

Supplementary materials

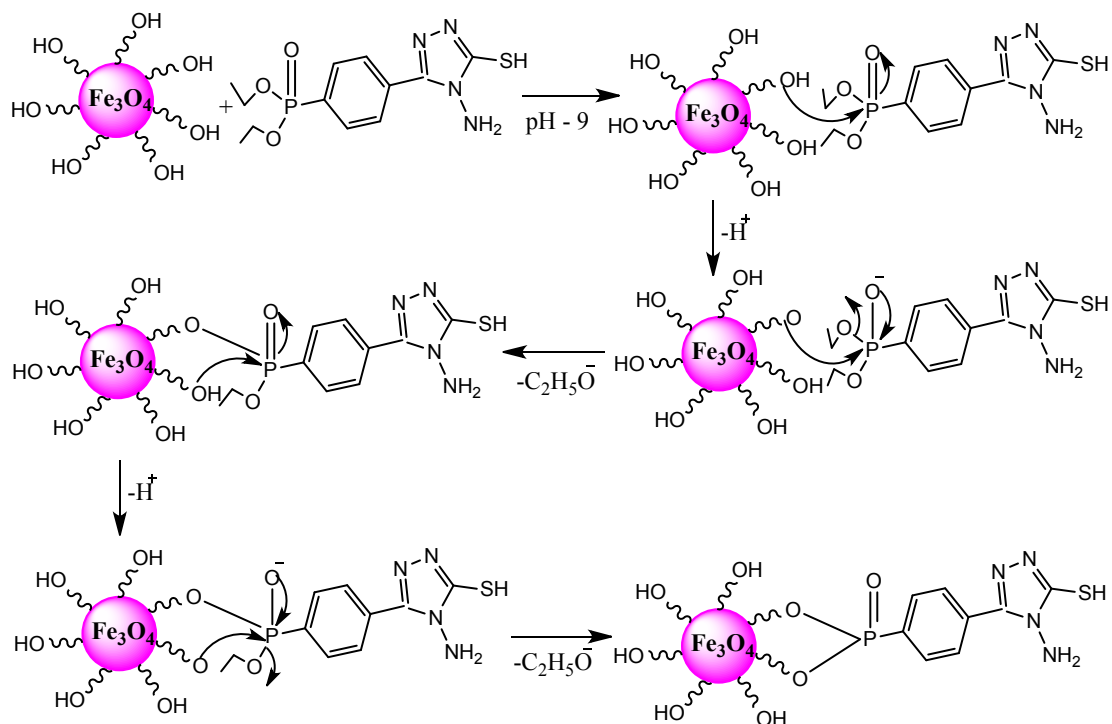
Rapid removal of cadmium ions by using diethyl 4-(4 amino-5-mercapto-4H-1,2,4-triazol-3-yl)-phenyl-phosphonate capped green synthesized Fe₃O₄ magnetic nanoparticles

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Scheme S1 The mechanism of magnetite demonstrating covalently attachment of the ligand on the Fe_3O_4 MNPs.

Table S1. Kinetic parameters of pseudo-first-order and pseudo-second-order models for the adsorption of Cd(II) on the DEAMTPP @ Fe_3O_4 MNPs.

Pseudo-first-order				Pseudo-second-order		
$q_{e, \text{exp}}$ (mg/g)	k_1 (g/mg min ⁻¹)	$q_{e, \text{cal}}$ (mg/g)	R^2	k_1 (g/mg min ⁻¹)	$q_{e, \text{cal}}$ (mg/g)	R^2
19.223	0.242	11.125	0.869	0.0066	20.790	0.996

Table S2. Langmuir and Freundlich isotherm constants

Isotherm type	Constant	Value
Langmuir	q_m (mg/g)	49.10
	b (L/mg)	0.585
	R^2	0.9996
Freundlich	k_f (mg/g)	19.427
	n	4.766
	R^2	0.9881

