

Supporting Information

Mechanistic Insights into the Synergetic Remediation and Amendment Effects of Zeolite/biochar Composite on Heavy Metal-Polluted Red Soil

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S-1. Preparation of polluted red soil.

The polluted red soil was prepared artificially with the addition of $\text{Pb}(\text{NO}_3)_2$ and $\text{Cd}(\text{NO}_3)_2 \cdot 4\text{H}_2\text{O}$ solution, and concentration of Pb^{2+} and Cd^{2+} were controlled to be 100 mg kg^{-1} , respectively. The polluted red soil was put in polyethene pots and incubated for 10 days at room temperature (25°C) to ensure that the heavy metal ions are homogeneously mixed with the red soil. The soil water content was controlled to be 70% of the field water holding capacity by weighing the pots.

S-2. Heavy metal solution adsorption experiment.

The heavy metals solution adsorption experiments with ANA zeolite and biochar composite were both carried out in conical flasks. The adsorption experiments were carried out with 0.2 g materials and 50 mL 1.0 g L^{-1} heavy metal solutions. The pH value of the adsorption solution was adjusted to the value of 6.0 similar to the natural soil with 1 M HNO_3 solution. The mixture suspensions were stirred at 600 rpm for 24 h at 25°C . After the adsorption experiment, the materials were filtered, washed by DI water and dried for further characterizations.

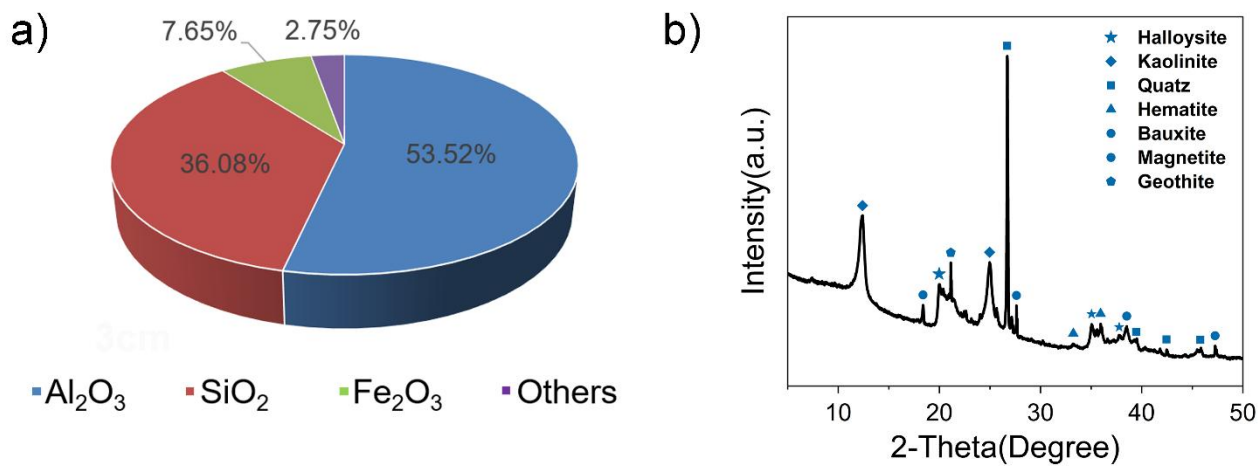


Fig. S1 Characterization of raw red soil. a) XRF analysis; b) XRD pattern.

