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Efficient removal of Pb(Ⅱ) and Cr(Ⅵ) from acidic wastewater by porous thiophosphoryl polyethyleneimine

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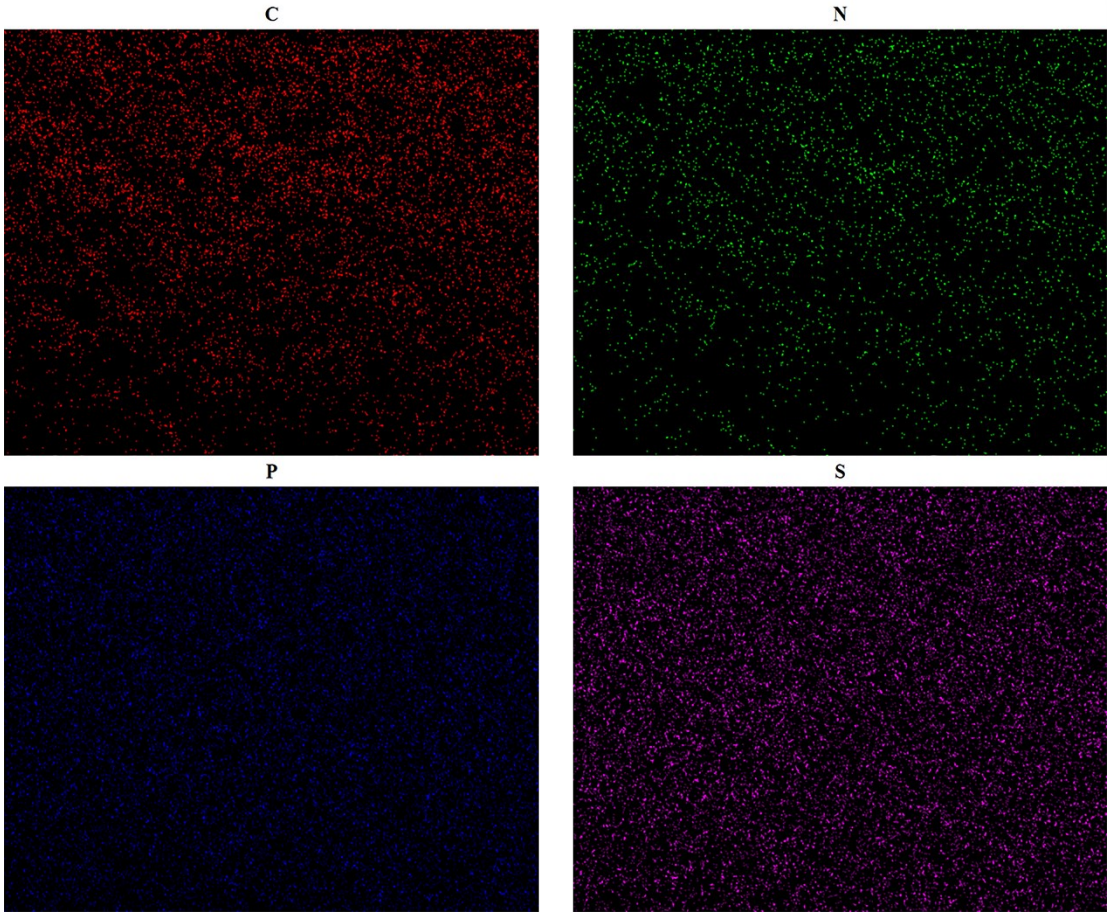

Fig. S1 EDS mapping images of the adsorbent.

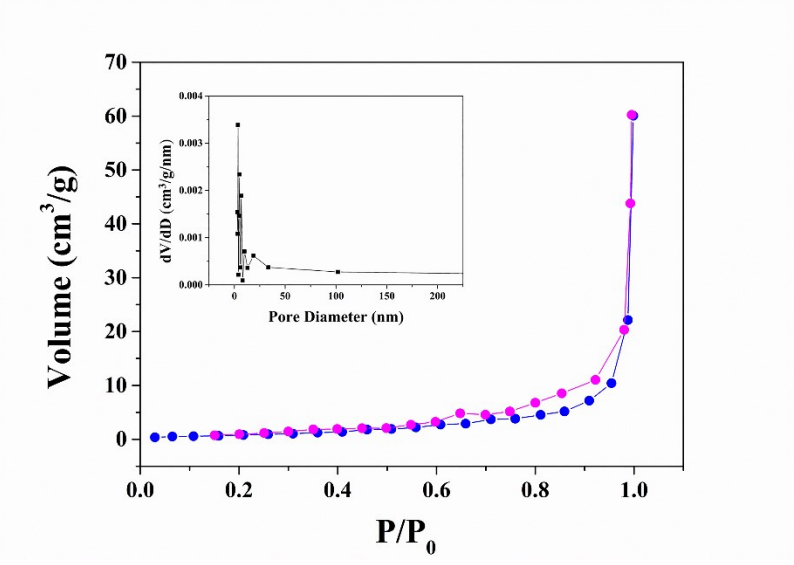

Fig. S2 N_2 adsorption–desorption isotherms of TPEI (inset: the corresponding pore size distribution curves).

