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ADSORPTION OF CONGO RED BY MG(OH)₂ MODIFIED DIATOMITE

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ARTICLE DETAILS

ABSTRACT

Article History:

Received 26 June 2018 Accepted 2 July 2018 Available online 1 August 2018 The diatomite was modified by a grinding method to obtain a magnesium hydroxide-modified diatomite composite material. The prepared material was used as an adsorbent for the adsorption of anionic dye congo Red. The influence of time, pH, concentration, and other conditions on the adsorption properties of Mg(OH)2 modified diatomite is studied. $Mg(OH)_2$ modified diatomite is found to have a good adsorption effect congo red. The adsorption time shows that as the adsorption time increases, the amount of adsorption increases and tends to balance at 3 hours. Adsorption temperature shows that the increase in temperature favors the adsorption. The initial concentration of the dye indicates that as the concentration increases, the amount of adsorption will increase. Research on the adsorption kinetics reveals that the kinetics model of adsorption corresponds to pseudo-second-order kinetics and the adsorption isotherm indicates that adsorption lines fit with the Langmuir model. The adsorbent is suitable for congo red removal in waste water. In addition, these products are widely available and are easy to prepare.

KEYWORDS

Diatomite, congored, adsorption.

1. INTRODUCTION

The rapid development of global industrialization has caused a severe test for our living environment. Among them, water pollution is a prominent performance [1,2]. The printing and dyeing industry consumes and discharges large amounts of wastewater in all industries [3-5]. The complexity of printing and dyeing wastewater is considered as one of the most difficult pollutants to handle [6,7]. The outflow of non-ferrous substances can harm human health and destroy ecological balance. For the treatment of dyes in wastewater, the adsorption method has the advantages of good effect and simple operation compared to the traditional methods [8,9].

Diatomite is a kind of clay mineral. As an adsorbent has great application value and widely used in the treatment of heavy metals and organic pollutants [10,11]. Diatomite is a kind of bio-sedimentary rock. Natural material formed by skeleton remains of aquatic plants. Widely exist in all regions of the world, with unique physical properties such as high permeability, large specific surface area, and small particle size [12,13]. The original diatomite often has associated impurities and the adsorption performance is limited. Therefore, it is necessary to modify the diatomite to improve its adsorption capacity [14].

In this paper, magnesium hydroxide modified diatomite material was prepared. The adsorbent was used as dye congo red for adsorption, and the influence of time, temperature and other conditions on its adsorption performance was investigated. The adsorption kinetics and isothermal adsorption model were used to explore the adsorption mechanism.

2. EXPERIMENTAL

2.1 Materials

Diatomite, Magnesium chloride, Sodium hydroxide were purchased from Yongda (Tianjin, China). Congo red was purchased from Beifang (Tianjin, China).

2.2 Instruments

The ultrapure water was purified using a Milli-Q Reagent Water System (Millipore, Bedford, MA, USA). A WE-1 water bath oscillator (Tianjin Uno Instruments Co., Ltd.) was used and spectral measurements were taken with a TU-1810 UV-visible spectrophotometer (Beijing Spectrum General Instrument Co., Ltd.). The SEM/EDS experiments were performed on a JSM-6490LV SEM (JEOL, Japan)

2.3 Adsorbent preparation

2.3.1 Diatomite heat activation

Diatomite was taken in a muffle furnace and calcined at 450 °C for 2 h.

2.3.2 Preparation of Magnesium hydroxide modified diatomite

Magnesium chloride (MgCl₂·6H₂O) were dried at 120 °C for 24 h and then stored in a desiccator at room temperature. Weigh the same quality of diatomite and dried MgCl₂·6H₂O in an agate mortar, grinding and mixing, the appropriate NaOH to join MgCl₂·6H₂O):n(NaOH)=1:1.5), grind to complete reaction. Put aging in air for hours. Repeated washing with deionized water, remove Cl- (tested with AgNO₃). Place the filter cake in the oven and dry it at 110 °C for more than 9 h. Collect spare [15].