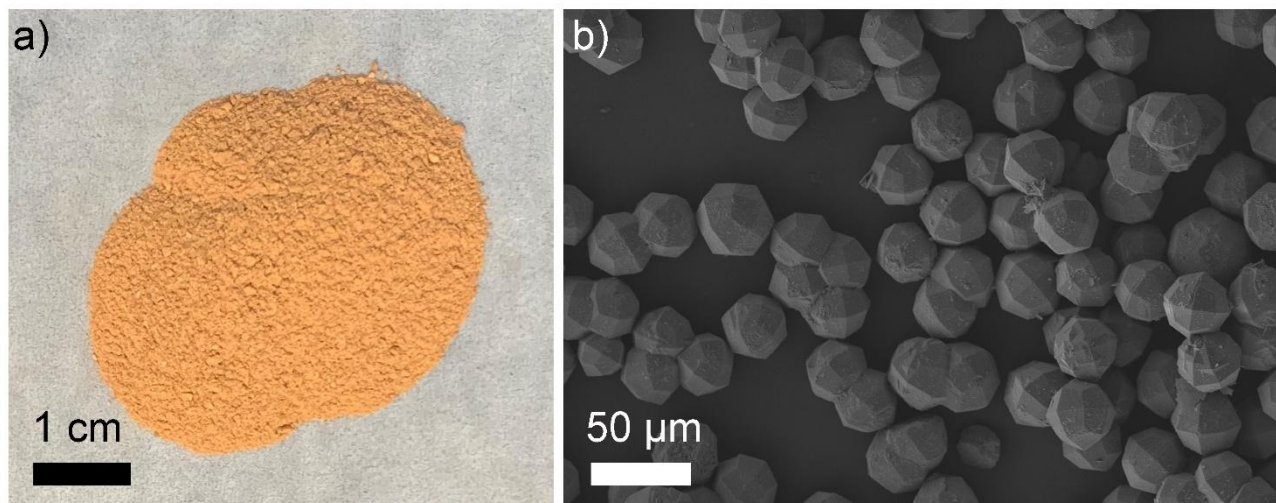


Fig. S2 Characterization of as-synthesized ANA zeolite. a) Photograph; b) SEM image

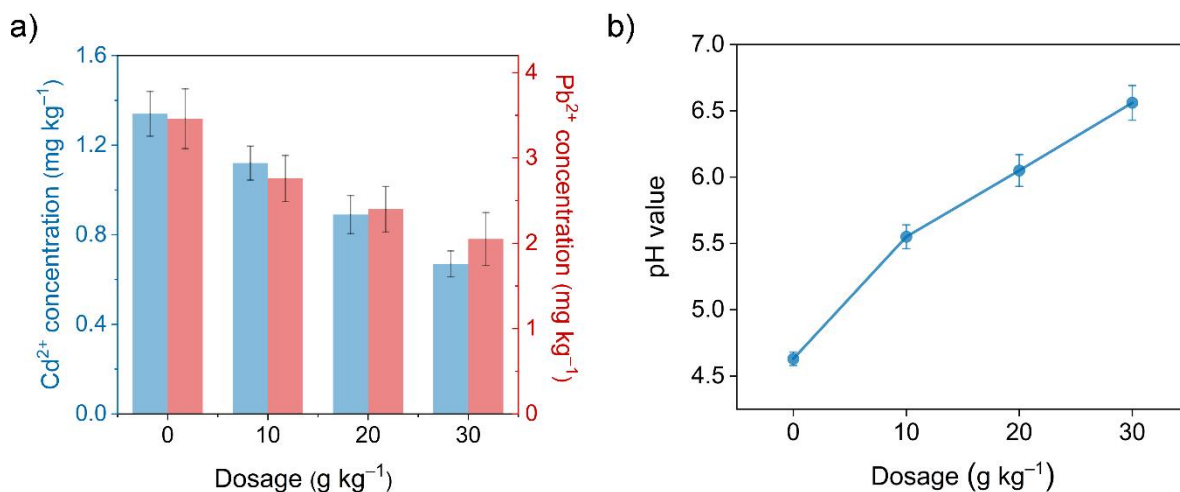


Fig. S3 Red soil quality parameters with zeolite/biochar composite addition. a); Pb^{2+} and Cd^{2+} concentrations; b) pH value.

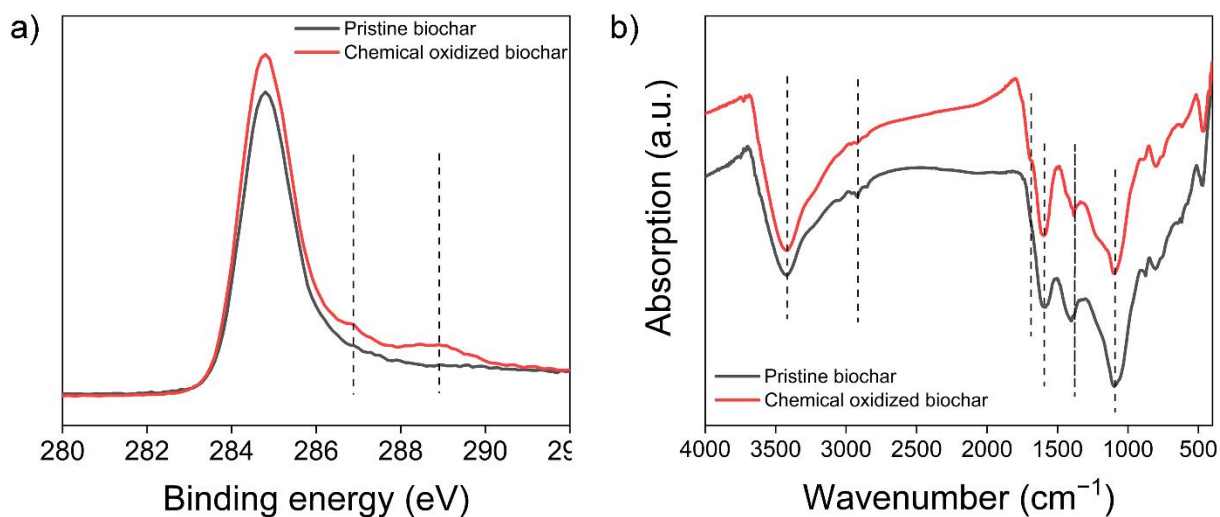


Fig. S4 Characterization of pristine and chemical oxidized biochar. a) FT-IR spectra; b) XPS spectra.