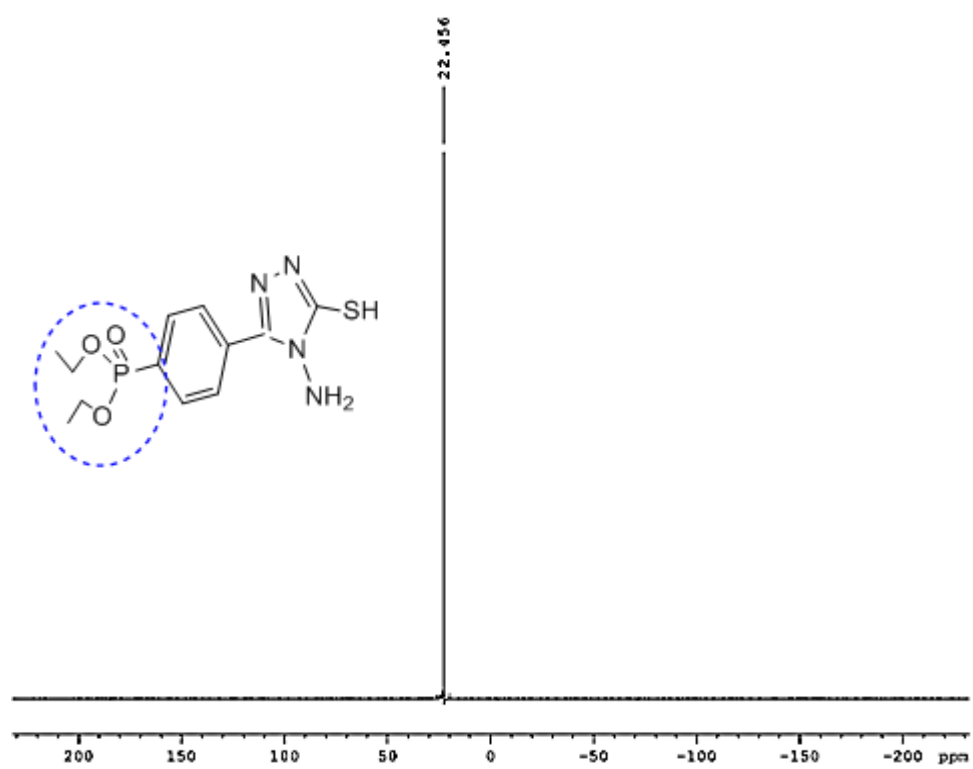


Fig. S1 ³¹P NMR spectrum of DEAMTPP.

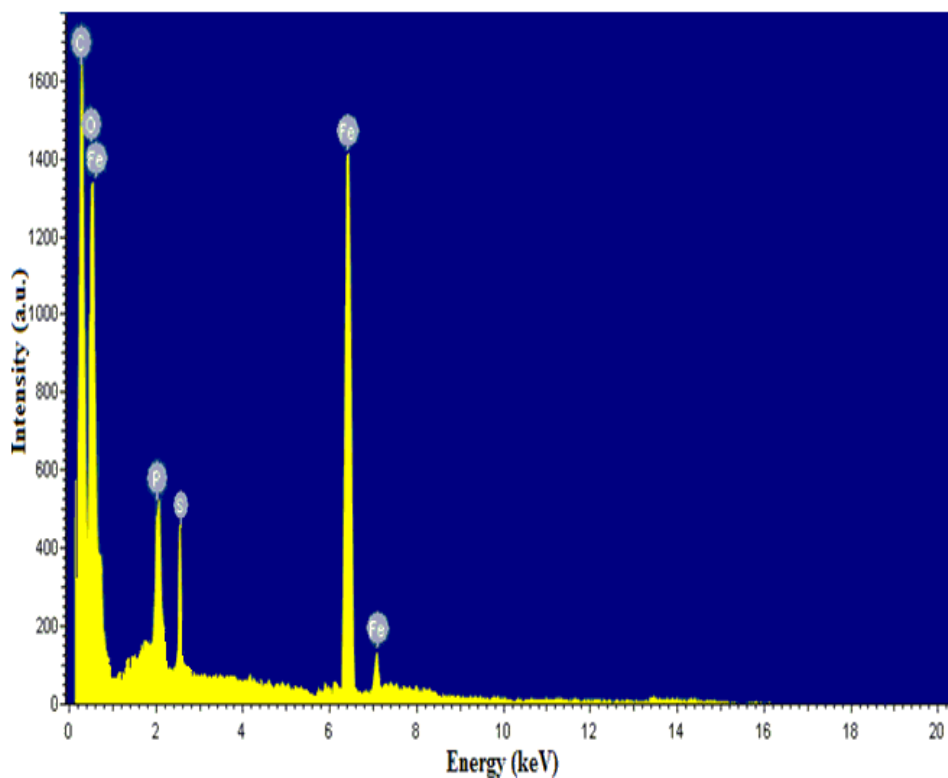


Fig. S2 EDS spectrum of DEAMTPP@ Fe₃O₄ MNPs.

