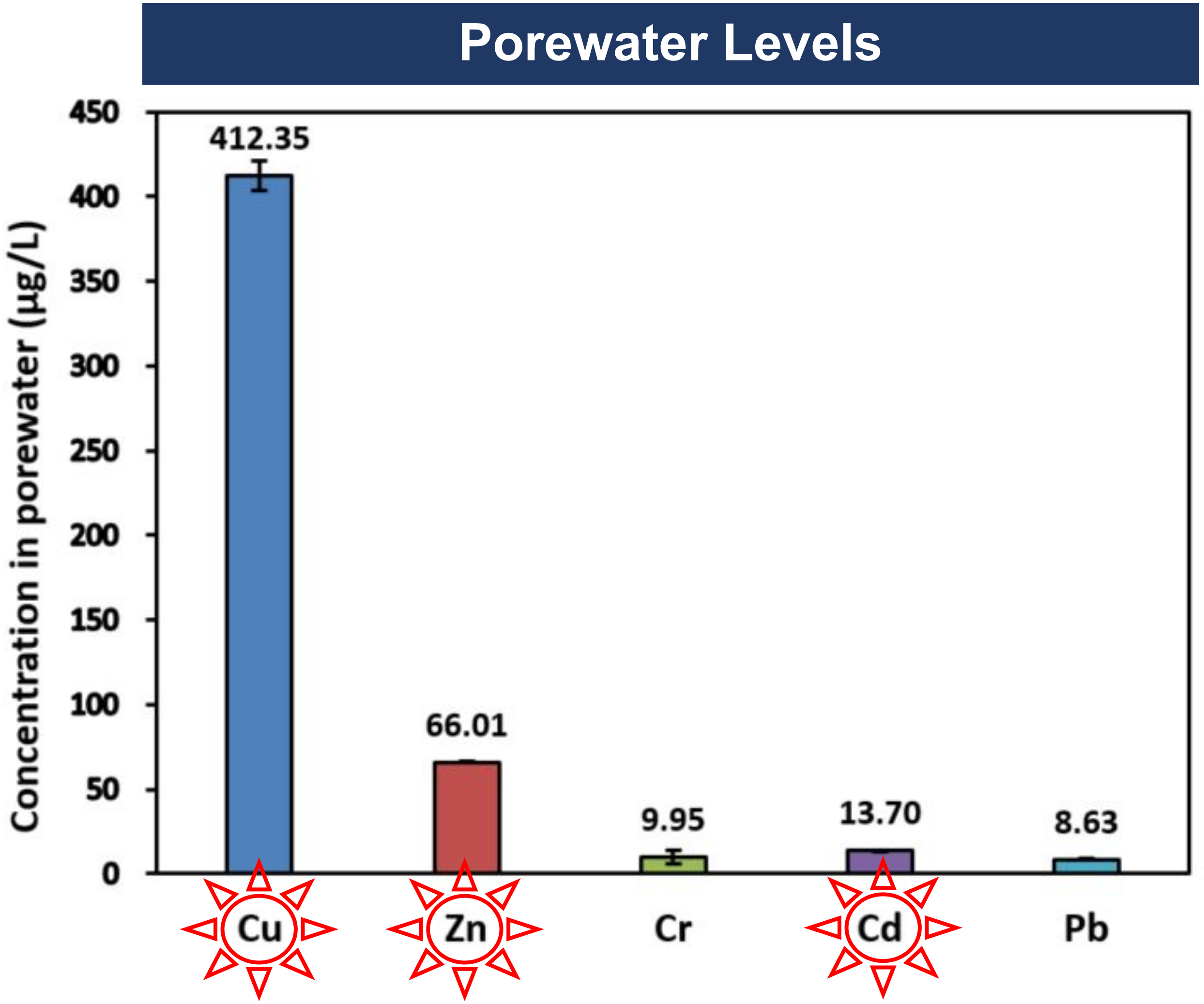

Leaf Biochar 600℃ (LB600)

Selected physical and chemical properties of adsorbents.