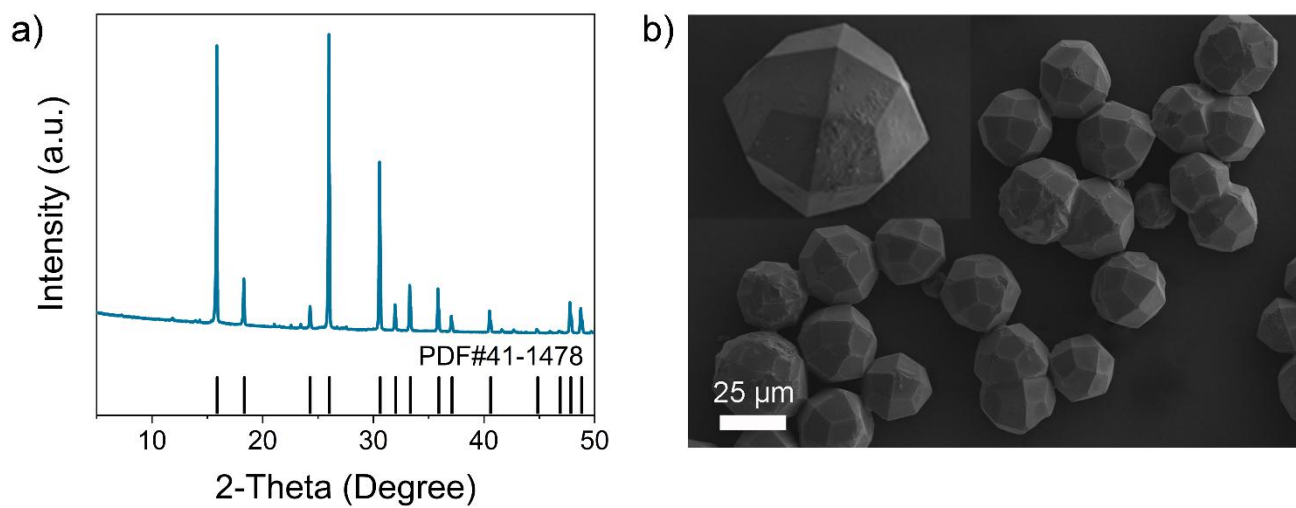


Fig. S5 Characterization of chemically oxidized ANA zeolite. a) XRD pattern; b) SEM image.

Table S1. Properties of raw red soil.

Parameters	Value
pH (H ₂ O)	4.63
Organic matter (%)	0.56
Total N (mg kg ⁻¹)	915
Fast available P (mg kg ⁻¹)	1.0
Fast available K (mg kg ⁻¹)	124
Bioavailable Pb (mg kg ⁻¹)	19.30
Bioavailable Cu (mg kg ⁻¹)	1.56
Bioavailable Cd (mg kg ⁻¹)	0.16
Bioavailable Zn (mg kg ⁻¹)	11.73

Table S2. Cost evaluation to produce 1 ton of zeolite/biochar composite.

Raw materials	Dosage (ton or kw·h)	Individual Cost (\$/ton)	Total Cost (\$/ton)
Red soil	0.4375	0	
SiO ₂	0.15	2.1	
NaOH	0.35	88	286.7
Rice straw	0.56	39	
Electric power	1020	117.6	
Others	-	40	

Table S3. Properties of as-prepared rice straw biochar.

Parameters	Value	%
pH (H ₂ O)	9.93	-
Surface area (m ² g ⁻¹)	20.6	-
Element composition (m %)	C	55.52
	O	8.24
	K	5.49
	Si	3.82
	Cl	2.56
	H	2.29
	N	1.33
	P	0.56
	Mg	0.44
	Na	0.41
	Ca	0.29
	Mn	0.19
	S	0.10
	Fe	0.05
Al	0.02	
Zn	0.01	
O/C molar ratio	0.11	-
H/C molar ratio	0.50	-
C/N molar ratio	48.7	-

Table S4. Elemental composition of chemical oxidized biochar.

C	H	O	N	S	O:C	H:C
63.27	3.07	16.83	1.38	0.11	0.20	0.58