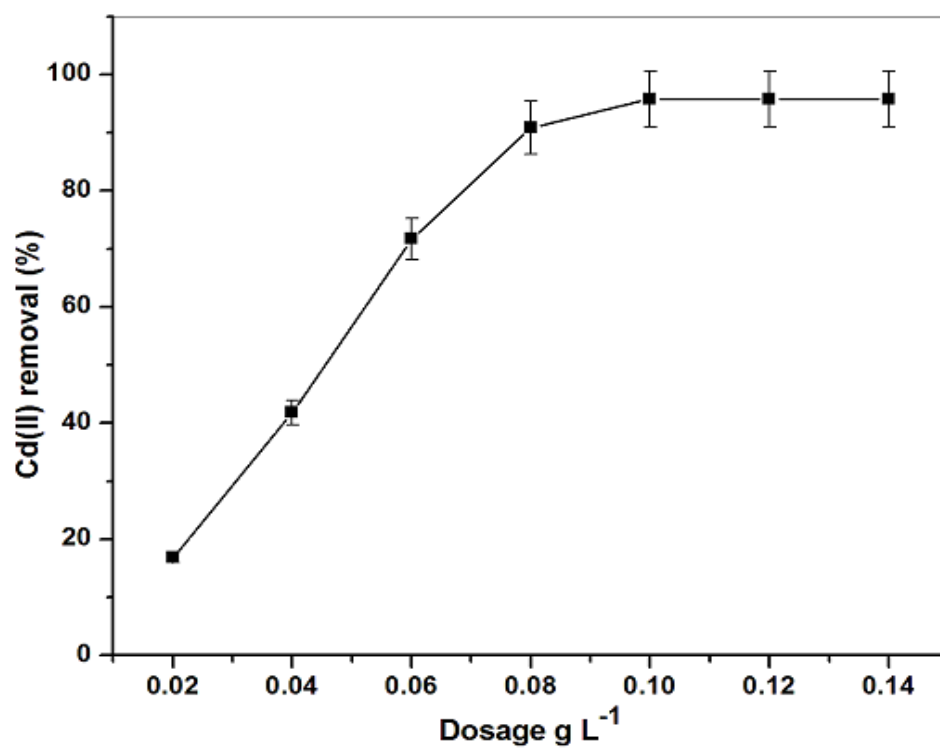


Fig. S3 Effect of adsorbent dosage on the removal rate of Cd(II) ions.

Selective adsorption experiment

The selectivity of the adsorbent material for various metal ions is an important parameter related to the application potential of adsorption processes. Stock solutions for selectivity experiments were prepared using nitrate or sulfate metal salts ($\text{Cd}(\text{NO}_3)_2 \cdot 4\text{H}_2\text{O}$, $\text{Zn}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$, $\text{Co}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$, $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ and $\text{Ni}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$) dissolving in deionized Millipore water. The DEAMTPP@ Fe_3O_4 composite (5 mg) was placed in a 100 mL Erlenmeyer flask with of a metal ion (Cd^{2+} , Zn^{2+} , Co^{2+} , Cu^{2+} , and Ni^{2+}) mixture solution (50.0 mL, concentration: 60 mg/L, pH: 6.0). The mixture solution was ultrasonicated for 14 min and shaken in an incubator for 1 hour at 25 °C. After adsorbing with the mixed metal ions, the magnetic nano-adsorbent was separated from the solution. The concentrations of the mixed metal ions were determined using atomic absorption spectroscopy (AAS).

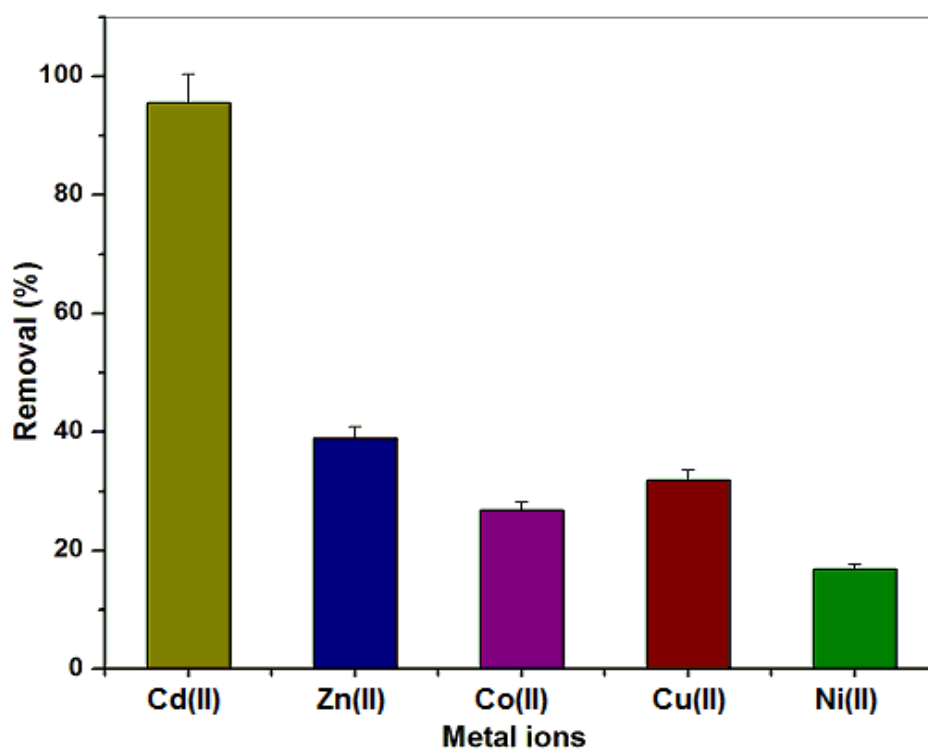


Fig. S4 Cd(II) removal on the DEAMTPP@ Fe_3O_4 MNPs from a mixed solution of heavy metal ions(Cd, Zn, Co, Cu and Ni).