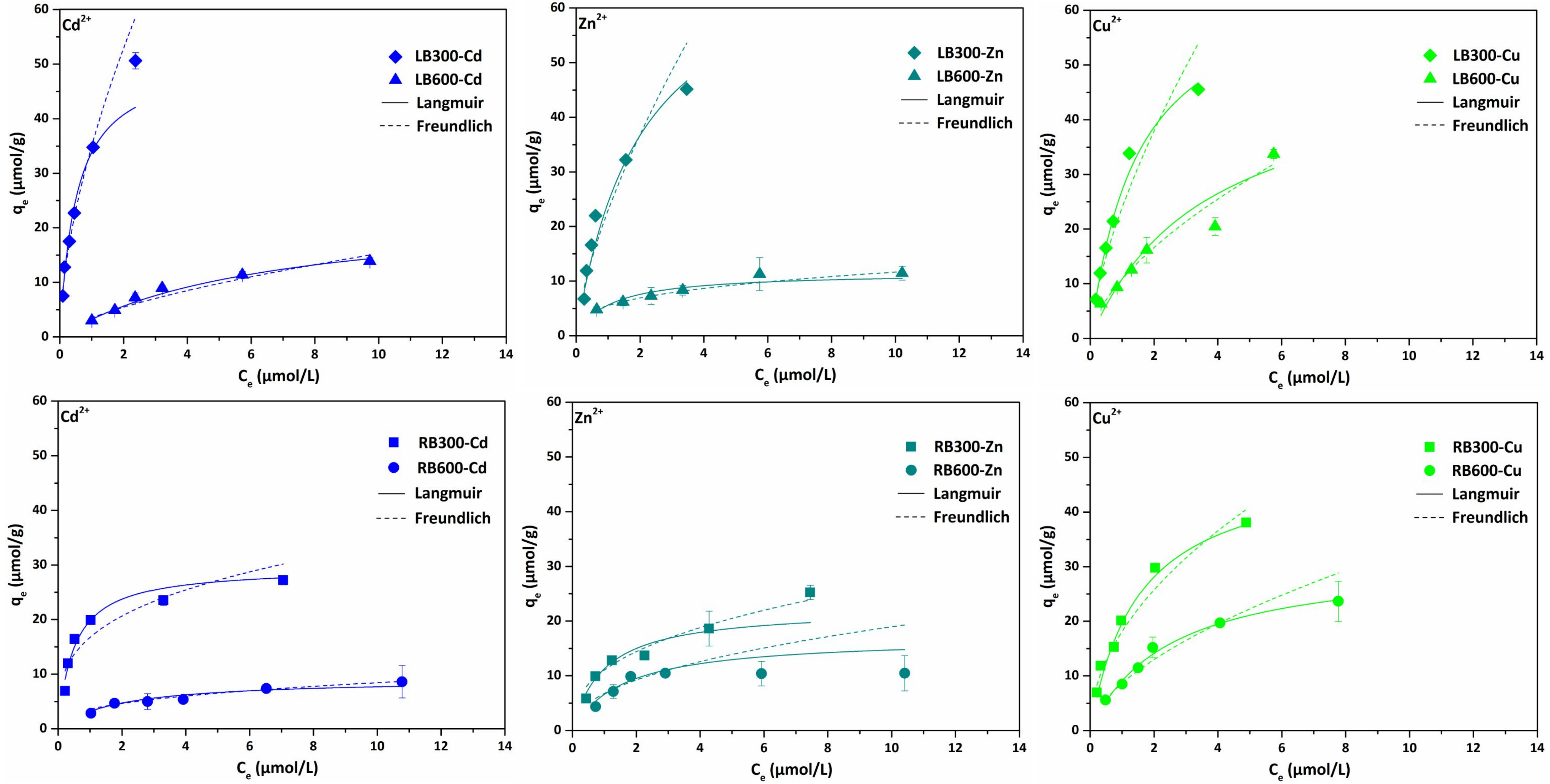
Properties	Ricehusk	RB300	RB600	Leaf	LB300	LB600
Moisture (%)	4.22 ± 0.08	2.32 ± 0.08	1.81 ± 0.08	7.74 ± 0.16	3.13 ± 0.10	2.50 ± 0.33
Volatile Matter (%)	67.55 ± 0.22	35.71 ± 0.34 ↓	13.84 ± 0.54 ↓	68.57 ± 0.03	51.75 ± 0.59 ↓	18.98 ± 0.72 ↓
Fixed Carbon (%)	12.89 ± 0.19	39.08 ± 0.42 ↑	49.14 ± 0.49 ↑	16.05 ± 0.10	37.11 ± 1.00 ↑	59.49 ± 1.16 ↑
Ash Contents (%)	15.34 ± 0.05	22.89 ± 0.004 ↑	35.21 ± 0.04 ↑	7.64 ± 0.02	8.01 ± 0.50 ↑	19.03 ± 0.11 ↑
C %	42.319 ± 0.013	50.228 ± 0.011 ↑	56.065 ± 0.165 ↑	48.412 ± 0.115	55.194 ± 0.043 ↑	63.909 ± 0.005 ↑
H %	6.031 ± 0.181	4.264 ± 0.195 ↓	2.500 ± 0.127 ↓	6.697 ± 0.021	5.589 ± 0.290 ↓	2.925 ± 0.197 ↓
N %	0.875 ± 0.016	1.075 ± 0.028	0.942 ± 0.042	1.247 ± 0.004	1.477 ± 0.081	1.486 ± 0.060
O %	41.801 ± 0.037	23.539 ± 0.018 ↓	7.013 ± 0.094 ↓	39.589 ± 0.238	32.188 ± 0.143 ↓	16.641 ± 0.281 ↓
S %	0.072 ± 0.030	-	-	0.089 ± 0.011	0.015 ± 0.021	0.033 ± 0.001
O/C	0.988 ± 0.001	0.469 ± 0.000 ↓	0.125 ± 0.002 ↓	0.818 ± 0.007	0.583 ± 0.003 ↓	0.260 ± 0.004 ↓
H/C	0.143 ± 0.004	0.085 ± 0.004 ↓	0.045 ± 0.002 ↓	0.138 ± 0.000	0.101 ± 0.005 ↓	0.046 ± 0.003 ↓
(O+N)/C	1.008 ± 0.001	0.490 ± 0.001 ↓	0.142 ± 0.001 ↓	0.844 ± 0.007	0.610 ± 0.005 ↓	0.284 ± 0.003 ↓
SA (m^2/ g)		1.05	224.91		1.17	205.10
V_{total} (cm^3/ g)		0.005	0.142		0.004	0.146
Pore Size (nm)		19.59	3.68		19.30	5.74
pH		6.48 ± 0.01	8.20 ± 0.14		6.03 ± 0.03	7.90 ± 0.13

Levels of heavy metals in the tested soil (at ppm) and its porewater (at ppb)



