RESEARCH ARTICLE

Removal of Rose Bengal Dye from Aqueous Solution using Low Cost (SA-g-PAAc) Hydrogel: Equilibrium and Kinetic Study

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ABSTRACT

Hydrogels are considered one of the most important polymers, with very low economic costs for treating dyes from an aqueous solution. In this study, sodium alginate (SA), a kind of polysaccharide, and acrylic acid is an organic compound, N'-Methylene-bis-acrylamide (MBA) as a cross-linked agent, were used to prepare the hydrogel by free radical method. Studies have shown that sodium lignite-based nano-hydrogel is environmentally friendly, more cost-effective and highly efficient in remove dye in aqueous solution. The hydrogel adsorption characteristic was analyzed *via* scanning electron microscope (SEM). The data appear that the surface contains many pores and has a sponge-like structure. also the results showed that the hydrogel is the XRD of (SA-g-PAAc) a wide band at 2θ = 20.52° within the calculated d = 4.21A°. Study isotherm adsorption the highest (R^2=0.9903) related to the isotherm Freundlich and Kinetic model the adsorption process of Rose Bengal dye on the SA-g-PAAc hydrogel follows a second model.

Keywords: Acrylic acid, Sodium alginate, Hydrogel, Adsorption, Rose Bengal dye

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INTRODUCTION

Hydrogels are polymer chains with hydrophilic cross-linking that may hold fluids for prolonged periods. As a result, hydrogels are employed in a variety of industries, including agriculture, medicine delivery, diapers, and adsorbent material.[1-3] The use of polysaccharide-based hydrogels as adsorbents has various benefits, including strong adsorptive, recovery capabilities, and biodegradability.[4,5] Cellulose, chitin, chitosan, alginate, xanthan gum, and carrageenan are some of the polysaccharides that have been utilized to make hydrogels. Hydrogels have been utilized to get rid of many contaminants such as dyes, heavy metals, and organic pollutants due to their high adsorption ability. Hydrogels often contain polar or ion functional groups, while dyes are mostly ionic (positive or negative), and three mechanisms often explain dye adsorption on gels depending on the chemical nature of the dye and hydrogels.[6-8] These are Electrostatic overlaps between the different functional aggregates of the charge for both dye and hydrogel, Hydrogen affinity between dye and hydrogel, and non-waterproof overlaps between the non-polar components of both dye particles and hydrogel.[9,10] In this study, application of SA-g-PAAc hydrogel by synthesis polymerization of free radicals, x-ray crystallography (XRD) and field emission scanning electron microscopy (FESEM) was utilized to characterize the materials as they were produced. The usage of nano-composite as adsorbents for removing RB dye from an aqueous medium was thoroughly investigated. The adsorption process of the adsorbents was investigated using adsorption kinetics.

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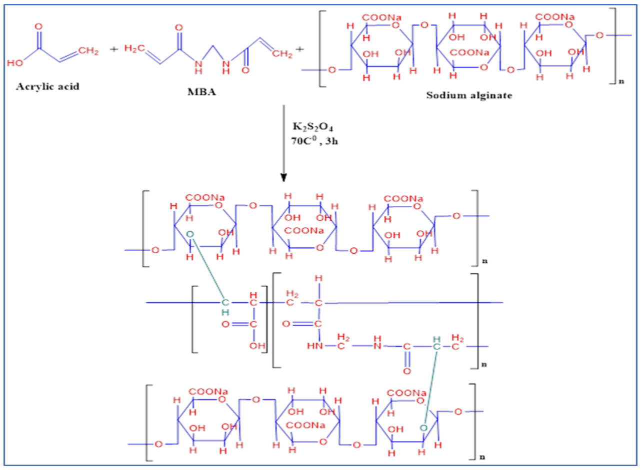

Figure 1: Preparation of (SA-g-PAAc) hydrogel

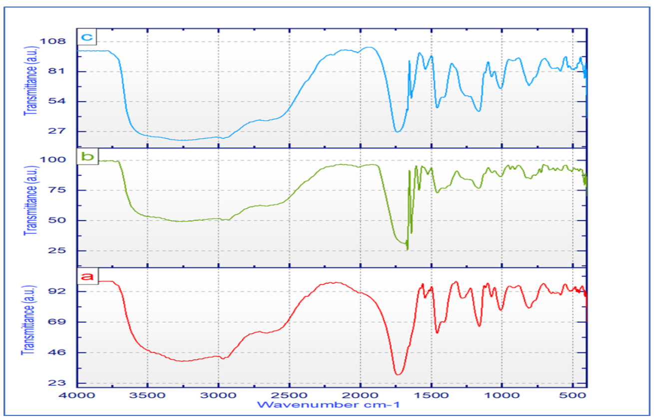

Figure 2: Infrared spectrum a) (SA-g-PAAc) hydrogelbefoure adsorption , b) (SA-g-PAAc) hydrogel After adsorption