2.3 Adsorption studies

A 500 mg/L dye mother liquor was prepared. It was subsequently diluted to the desired concentration. The appropriate amount of dye solution was added to a 100 mL Erlenmeyer flask and the appropriate amount of adsorbent was weighed. The Erlenmeyer flask was heated in a water bath and shaken for adsorption. After the reaction was completed, an appropriate amount of sample was taken and centrifugal separation. Take supernatant and the absorbance of the dye liquid after its adsorption was

2.4 Analytical method

UV–visible spectrophotometer measurements of the congo red absorbance were λ = 496 nm . The absorbance q_t (in mg/g) can be calculated by using:

$$q_t = \frac{(C_0 - C_t) \times V}{m} \tag{1}$$

and the adsorption rate $\boldsymbol{\eta}$ is given by

$$\eta = \frac{C_0 - C_t}{C_0} \times 100\%, \tag{2}$$

where C_0 (in mg/L) is the initial concentration of the dye solution, C_t (in mg/L) is the concentration of the dye solution adsorbed by time t, V (in milliliters) is the initial dosing volume of the dye solution, and m (in grams) is the adsorbent quality.

3. RESULTS AND DISCUSSION

3.1 Characterization of Mg (OH)₂ modified diatomite

3.1.1 SEM analysis

Figure 1(a) shows the original diatomite. It can be seen from the SEM that there is a certain amount of impuritys on the surface of diatomite. The appearance of the diatomite has a round cake shape and a porous structure on the surface. Figure 1(b) shows the Mg $(OH)_2$ modified diatomite. It can be seen that the surface of the diatomite is roughened and it can be demonstrated that the diatomite and the magnesium hydroxide are successfully compounded by the grinding method.

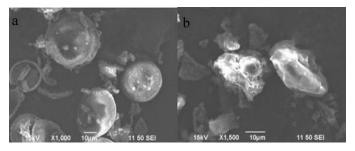


Figure 1: SEM images of (A) original diatomite and (B) Mg (OH)₂ modified diatomite

3.1.2 EDS analysis

Figure 2(a) shows the original diatomite. It can be seen from the EDS analysis that the detected element is Si and O in the main component SiO_2 in diatomite. Figure 2(b) shows the $Mg(OH)_2$ modified diatomite. It can be seen increased Mg compared to original diatomite. The successful preparation of $Mg(OH)_2$ modified diatomite.

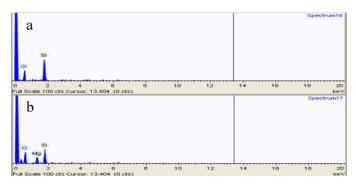


Figure 2: EDS images of (A) original diatomite and (B) Mg(OH)₂ modified diatomite

3.2 Effect of related factors on the adsorption

3.2.1 Effect of time on the adsorption

The simulated dye wastewater solution of congo red was prepared with a

concentration of 50 mg/L. Take 50mL dye into a 100 mL conical flask. Add adsorbent 20 mg. Figure 3 show that $Mg(OH)_2$ modified diatomite has a good adsorption effect on the congo red. At 3 hours, the adsorption of congo red tends to be balanced with an adsorption rate of 88.86% and an adsorption capacity of 111.07 mg/g.

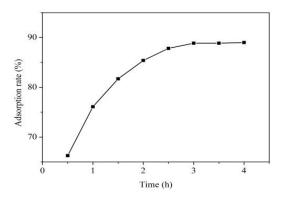


Figure 3: Effect of time on the dye adsorption rate

3.2.2 Effect of temperature on the adsorption

The initial concentration of dye was 50 mg/L and the volume was 50 mL. Adsorption experiments were conducted at 25° C, 35° C, and 45° C, respectively. Figure 4 show that, with the increase of temperature, the adsorption rate increases and the adsorption capacity also increases to a certain extent. The adsorption rate of congo red increases from 88.86% at 25° C to 90.77% at 45° C. The adsorption capacity increases from 111.07 mg/g at 25° C to 113.47 mg/g at 45° C.