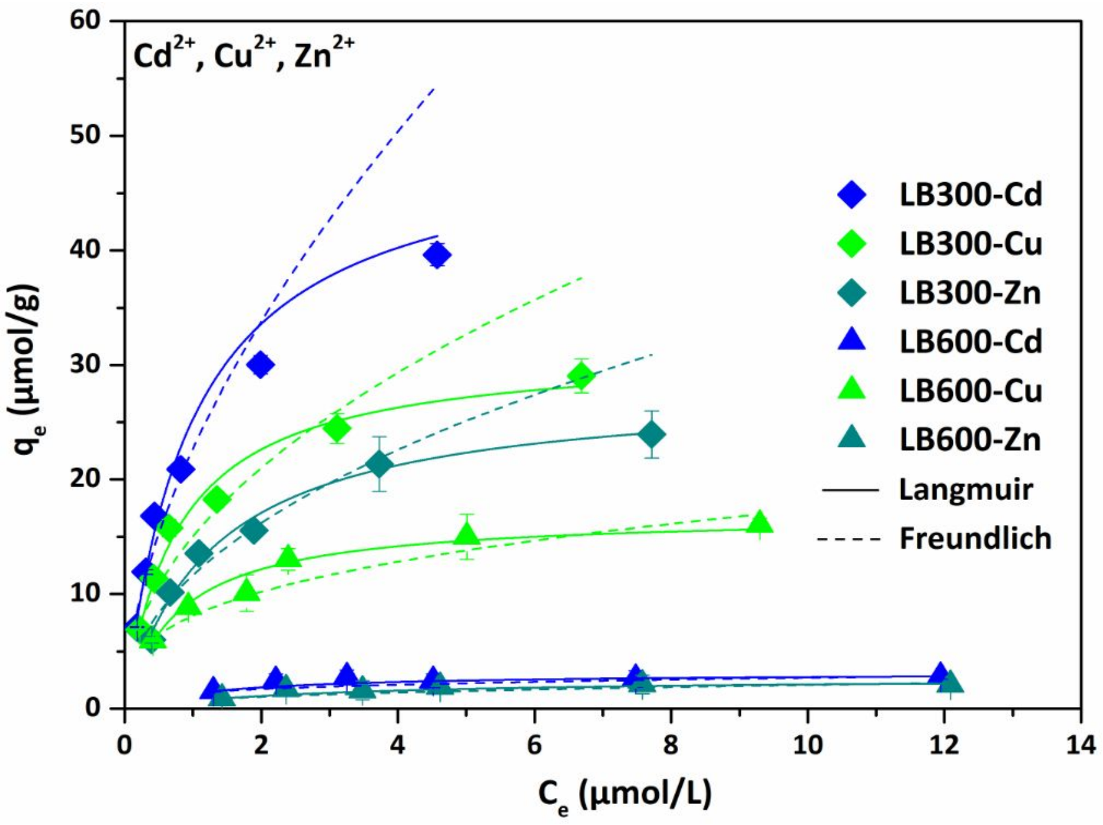


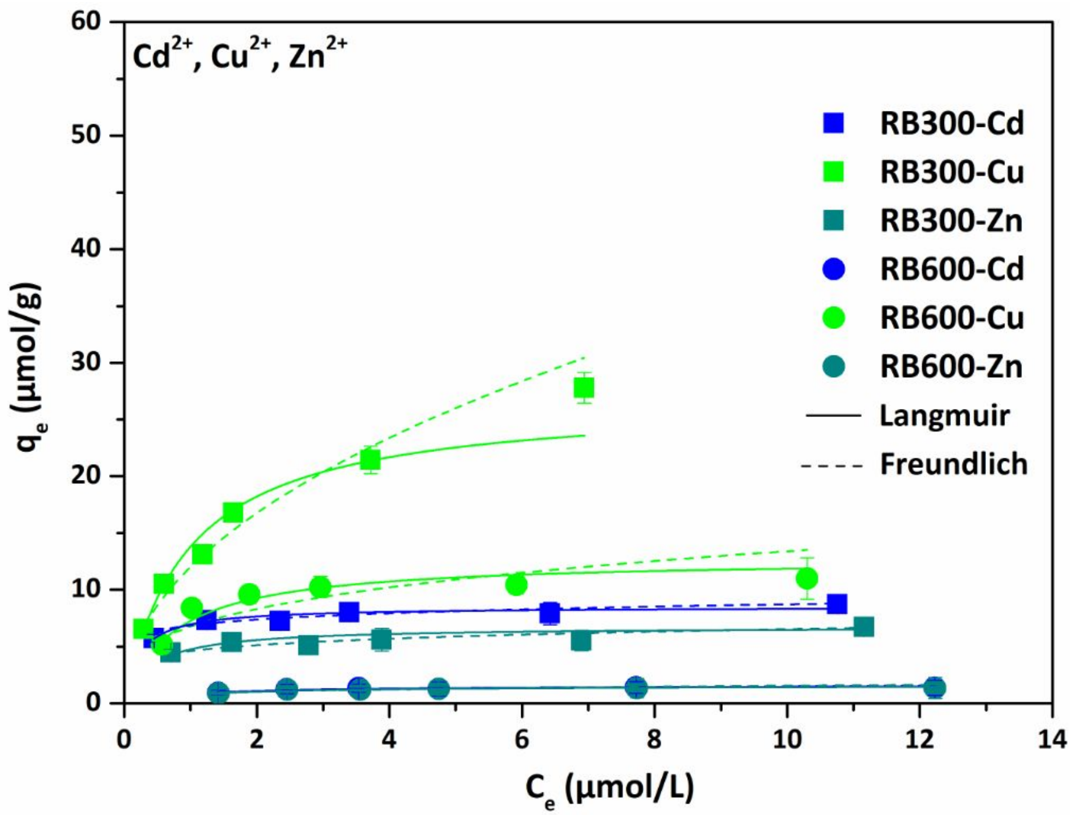
Mono-metal systems: 300 ºC > 600 ºC; camphor leaf > rice huskk



Trio-metal systems: 300 ºC > 600 ºC; camphor leaf > rice husk

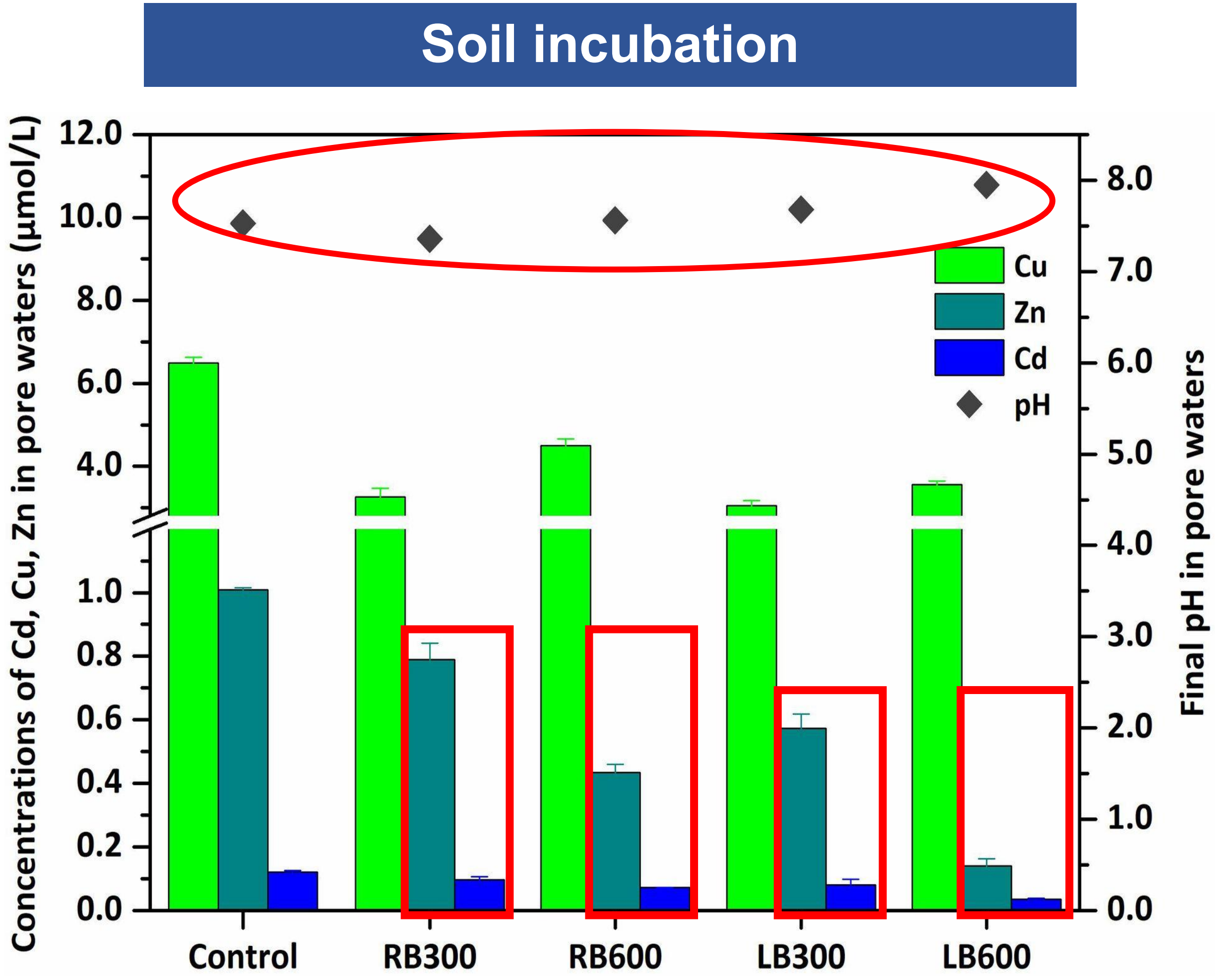
For most BCs: Cu(II) > Cd(II) ≈ Zn(II), but for LB300: Cd(II) > Cu(II) > Zn(II)0





