The Adsorption Characteristics of Phosphorus-Modified Corn Stover Biochar on Lead and Cadmium

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Supplementary materials

1. Experimental reagent

Table S1. List of experimental reagents

Reagent	Purity	Manufacturer
$Pb(NO_3)_2$	Analytical pure	Sinopharm Chemical Reagent Company
$Cd(NO_3)_2{\cdot}4H_2O$	Analytical pure	Sinopharm Chemical Reagent Company
$NaNO_3$	Analytical pure	Sinopharm Chemical Reagent Company
HNO_3	Analytical pure	Sinopharm Chemical Reagent Company
NaOH	Analytical pure	Sinopharm Chemical Reagent Company
K_3PO_4	Analytical pure	Shanghai Aladdin Biochemical Technology Co., Ltd.

2. Equipment

Scanning electron microscopy (JSM-7800F scanning electron microscope, Electronics Company, Japan) is used to determine the surface morphology characteristics of biochar samples. The specific surface integral analyzer (ASAP2460, Mike Company, USA) is used to measure the specific surface area and pore structure of biochar samples by nitrogen isothermal adsorption at 77k conditions. Fourier infrared Spectrometer (Nicolet iS500 Fourier infrared spectrometer, Thermo Fisher Scientific, USA) is used to characterize the surface functional groups of biochar. Its scanning range is 4000-400cm^{-1}, the resolution is 4cm^{-1}, and the number of scans is 128. X-ray diffractometer (XRD-6000 diffractometer, Shimadzu Company, Japan) is used to determine the crystalline substances contained in biochar samples. The scanning rate is set to 10 (°)/min, the step size is 0.02°, and the data collected ranges from 5° to 85°. The X-ray photoelectronic energy spectrometer (Thermo ESCALAB 250XI, Thermo Fisher Scientific, USA) is used to analyze the elemental content of the surface of biochar and calibrate the spectral binding energy with the aliphatic carbon electron binding energy (284.8 eV) of non-polluting C 1s. The atomic absorption spectrophotometer (TAS-986F type, Beijing General Analytical Instruments Co., Ltd.) is used to determine the content of heavy metals. The marking of cadmium is 0.2 mg/L, 0.4 mg/L, 0.6 mg/L and 0.8 mg/L, and the marking of lead is 2 mg/L, 4 mg/L, 6 mg/L, 8 mg/L and 10 mg/L respectively.

3. Comparison of the adsorption of lead and cadmium by unmodified biochar under different temperature conditions

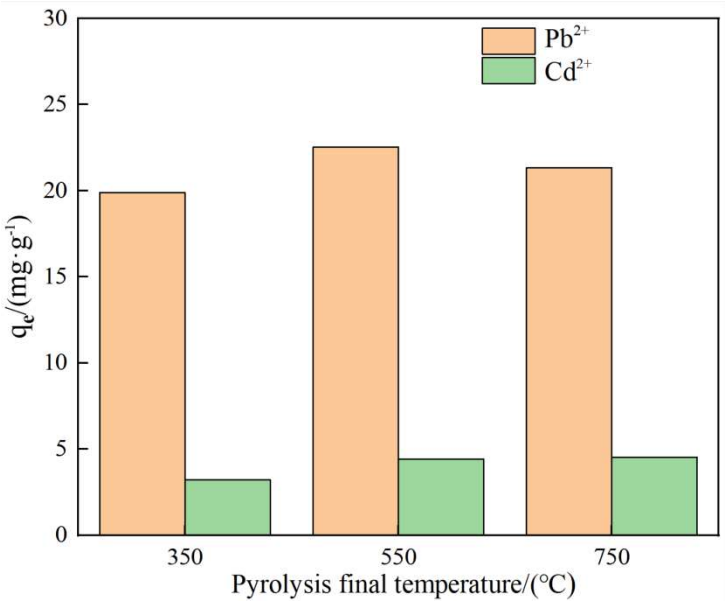


Figure S1. Adsorption of Pb^{2+} and Cd^{2+} by unmodified biochar at different pyrolysis temperatures

4. Data sheet of adsorption experiment

Table S2. Experimental data of adsorption dynamics

Sample name	Average value		Standard deviation	
	Pb^{2+}	Cd^{2+}	Pb^{2+}	Cd^{2+}
BC550	22.50	3.961	0.799	0.182
1PBC750	129.95	11.98	0.718	0.195
1PBC550	139.92	12.654	1.947	0.310
2PBC550	145.48	14.533	0.877	0.230
2PBC750	139.93	13.642	0.410	0.460

Table S3. Effect of different pH on adsorption volume

pH	Average value				Standard deviation			
	BC550		2PBC550		BC550		2PBC550	
	Pb^{2+}	Cd^{2+}	Pb^{2+}	Cd^{2+}	Pb^{2+}	Cd^{2+}	Pb^{2+}	Cd^{2+}
2	15.34	2.946	123.56	9.532	0.326	0.026	1.310	0.524
3	18.57	3.543	131.45	14.456	0.443	0.043	1.519	0.342
4	21.76	3.961	137.32	14.499	0.575	0.540	1.630	0.325
5	22.53	3.961	145.48	14.771	0.696	0.217	0.480	0.349
6	22.5	4.021	145	14.761	1.106	0.166	0.823	1.064
7	20.32	3.951	142.31	14.761	1.043	0.075	0.487	0.524
8	18.31	3.911	139.41	14.749	0.749	0.249	1.605	0.364

Table S4. The comparison of maximum adsorption capacities of different biochars for Pb^{2+} or Cd^{2+}

Raw material	Modifier	Heavy metals	Qm ($mg \cdot g^{-1}$)	pH	Equilibrium time (h)	Reference
Feather	KOH	Cd	62.136	5	24	[35]
		Pb	142.996			
Feather	H_3PO_4	Cd	7.84	5	24	[36]
		Pb	24.41			
Coir	$KMnO_4$ and HNO_3	Cd	47.46	5	24	[37]
		Pb	160.41			
Dairy manure	NaOH	Cd	68.08	5	24	[38]
		Pb	175.53			
Soybean straw	$MgCl_2$	Cd	20.19	5	24	[39]
		Pb	157.06			
Corn stalks	K_3PO_4	Cd	34.154	5	24	This work
		Pb	284.171			

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