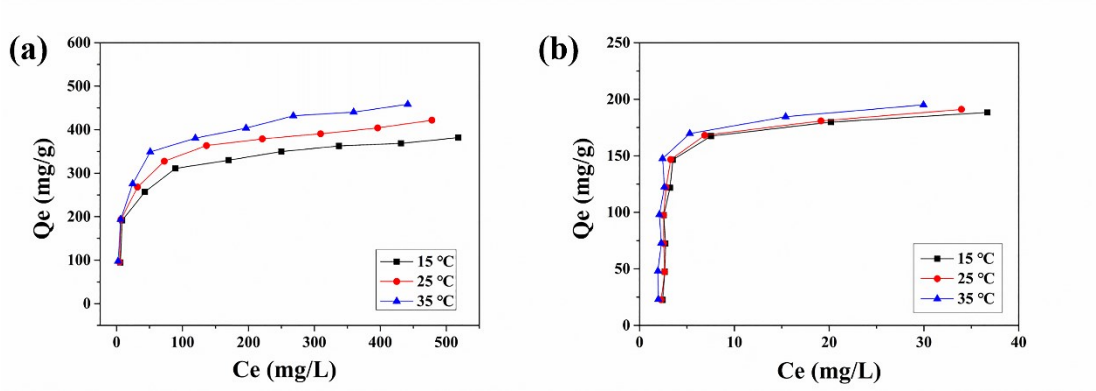

Fig. S3 Adsorption isotherms of Pb(Ⅱ) and Cr(Ⅵ) at different temperatures.

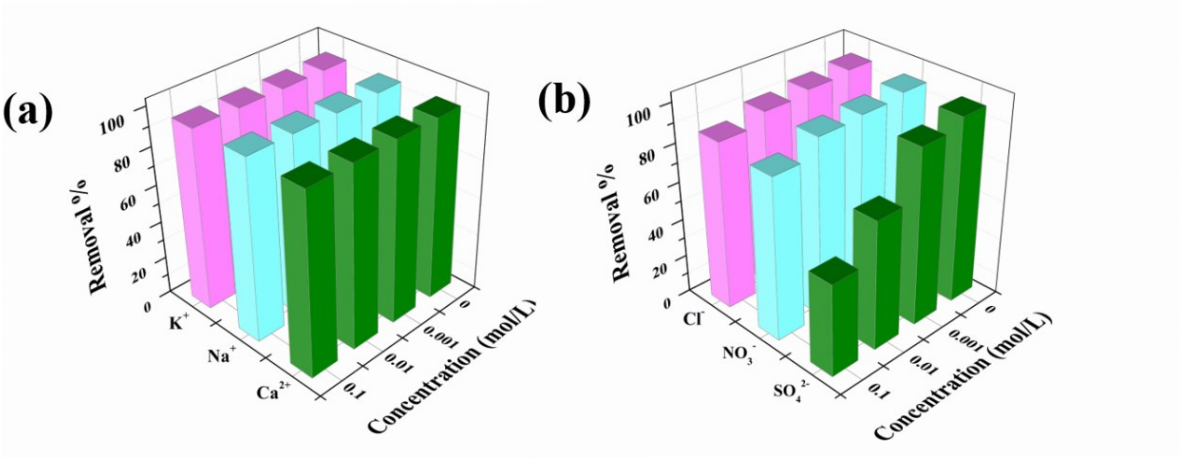

Fig. S4 Influence of competitive ions on Pb(Ⅱ) (a) and Cr(Ⅵ) (b) adsorption.