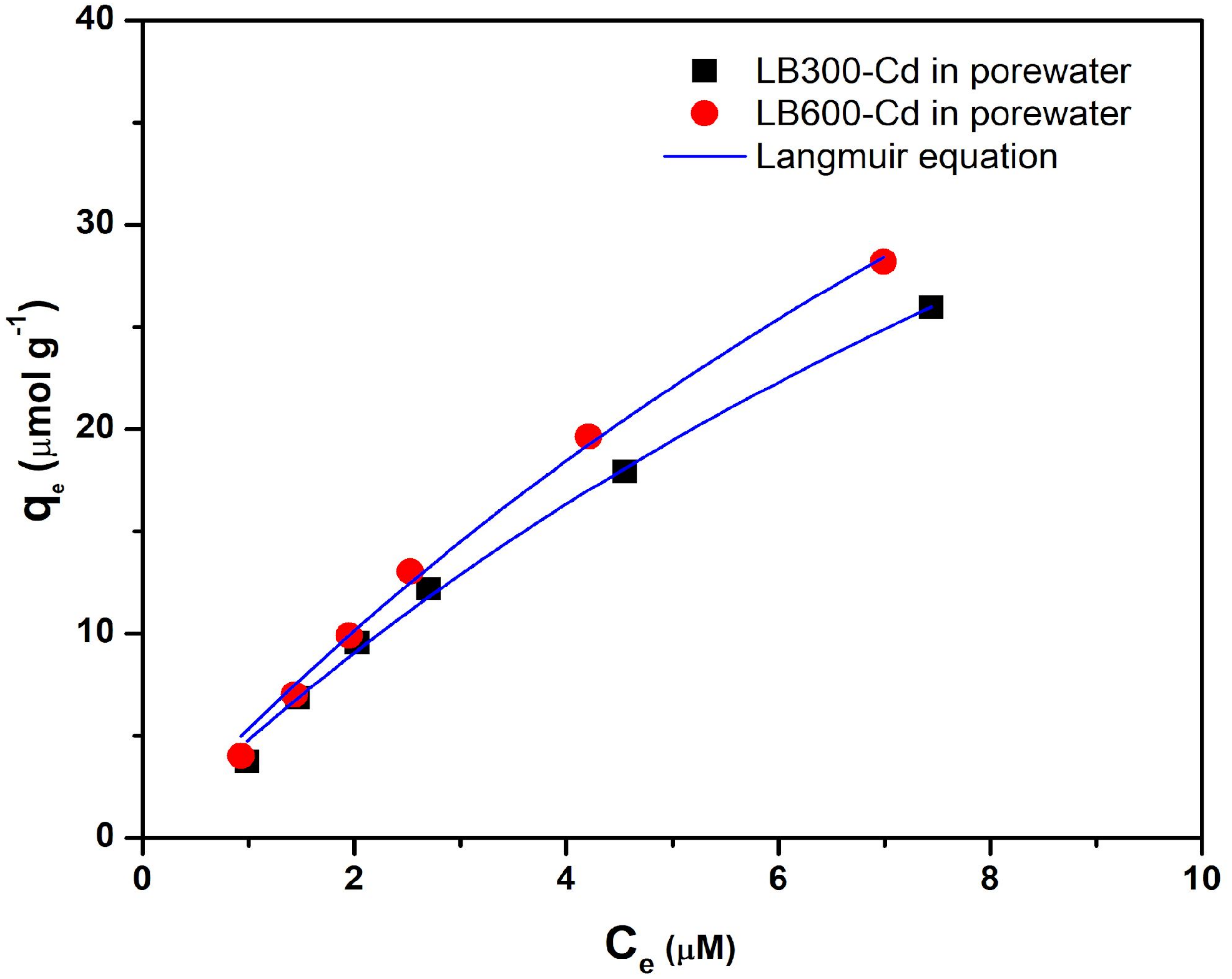
Reductions of HM concentrations in porewater of soil amended with BCs

