Effective adsorbents for removal Cd(II) ion in solution from activated carbon of palm oil shell coated with magnetite particles

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Abstract

Investigation of the ability of activated carbon (AC) adsorption from modification of palm oil shells by coating magnetite (Fe_3O_4) particles to Cd(II) ions in solution was studied through a series of adsorption experiments with a batch method. The activated carbon adsorbents (PPAC-P) and the activated carbon-magnetite (PPAC-MnPs) were characterized by Fourier transform spectrometer to identify the functional groups, X-ray diffraction to study the level of material crystallization, scanning electron microscopy-energy-dispersive X-ray analysis to analyze the surface morphology of material and element constituents, as well as Brunauer-Emmett-Teller analyzer to analyze the surface areas of the adsorbents. The concentrations of Cd(II) ions in the solution were determined using atomic absorption spectrophotometer. The adsorption process of Cd(II) ions by PPAC-P and PPAC-MnPs was optimum at pH 6 and 7 with contact time of 90 minutes, respectively. The adsorption kinetics of Cd(II) ions in PPAC-P and PPAC-MnPs have a tendency to follow the pseudo second-order kinetics model and the Freundlich adsorption isotherm model with a value of $R^2 > 0.99$. These suggested that the adsorption process of the Cd(II) ions on PPAC-P and PPAC-PMnPs were described as heterogeneous adsorption. PPAC-PMnPs adsorbents can be used repeatedly with % Cd(II) ions adsorbed almost constant for 4 cycles with adsorption efficiency > 80%.

Full Text

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Tables

Table 1 Adsorption kinetic parameter for the adsorption of Cd(II) ion on PPAC-P and PPAC-MnPs.

Adsorbents	Pseudo-first-order		Pseudo-second-order	
	k_1 (min^{-1})	R^2	$k_2 \times 10^{-4}$ ($\text{g mg}^{-1} \text{min}^{-1}$)	R^2
PPAC-P	0.071	0.839	8.240	0.982
PPAC-PMnPs	0.110	0.931	40.640	0.993

Table 2 Intra particle diffusion model for Cd(II) ion on PPAC-P and PPAC-MnPs

Adsorbent	Initial linear portion			Second linear portion		
	k_{i1} ($\text{mg g}^{-1} \text{min}^{-0.5}$)	C_1 (mg g^{-1})	R_1^2	k_{i2} ($\text{mg g}^{-1} \text{min}^{-0.5}$)	C_2 (mg g^{-1})	R_2^2
PPAC-P	4.316	9.414	0.975	1.716	29.554	0.821
PPAC-PMnPs	3.882	16.916	0.993	0.169	46.180	0.942

Table 3 Langmuir and Freundlich parameters for the adsorption of Cd(II) ion on PPAC-P and PPAC-MnPs.

Adsorbent		PPAC-P	PPAC-MnPs
Models	Parameters		
Langmuir	q_{exp} (mg g ⁻¹)	69.332	80.400
	q_m (mg g ⁻¹)	92.131	104.074
	$K_L \times 10^{-4}$ (L mg ⁻¹)	8.197	9.259
	R^2	0.852	0.819
	$RMSE$	3.599	4.363
	χ^2	3.895	4.203
Freundlich	K_F (mg g ⁻¹) (L mg ⁻¹) ^{1/n}	2.802	3.114
	n	1.430	1.382
	R^2	0.994	0.995
	$RMSE$	3.211	2.735
	χ^2	1.232	0.896

Table 4 The adsorption capacity of Cd(II) ion on PPAC-PMnPs compared with other adsorbents.

Adsorbent		q_m (mg g ⁻¹)	Experimental condition (pH)	Reference
Cd(II) ion-imprinted ionic polymer		83.89	5.0	[3]
<i>Nannochloropsis</i> sp.-Silica		23.81	5.0	[48]
Urea-modified wheat straw		39.22	6.0	[49]
Olive stone activated carbon		11.72	5.0	[50]
Mercapto-modified graphene oxide		36.0	5.0	[51]
Carboxyl-modified jute fiber		88.98	6.6	[52]
Cellulose nanofiber		45.90	4.0	[53]
Iron-trimesic frameworks	metal-organic	54.95	7.0	[54]
PPAC-PMnPs		80.40	7.0	This work

Figures

Figure 1

Infrared spectra of the (a) PPAC-P and (b) PPAC-PMnPs.

Figure 2

XRD patterns of (a) Magnetite, (b) PPAC-P, and (c) PPAC-MnPs.

Figure 3

(a) N_2 adsorption/desorption isotherms and (b) pore size distribution of PPAC-P and PPAC-PMnPs.

Figure 4

(a) N₂ adsorption/desorption isotherms and (b) pore size distribution of PPAC-P and PPAC-PMnPs.

Figure 5

(a) N₂ adsorption/desorption isotherms and (b) pore size distribution of PPAC-P and PPAC-PMnPs.

Figure 6

Influence of contact time on adsorption of Cd(II) ion onto PPAC-P and PPAC-PMnPs.

Figure 7

Intra-particle diffusion (IPD) model-predicted kinetics of Cd(II) ion sorption by PPAC-P and PPAC-MnPs.

Figure 8

Adsorption isotherm model of Cd(II) ions on (a) PPAC-P dan (b) PPAC-MnPs.

Figure 9

Reusability number efficiency of the adsorption-desorption process of Cd(II) ion on PPAC-P and PPAC-MnPs.