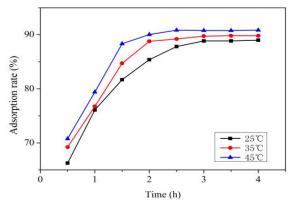


Figure 4: Effect of temperature on the dye adsorption rate

3.2.3 Effect of pH on the adsorption

In this section, the effects of pH 4–9 on sorption properties were investigated for congo red. Figure 5 show that, with the increase of PH, the adsorption performance exhibits a downward trend. For the congo red at a pH of 4–9, the adsorption rate (adsorption capacity) decreased from 90.92% (113.65 mg/g) to 67.90% (84.87 mg/g).

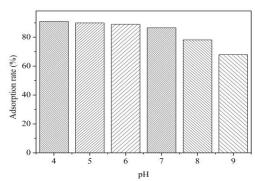


Figure 5: Effect of pH on the dye adsorption rate

3.3 Kinetics model of adsorption

Pseudo-first-order kinetics and pseudo-second-order kinetics models are used to study the adsorption kinetics of $Mg(OH)_2$ modified diatomite. The following equations hold for the two kinetics models of adsorption:

$$\ln(q_e - q_t) = \ln q_e - K_1 t \tag{3}$$

And

$$\frac{t}{q_t} = \frac{1}{K_2 q_m^2} + \frac{t}{q_m} \tag{4}$$

where qm is the equilibrium adsorption capacity (in mg/g), qt is the adsorption capacity at a certain time t, respectively, and K_1 and K_2 are pseudo-first-order kinetics and pseudo-second-order kinetics model rate constants.

Table 1 lists the congo red kinetics models of adsorption parameters. The congo red pseudo-second-order kinetics model correlation coefficients were significantly better than those of the pseudo-first-order kinetics model, indicating that the adsorption behavior can be described well by the pseudo-second-order kinetics model. The congo red theoretical maximum adsorption capacity is 121.92 mg/g.

Table 1: Kinetics model of adsorption-related parameters

Pseudo-first			Pseudo-second			
q _{m,cal} (mg/g)	K ₁ (h ⁻¹)	\mathbb{R}^2	$q_{m,cal}$ (mg/g)	$K_2 \left(g/(mg \cdot h) \right)$	R ²	
121.92	1.9832	0.9290	117.65	3.802×10 ⁻²	0.9998	

3.4 Adsorption isotherm

Different concentrations (60–80 mg/g) of congo red dye solution were introduced for studying the adsorption isotherms. The Langmuir model and the Freundlich model are usually used to express the adsorption isotherm model. The following equations comprise the two adsorption isotherm models:

$$\frac{C_e}{q_e} = \frac{C_e}{q_m} + \frac{1}{q_m K_L} \tag{5}$$

and

$$\ln q_e = \ln K_F + \frac{1}{n} \ln C_e \tag{6}$$

Table 2 list the two isothermal adsorption model parameters of the congo red. From the table we can see that, the Langmuir model correlation coefficients are higher than those of the Freundlich model, which shows that the Langmuir model can better describe the adsorption process. The congo red theoretical maximum adsorption capacity is 147.06 mg/g.

 Table 2: Adsorption-isotherm-related parameters

Langmuir			Freundlich			
q _m (mg/g)	K_{L}	\mathbb{R}^2	K_{F}	n	R ²	
147.06	0.4047	0.9978	85.87	7.18	0.9381	

4. CONCLUSIONS

In this paper, diatomite was first treated with heat activation, and then the $Mg(OH)_2$ diatomite modified material was prepared by grinding, which was applied to simulating dye wastewater congo red adsorption. The following conclusions are reached:

- (1) SEM and EDS results confirm that the $Mg(OH)_2$ modified diatomite was prepared successfully.
- (2) Mg(OH) $_2$ modified diatomite adsorbent has a good adsorption effect on the congo red. Congo red reached adsorption equilibrium at 3 h and heating is conducive to the adsorption. Within the investigated pH range, the adsorption capacity gradually decreased with the increase of pH.
- (3) The kinetics models of adsorption and adsorption isotherms for the Mg(OH)₂ modified diatomite for the congo red are in line with the pseudosecond-order kinetics and the Langmuir model, respectively.

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