For Cd & Zn: 600°C > 300°C



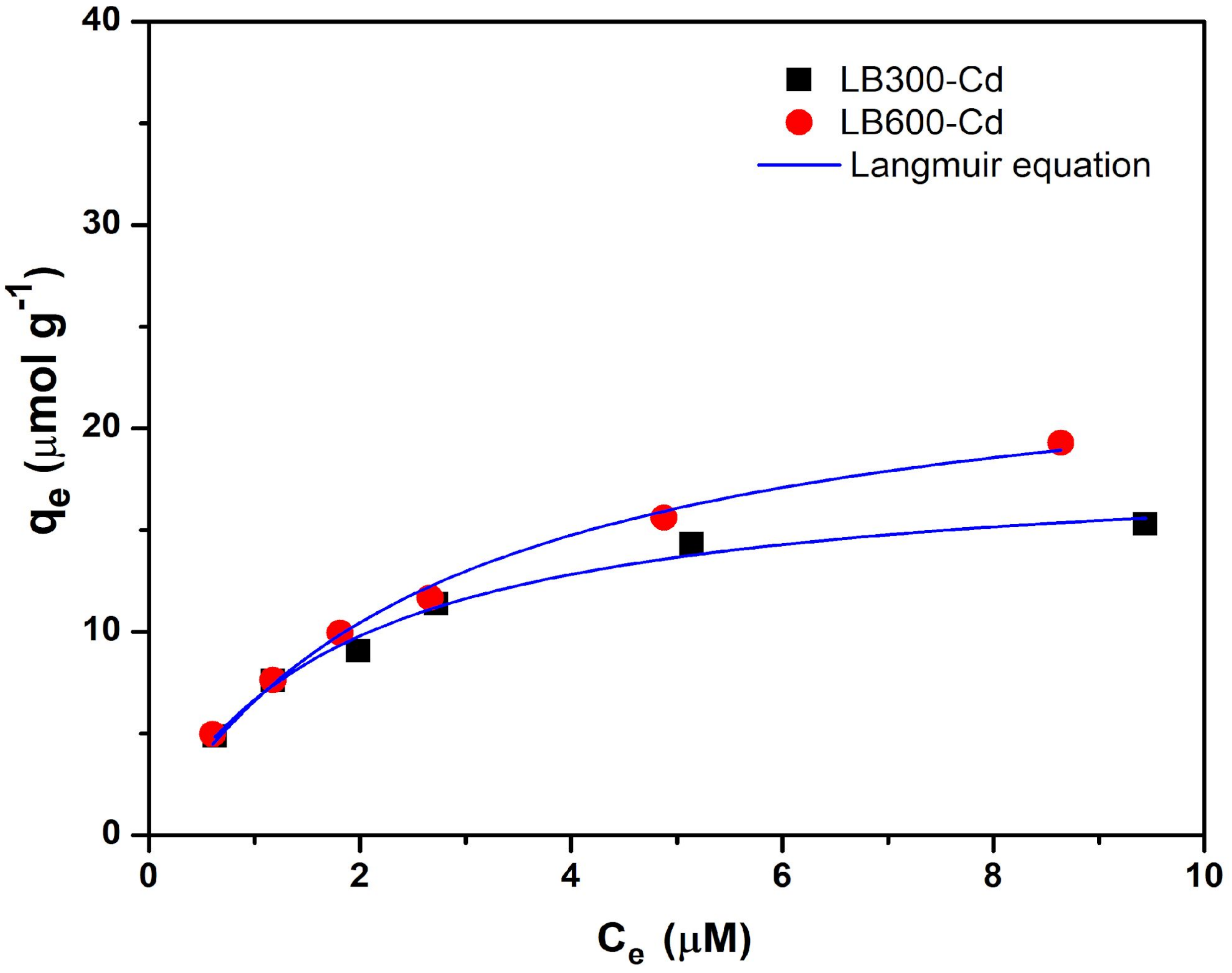
Probing the role of DOM in aqueous-adsorption and soil-stabilization of Cd by BC

