

Supplementary Materials

Table S1. Experimental instruments.

Number	Experimental instruments	Specifications	Use
1	Electronic balance	AUY220	Weight
2	Tube furnace	SG—GL1400	Carbonized sample
3	Constant temperature drying oven	DZ47—60	Dry sample
4	Atomic absorption spectrophotometer	TAS—990SUPERAFG	Measure the concentration of heavy metal solution
5	Constant temperature culture oscillator	THZ—82	oscillation
6	Pulverizer	LD—500A	Crushed sample
7	Vacuum pump	2XZ—4	Pump the tubular furnace into vacuum state
8	Peristaltic pump	YZ1515X	Control solution flow
9	Electric heating plate	DFD—7000	For digestion of sediment samples
10	Centrifuge	CenLee16k	Centrifuge the sediment sample
11	Constant—temperature water bath (HH—2)	HH—2	Heated sample

Table S2. Experimental reagents.

Number	Chemical reaction	Vender	Fineness	Use
1	CuSO ₄ ·5H ₂ O	Nanjing Chemical Reagents Co., Ltd.	AR	Compound Cu(II) solution
2	CdSO ₄ ·8/3H ₂ O	MacClean	AR	Compound Cd(II) solution
3	SiO ₂	Sinopharm Group Chemical Reagent Co., Ltd.	AR	Fixed carbon bed
4	HF	Sinopharm Group Chemical Reagent Co., Ltd.	AR	Digested sediment sample
5	HClO ₄	Sinopharm Group Chemical Reagent Co., Ltd.	AR	Digested sediment sample
6	SiO ₃	Sinopharm Group Chemical Reagent Co., Ltd.	AR	Fixed charcoal bed
7	HCl	Nanjing Chemical Reagents Co., Ltd.	AR	Nitric acid—hydrochloric acid mixture is configured
8	CH ₃ COOH	Nanjing Chemical Reagents Co., Ltd.	AR	Extracted acid extracts the heavy metals Cu(II) and Cd(II)
9	NH ₂ OH·HCl	Sinopharm Group Chemical Reagent Co., Ltd.	AR	Extracting acid—recoverable heavy metals Cu(II) and Cd(II)
10	H ₂ O ₂	Nanjing Chemical Reagents Co., Ltd.	AR	Extracting acid oxidation state heavy metals Cu(II) and Cd(II)
11	NH ₄ COOH	Sinopharm Group Chemical Reagent Co., Ltd.	AR	A TCLP toxic leaching extract was prepared

Determination of different forms of heavy metals in sediment by BCR extraction method

According to the BCR extraction method, the different forms of heavy metals in soil and sediment can be divided into: weakly extractable, reducible, oxidizable and residual [93]. The specific extraction methods of heavy metals in various forms are as follows:

(1) Determination of acid-extractable heavy metal (ACI) content

(i) Weigh 1g of the treated sediment sample to be measured with an electronic balance and put it into a 100ml centrifuge tube, add 40ml of acetic acid (CH_3COOH) solution with a concentration of 0.11 mol/L into it, put the centrifuge tube into a thermostatic oscillator, and oscillate for 16h at a rotating speed of 250r/min and a temperature of 25°C;

(ii) Put the centrifuge tube into the centrifuge, centrifuge the sample at 4000r/min for 15min, and then use the supernatant. After filtering with a 0.22 μm filter head, transfer it into a 50ml volumetric flask to volume with deionized water, and measure the concentration of heavy metals Cu (II) and Cd (II) in the supernatant with an atomic absorption spectrophotometer;

(iii) Add 20ml of deionized water to the remaining sediment sample, put it into a thermostatic oscillator, shake for 15min, and then centrifuge at 4000r/min for 15min to remove the upper liquid. The remaining sediment sample is used for the next experiment.