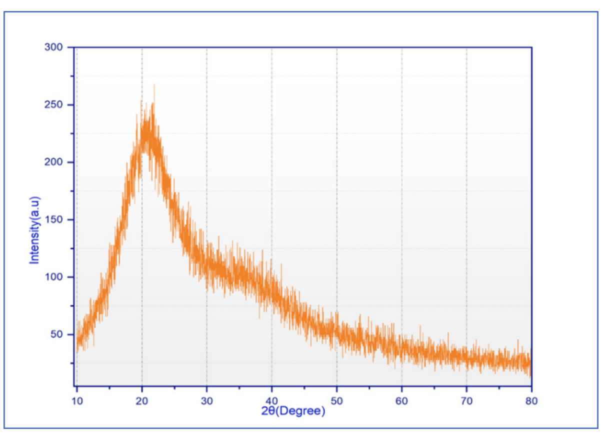

Figure 3: XRD of (SA-g-PAAc) hydrogel

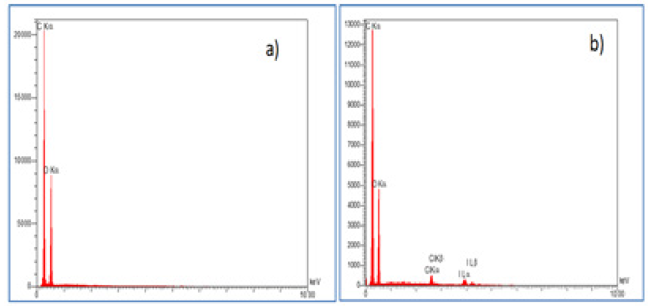

Figure 4: EDX a) SA-g-PAAc hydrogel , b) SA-g-PAAc hydrogel after adsorption RB dye

EXPERIMENTAL PART

Preparation of (SA-g-PAAc) Hydrogel

The (SA-g-PAAc) hydrogel cross-linked was prepared free radical co-polymerization in aqueous solution which included sodium alginate (0.31 g) dissolving in (5 mL) of DW and placed in a three-mouth circular flask connected to a condenser, separating funnel and gas N_2. Inside the water bath with stirring until complete dissolution, then add to it acrylic acid (3 g) as well as (0.05 g) of each of the cross-linking agent MBA and the initiator KPS dissolved in (1-mL) of distilled water respectively, and in the presence of N_2 at a temperature of 70ºC and for a period of three hours; At that, a cross-linked hydrogel is formed and it is cut into small pieces, followed by washing with distilled water with continuous stirring for (6 hours) and replacing the water every 1-hour in order to get rid of the unreacted monomers after that drying in the oven at 50ºC until we get a weight constant, as shown in Figure 1.

RESULTS AND DISCUSSION

FT-IR

Infrared spectrum of (RB) dye adsorption on (SA-g-PAAc) hydrogel is as appear in Figure 2. The absorption bands appeared within about 3300–3000 cm^{-1}, which indicates the stretchable vibrations of OH and CH groups, also which appeared in the range 1600–1400 cm^{-1}, refer to the C=C group of the aromatic benzene ring, as it appeared within the range 850–650 cm^{-1}, which refers to the C-Cl group. While the range is 600–500 cm^{-1}, it refers to the group C-I.[11,12]

XRD

XRD spectra were used to study the structural properties represented by the structure and crystal size of the (SA-g-PAAc) hydrogel in its solid state using a single light of wavelength 1.5104 Aº from Cu-Kα source within the angular range 2θ is (0-80) degrees, as The (XRD) spectra appear in Figure 3

Table 1: Statistical of kinetic model first order and second order

Dye	*First order*			*Second order*			
	$k_1(min^{-1})$	$q_e mg/g)$)	R^2	$K_2 (g.\ mg^{-1}.\ min^{-1})$	$q_e (mg/g)$	R^2	$H (mg.\ g^{-1}.\ min^{-1})$
R B	213 X10^{-4}	1.60352	0.5506	7.847 X 10^{-4}	49.505	1	192.308