Adsorptions conducted with porewater



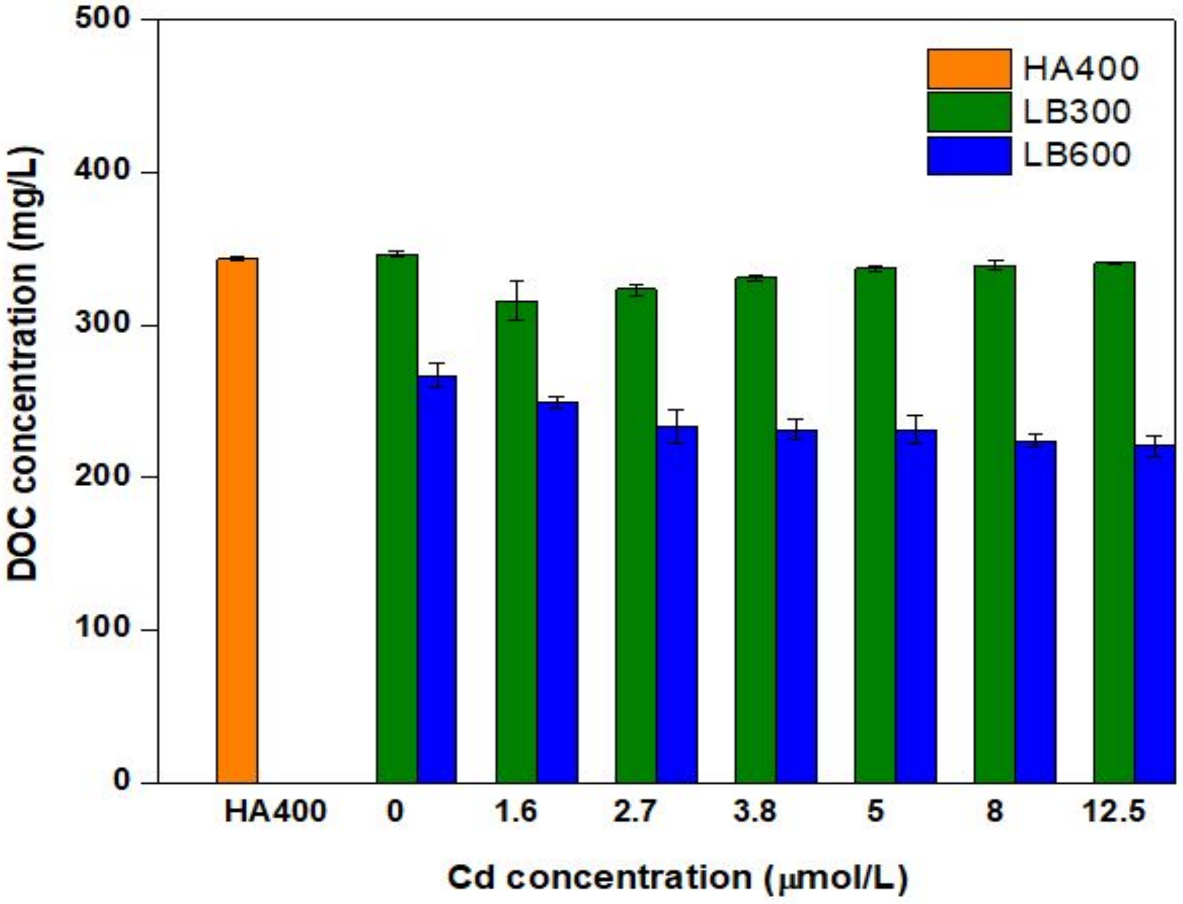
LB600 > LB300

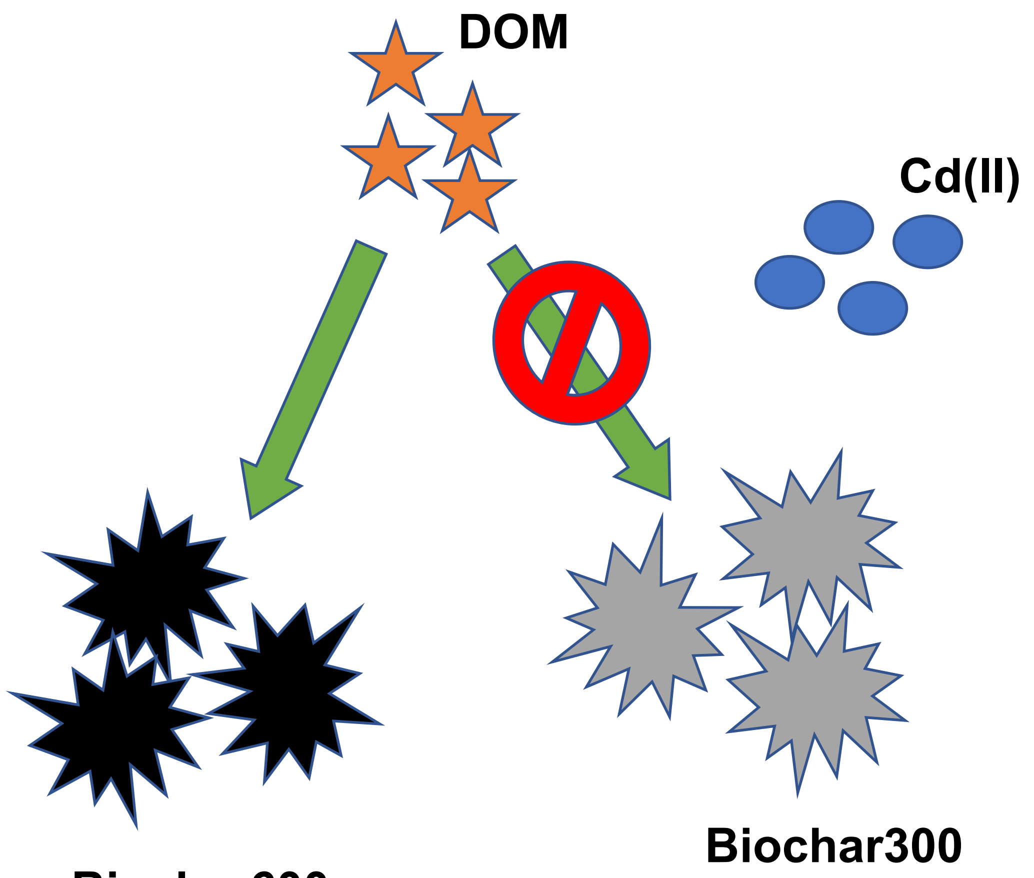
Adsorption in DI water with humic acid



LB600 > LB300

Role of DOM for immobilization of HMs by biochar in the soil matrix

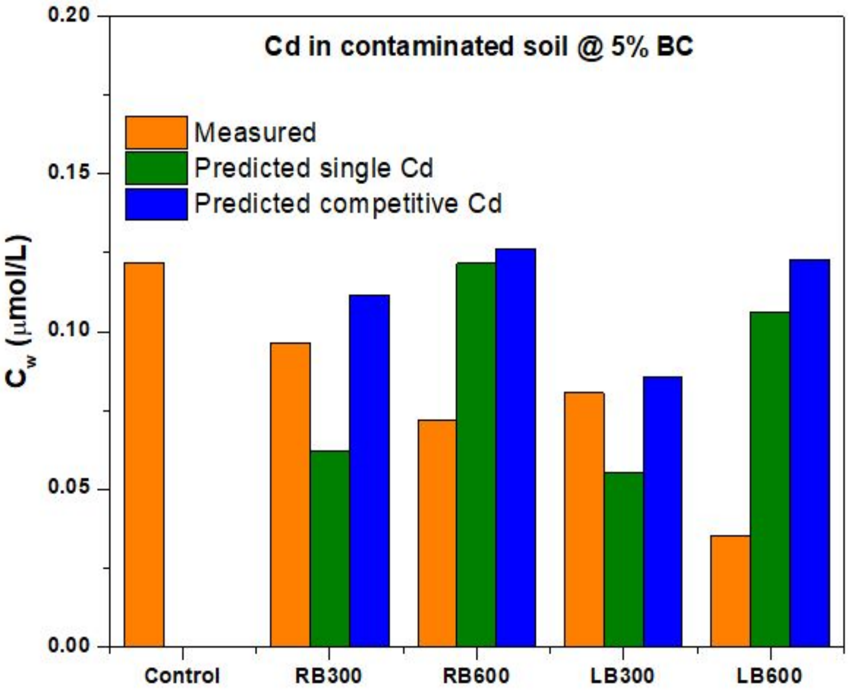


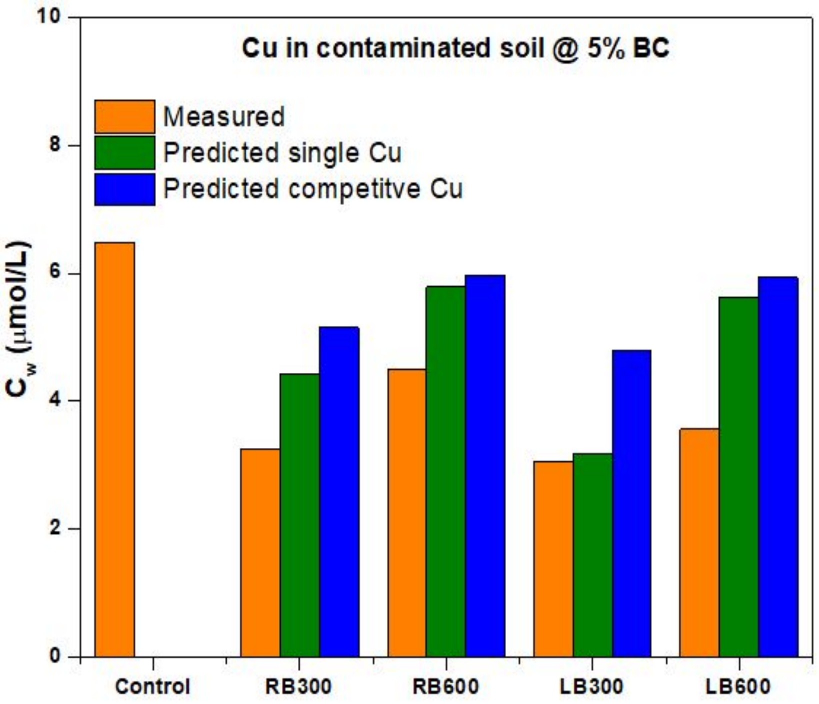


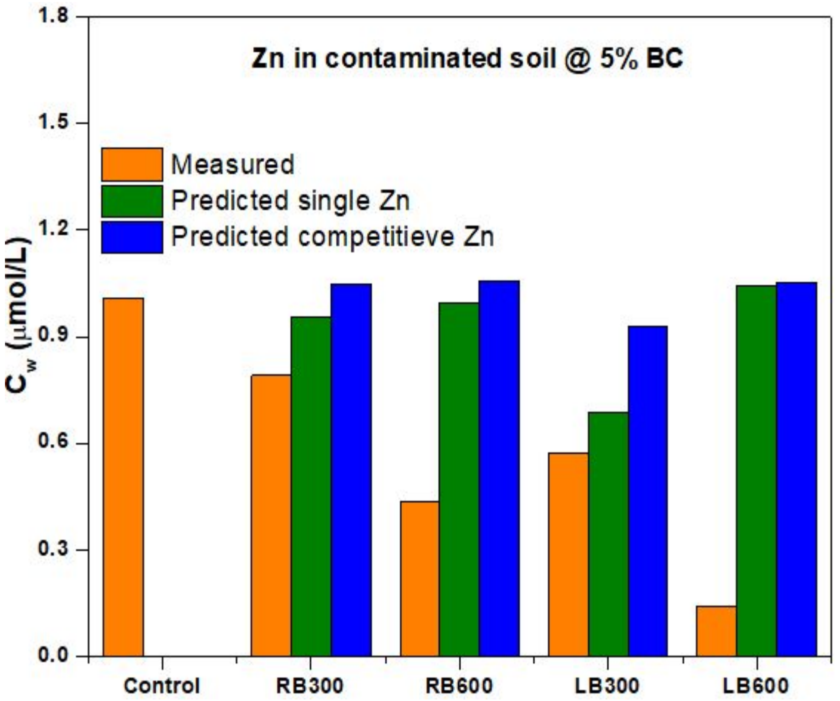
DOM & Cd(II) concentrations: ↓

Modeling pore water reductions for Cd, Cu and Zn in contaminated soil