(2) Determination of reducible heavy metal (FEM) content

(i) Add 40ml of 0.5mol/L hydroxylamine hydrochloride ($\text{NH}_2\text{OH} \cdot \text{HCl}$) with 0.05mol/L nitric acid (HNO_3) to the remaining sediment sample in the previous step by adjusting the pH to 2, put the centrifuge tube into a thermostatic oscillator, and oscillate for 16h at a speed of 250r/min and a temperature of 25°C;

(ii) Put the centrifuge tube into a centrifuge, centrifuge the sample at a speed of 4000r/min for 15min, filter the supernatant with a 0.22 μm filter head, and then transfer it into a 50ml volumetric flask to volume with deionized water. Measure the concentration of heavy metals Cu (II) and Cd (II) in the supernatant with an atomic absorption spectrophotometer;

(iii) Add 20 ml of deionized water to the remaining sediment sample, put it into a thermostatic oscillator, shake for 15min, and then centrifuge at 4000r/min for 15min to remove the upper liquid. The remaining sediment sample is used for the next experiment.

(3) Determination of oxidizable heavy metal (ORG) content.

(i) Add 10ml of hydrogen peroxide (H_2O_2) with a concentration of 8.8mol/L into the remaining sediment sample, adjust its pH value to 2–3 with nitric acid (HNO_3), put the centrifuge tube into a thermostatic oscillator, loosen the cover of the centrifuge tube, and oscillate at room temperature for 1h, then put the centrifuge tube into a thermostatic water bath at 85°C for 1h, open the cover and continue heating to a volume of no more than 3ml;

(ii) Then add 10ml of hydrogen peroxide (H_2O_2) which is consistent with the above conditions, place it in a constant temperature water bath at 85°C for 2h, open the lid and heat it to 1ml of solution volume;

(iii) Place it for cooling, then add 50 ml of ammonium acetate (NH_4COOH) solution with a concentration of 1mol/L into it, adjust its pH to 2–3 with nitric acid, put the centrifuge tube into a thermostatic oscillator, shake it for 16h at a speed of 250r/min and a temperature of 25°C, and then put it into a centrifuge, centrifuge it at a speed of 4000r/min for 15min, and then transfer the supernatant into a 50 ml volumetric flask, and use deionized water to fix the volume, The concentrations of heavy metals Cu (II) and Cd (II) in the supernatant were determined by atomic absorption spectrophotometer;

Determination of TCLP leaching toxicity risk of heavy metals in sediment

The methods to detect the risk of TCLP toxicity leaching in the sediment are as follows:

(1) Two kinds of extractants are prepared:

(i) Add 5.7ml of glacial acetic acid (CH_3COOH) into 500ml of deionized water, add 64.3ml of NaOH with a concentration of 1mol/L into a 1L volumetric flask, and adjust the pH of the solution to 4.93 ± 0.05 with 0.1mol/L of HCl and NaOH;

(ii) Add 5.7ml glacial acetic acid into a 1L volumetric flask and dilute it to volume with deionized water. Adjust the pH of the solution to 2.88 ± 0.05 with 0.1mol/L HCl and NaOH. Determine the extractant:

(2) Use an electronic balance to weigh 5g of the treated sediment to be measured and add it into a 500ml beaker, add 96.5 ml of deionized water, put the beaker into a magnetic stirrer and stir for 5 min, measure the pH of the solution, and if $\text{pH} < 5$, use the first extraction solution for extraction. On the contrary, add 3.5ml HCl with a concentration of 1mol/L into the beaker, heat for 10min at 50°C , and cool. However, the pH is measured after reaching room temperature. If pH is less than 5, the first extraction solution is used for extraction, otherwise, the second extraction solution is used for extraction.

(3) Extraction steps: weigh 2g of sediment with an electronic balance and add it into a 50ml centrifuge tube, add 40ml of extraction solution, put the centrifuge tube into a thermostatic oscillator, oscillate for 18h at 25°C and a rotating speed of 190r/min, open the cover regularly to release gas, and then put the centrifuge tube into a centrifuge at a rotating speed of 4000r/min for 15min, filter the solution with a 0.22 μm filter head, and then measure the heavy metal Cu (II) in it with an atomic spectrophotometer Cd (II) concentration.