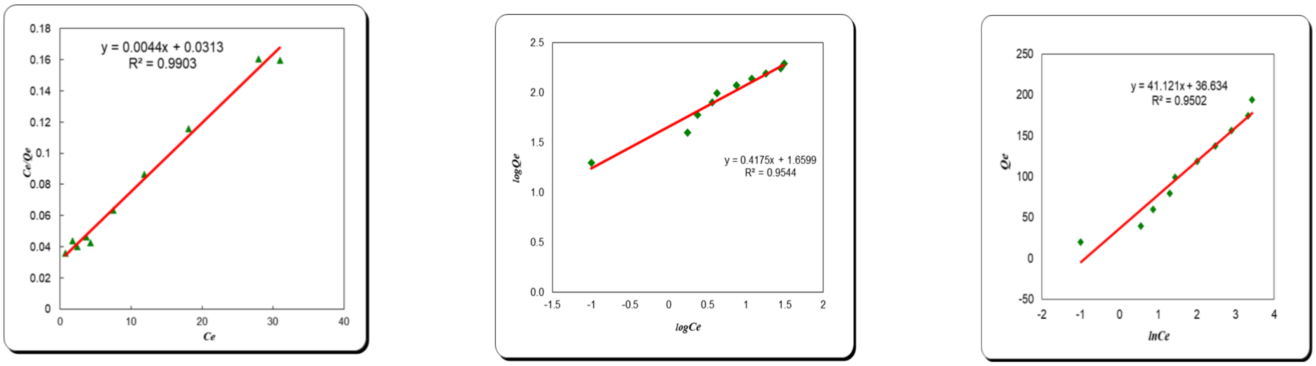

Figure 5: Langmuir isotherms (A), Freundlech isotherm (B), Temken isotherm (C) of RB dye adsorption on hydrogrl

appeared the presence of a wide band within the angular range 2θ (15–30)º, which indicates the nature amorphous of the cross-linked chemical structure of the SA-g-pAAc , as it is observed in the XRD spectrum of the SA-g-PAAc a wide band at 2θ = 21.50º within the calculated d = 4.21Aº.[13,14]

Energy Disperse X-raq (EDX)

For the success of the adsorption process, it is necessary to know the ratios of both carbon and oxygen before and after adsorption of the cross-linked SA-g-PAAc hydrogel , that the proportion of carbon in the hydrogel increased after adsorption, while the proportion of oxygen decreased, and the results also showed the proportions of chlorine and iodine, which indicates the adsorption of dye,[15] as shown in the Figure 4.

Adsorption Isotherms

Numerous isotherm equations are existing for studying sorption equilibrium parameter, and the utmost public being is the langmuir isotherm, lreundlich isotherms, and temkin isotherms. The model langmuir (Figure 5A) is built on the theory that there is a fixed amount of active sites, which regularly dispersed over the surface of the adsorbent; these sites have identical desirability for adsorbing a mono layer and do not have any interactions between adsorbed molecules. Furthermore, freundlich isotherm (Figure 5B) applicable for heterogeneous surface adsorption. This model supposes a positive relationship between adsorbate concentration adsorbent quantities on the surface. Similarly, the energy sorption proportionally declines at the end of the sorption centers of the adsorbent. model timken (Figure 5C) comprises an element that considers interactions of adsorbent-adsorbate. By disregarding the meager and important value of concentrations, the model supposes the adsorption heat of all molecules in the layer linearly decrease instead of the logarithmic with the coverage. Estimation of (R2) done via fitting the experimental equilibrium data for the dye-hydrogel system utilizing Langmuer, Freundlech, and Timken models.[13] Figure 4 show the highest (R^2 = 0.9903) related to the isotherm Freundlich.[16,17]

Kinetic Model

In order to determine the kinetic models of the adsorption process of RB dye on the surface of the SA-g-PAAc hydrogel, and because of its great importance for determining the time during which the adsorption process to reach the equilibrium, where concentrations (200 mg/L) were used from RB dye at a temperature of 25°C, where the analysis of the models for the first pseudo as well as the second pseudo-order appear in Figure 6 and Table 1 and based on the values of the (R2), the most suitable model was selected to describe the adsorption kinetics of the dye on to (SA-g-PAAc) hydrogel, that the (R^2) for the pseudo-second-order kinetics model, it is high compared to the first-pseudo-order, and the amount of adsorbent material that was calculated in this model is very close to the practical value that was calculated in the experiments compared to the amount of adsorbent material calculated in the first-order model, Therefore, the adsorption process of RB dye on to SA-g-PAAc.

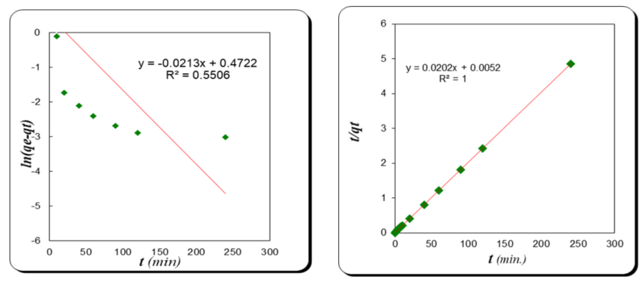

Figure 6: Kinetic model (a) First-order,(b) Second-order

CONCLUSION

- Preparation of (SA-g-PAAc) hydrogel nanocomposite by polymerization of free radicals
- Preparation of sodium lignite-based nano-hydrogel is environmentally friendly, more cost-effective and highly efficient in remove dye in aqueous solution
- The adsorption process of RB dye on to (SA-g-PAAc) hydrogel follows a second-order model.
- The highest (R^2 = 0.9903) related to the isotherm Freundlich.

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