Gomez-Eyles et al. (2013) *ES&T* → **Linear model**: $C_s = (f_{soil}K_{d\text{-}soil}C_w) + (f_{BC}K_{d\text{-}BC}C_w)$



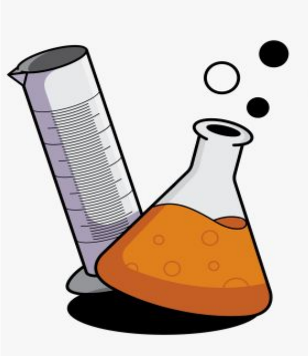




Taking into account the competition effect of other metals in DI water matrix did not significantly improve the predicting power of the model, which might be due to that:

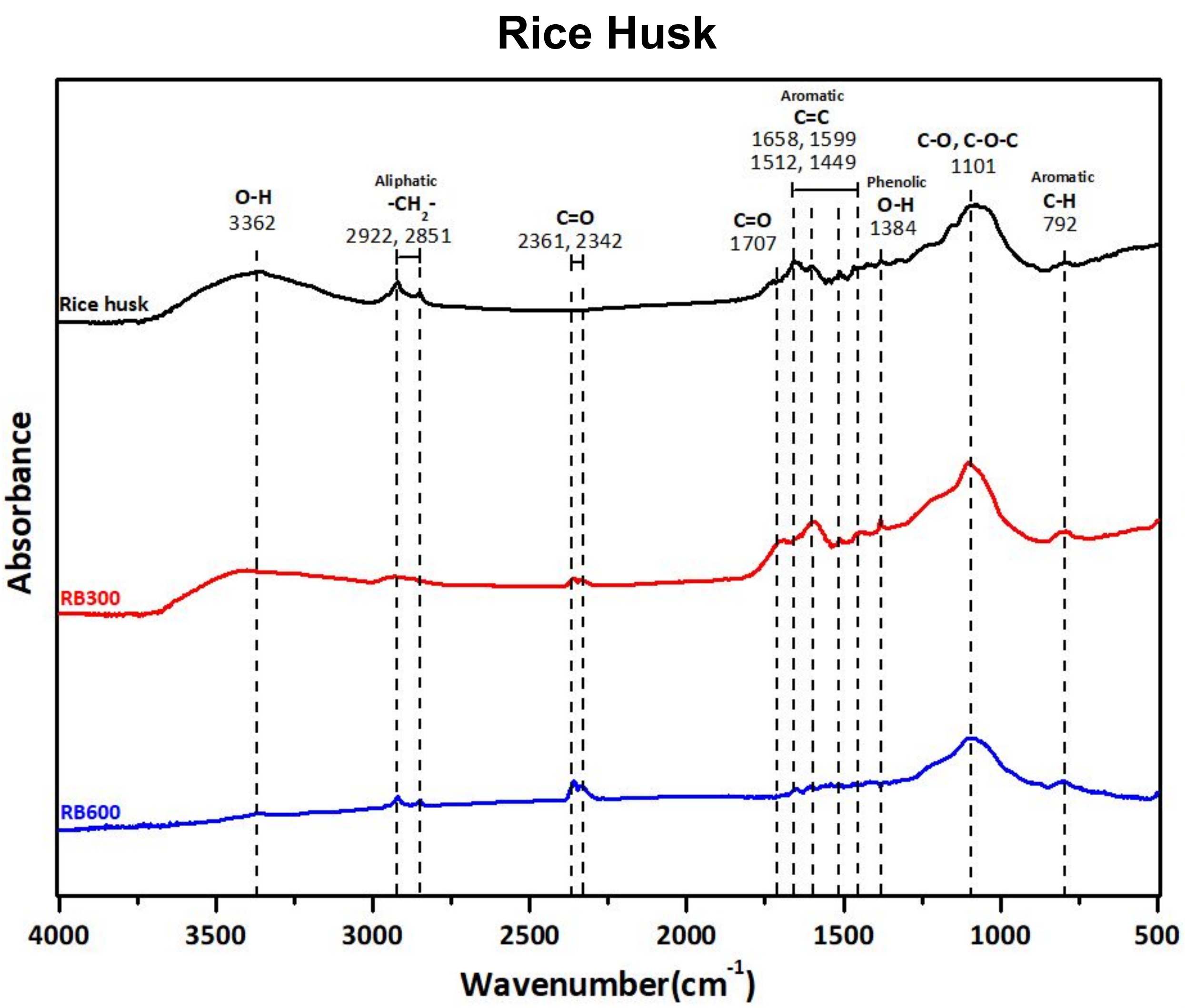
- The selected levels of metals were not low enough
- The influence of DOM was neglected
- The other unknown factors