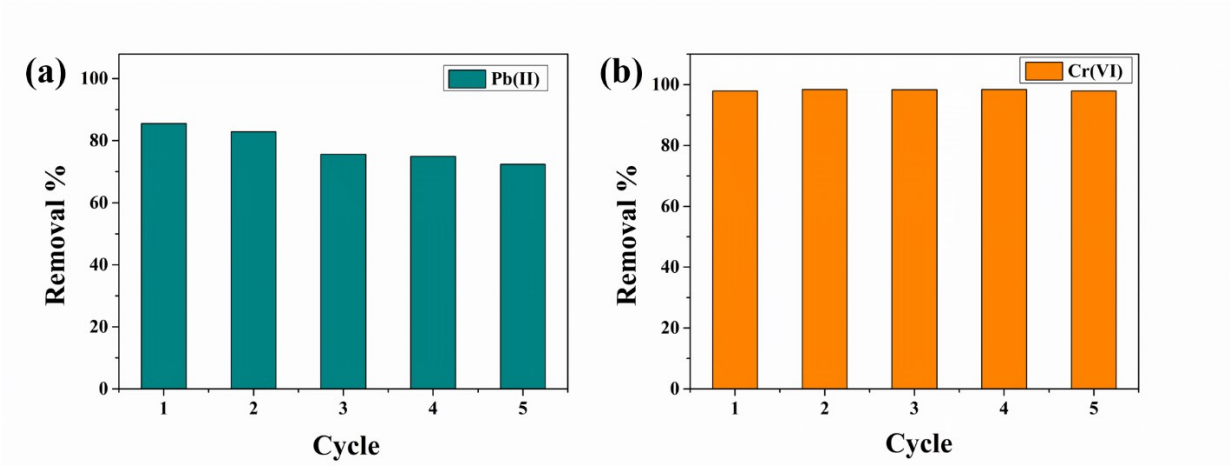

Fig. S5 The reusability of TPEI for removal of Pb(II) (a) and Cr(VI) (b).

Table S1. EDS elemental analysis of the adsorbent.

Elt.	**Line**	**Intensity (c/s)**	**Conc.**	**Units**	**Error 2-sig**	**MDL 3-sig**	
C	Ka	60.50	39.615	wt.%	2.161	1.685	
N	Ka	22.85	29.651	wt.%	2.730	2.332	
P	Ka	186.17	15.955	wt.%	0.460	0.260	
S	Ka	148.36	14.779	wt.%	0.481	0.286	
			100.000	Wt.%			Total

Table S2. Related parameters from kinetics equation.

Metal ion	C_0 (ppm)	Q_{exp} (mg/g)	Pseudo-first-order model			Pseudo-second-order model		
			K_1 (min^{-1})	Q_{cal} (mg/g)	R^2	K_2 (g/mg/min)	Q_{cal} (mg/g)	R^2
Pb(Ⅱ)	100	95.50	0.1511	33.5575	0.8062	0.0115	97.1817	0.9998
Cr(Ⅵ)	100	97.90	0.1790	7.8321	0.8441	0.0565	98.3284	0.9999

Table S3. Related parameters from isotherm equation.

Metal ion	Temperature (°C)	Langmuir isotherm			Freundlich isotherm		
		Q_{max} (mg/g)	K_L (L/mg)	R_L^2	K_F (mg/g)	n	R_F^2
Pb(II)	15 °C	389.10	0.0485	0.9982	87.50	3.9936	0.8274
	25 °C	425.53	0.0530	0.9976	94.06	3.8730	0.8394
	35 °C	462.96	0.0604	0.9972	103.66	3.8270	0.9023
Cr(VI)	15 °C	193.80	0.8012	0.9997	131.72	9.7380	0.9272
	25 °C	196.85	0.7937	0.9993	132.17	9.3397	0.9320
	35 °C	200.80	0.9920	0.9995	137.49	9.3861	0.9394

Table S4. Comparison of the adsorption capacity, equilibrium time and pH of TPEI with other adsorbents for Pb(II).

Adsorbents	Adsorption capacity (mg/g)	Equilibrium time (min)	pH	Referees
UiO-66-RSA	189.8	~180	4	[32]
Magnetic polyethyleneimine lignin	96.6	60	6	[33]
TEPA modified chitosan /$CoFe_2O_4$ particles	228.311	50	5	[34]
CeO_2–MoS_2 hybrid magnetic biochar	263.6	180	4	[35]
Fe-Mn-S@HCS	181.5	600	7	[36]
Cotton fiber functionalized with tetraethylenepentamine and chitosan	123.46	120	5	[37]
EDTA functionalized chitosan/ polyacrylamide hydrogel	138.41	170	5	[38]
Spherical PVA/ATP composites	45.87	720	5	[39]
PVA/PAA nanofibers	159	120	5	[40]
CPEI	1.01	/	3	[20]
CPEID	452.49	40	7	[21]
TPEI	**421.9**	**25**	**3**	**This work**

Table S5. Comparison of the adsorption capacity, equilibrium time and pH of TPEI with other adsorbents for Cr(VI).

Adsorbents	Adsorption capacity (mg/g)	Equilibrium time (min)	pH	Referees
Chitosan crosslinked modified silicon material	28.88	240	5~6	[41]
Modified chitosan gel	83.33	100	3	[42]
CYPH@IL101/chitosan capsule	104.38	> 960	3	[43]
Chitosan/$NiFe_2O_4$ (CNF) nanocomposites	31.523	120	2	[44]
PD-Fe_3O_4@CCS	129.03	75	3	[45]
(CPC)-modified montmorillonite	43.84	60	2	[46]
Mts-APTES/GO-OA interstratified composites	44.25	30	3	[47]
Wool keratin/PET composite nanofiber membrane	75.86	720	3	[48]
Magnetic phoenix tree leaves-derived biochar composite	55.0	1440	2	[49]
CPEI	1.43	/	3	[20]
TPEI	**191.04**	**10**	**2**	**This work**