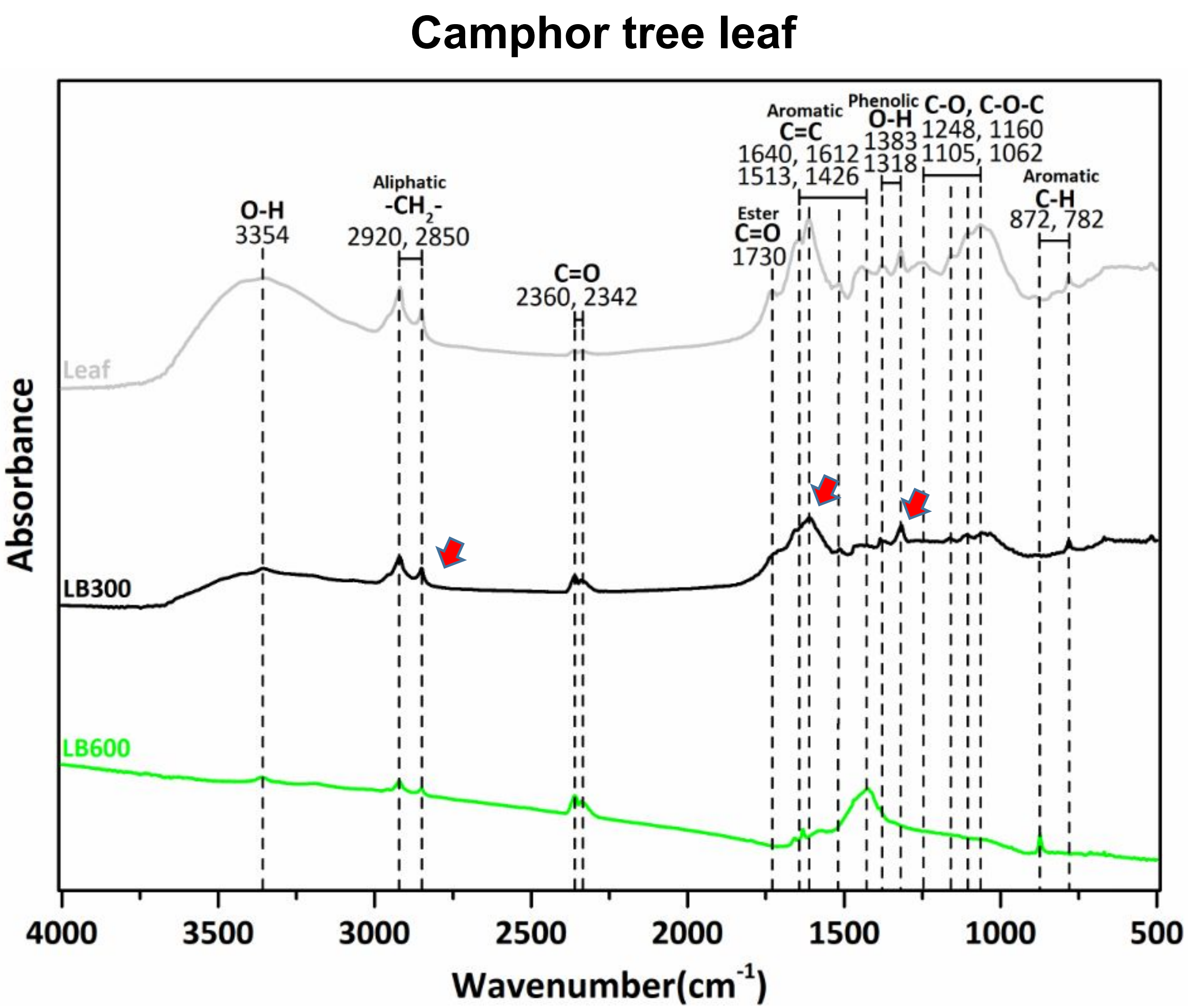
Conclusions



Thank you for your attention!

Possible adsorption mechanisms- FTIR spectra





Possible adsorption mechanisms- Boehm titration & XPS analysis results

The surface acid functional group content of various biochars

Adsorbent	Carboxylic (mmol/g)	Lactonic (mmol/g)	Phenolic (mmol/g)	Total acidity (mmol/g)
RB300	0.17	0.50	1.05	1.72
RB600	-	-	0.27	0.27
LB300	0.24	0.76	1.08	2.08
LB600	-	-	0.15	0.15

- Below detectable level.