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AQUEOUS RHODAMINE 6G TREATMENT WITH CROSS-LINKED COPOLYMER

Dr. Sandeep K, *Associate Professor, Dept of Chemistry,*
Adarsha College Of Engineering, Angul, Odissa.

ABSTRACT: Glycerin, styrene, and alt-maleic anhydride were used as a copolymer to extract the Rhoda mine 6G dye from water. Time in contact, initial dye concentration, temperature, sorbent amount, and solution pH were all measured to determine the degree of elimination. At equilibrium, we checked that the sorption data were consistent using Freundlich, D-R, and Langmuir isotherms. The maximum sorption capacity at equilibrium is 14.73 mg g-1, as indicated by the Langmuir equation. It is possible to evaluate its effect on the polymer-sorbent by applying the D-R equation and the average sorption energy of the Rhoda mine 6G dye (5.472 kJ mol-1). Scanning electron microscopy (SEM) was used to examine the surface characteristics and geometry of dye-loaded sorbents after sorption. Images captured by scanning electron microscopy (SEM) showed a connection between sorbents with uneven surfaces and Rhoda mine 6G dye molecules. The motion data were highly congruent with the pseudo-second-order model. The positive thermodynamic values of G° (7.45-6.04 kJ mol-1), H° (18.378 kJ mol-1), and S° (0.0374 kJ mol-1K-1) show that the adsorption process is predictable, unexpected, and generates heat.

Keywords: Adsorption, Cross-linked copolymer, Isotherms, Kinetic, Rhoda mine 6G dye

1. INTRODUCTION

The recycling of contaminated colors is hindered by synthetic materials and organic chemicals that create pleasant fragrances. Wastewater from factories may contain the same kinds of water contaminants. Little color changes can have a big impact on water's physical and chemical characteristics, making it look unappealing. Scientists have found that rhodamine-colored water is a telltale sign of malignancy in the dermal tissue.

A number of physical, biological, and chemical processes can cause water-containing solutions to lose their color. Membrane processes, ion exchange, flocculation, filtration, biological oxidation, solvent extraction, and biological osmosis are all part of the approaches. Research shows that Rhodamine 6G (Rh 6G) may be successfully extracted from water solutions using an adsorbent surface made of poly (fumaric acid-co-acrylic acid). While researching adsorption, we took temperature, ionic strength, contact time, pH, and adsorbent quantity into account. Using hydrogel, the Rh 6G dye can be easily extracted from water-based solutions. Three models were used for the analysis of the equilibrium adsorption data: Freundlich, Temkin, and Langmuir. Utilizing microparticles that were cross-linked with poly(N-vinyl caprolactam-co-maleic acid), Rhodamine 6G was extracted from water. We performed batch adsorption studies to measure the impact of several variables on dye adsorption, including initial pH, adsorbent dosage, temperature, dye concentration, and contact length. In terms of equilibrium adsorption data, the Langmuir isotherm model is spot on. There found a maximum absorption capacity of 2012 mg/g of Rh 6G at pH 10. An approximation based on second-order parameters could be used for the experimental data.

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The chitosan-g-(N-vinyl pyrrolidone) montmorillonite complexes absorb both the Rh 6G dye and water. By adjusting the sorbent concentration and the duration of its interaction with the material, we were able to increase absorption. Nothing changed even if the temperature went up. Our results on equilibrium and adsorption kinetics for Rh 6G allow us to calibrate the Freundlich model. Scientists tested the effectiveness of crushed palm shell in removing Rh 6G from water solutions using batch sorption studies. Here, we played around with different initial dye concentrations, contact times, pH levels, and adsorbent masses.

Adsorption data was modeled using pseudo-second-order and pseudo-first-order equations. When trying to understand the adsorption process, the pseudo-second-order model worked best. To investigate equilibrium, the Freundlich and Langmuir isotherms were used. All of the model's parameters were defined by us. The weight of Rh 6G remained constant at 25°C, which is 105.0 mg g⁻¹.

The decrease in free energy showed that adsorption occurred independently. To assess their impact on the organic dye adsorption, suffocated poly(styrene [ST]-alt-maleic anhydride [MA]) microspheres were synthesized from poly(St-alt-MA) by a sulfonation method. When tested against poly (St-alt-MA), the adsorbent demonstrated far greater efficiency in removing cationic dyes. We employed coffee grounds to research the rhodamine dyes' adsorption rates and isotherms when extracted from water. During the sorption process research, we measured fluid volume, temperature, ionic strength, and anions. Moreover, we developed and tested a chitosan-based hyperhydrophilic absorbent that could remove Rh 6G dye from water-based solutions. It was also observed that this absorbent is quite effective at removing dye. Adjustable parameters include solution pH, dye contact time, starting dye concentration, and adsorbent volume. Using a sorbent dosage of 1.0 g L⁻¹ and a pH of 10, 80.34% dye was successfully removed.

The link between ethylene blue and Rh 6G was investigated by drying and letting repose for a long time a mixture of dimethyl acrylate, acrylamide, sodium acrylate, and acrylic acid. We determined the equilibrium sorption capacities and adsorption rate constants. As the mole% of acrylamide increased, the equilibrium color absorption decreased. Sorbents, whether they are dry or inflated, can soak up the same amount of water. In comparison to the dry sorbent, the expanded sorbent absorbed the colors at a faster rate. When the sorbent was completely stretched, all of the negatively charged groups that help with adsorption were there. We used the Langmuir adsorption isotherm to see how the starting pigment concentration affected the adsorption.

The use of batch adsorption allowed for the examination of the Rh 6G binding process to bentonites. The effectiveness of Rh 6G adsorption was found to be affected by a number of variables, such as pH, starting concentration, adsorbent dosage, contact time, and temperature. In order to determine the isotherm values, the Freundlich, Temkin, and Langmuir models were applied to the equilibrium adsorption data. Observations of betonies have shown Rh 6G pseudo-second-order rate variations. Using Fe3O4 nanoparticle compositions, we evaluated the efficacy of magnetic biochar made from rice husk in removing the 8G dye. We looked at the kinetic, isothermal, and thermodynamic properties of the Rh 6G dye adsorption on magnetic biochar. When compared to pure biochar, the efficacy of the Fe3O4-composite biochar in removing Rh 6G is 94% greater. Results from kinetic and adsorption isotherm experiments validated the accuracy of the models used to forecast

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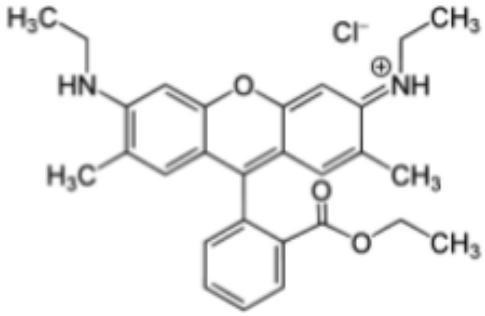
Rhodamine adhesion on magnetic Fe3O4-biochar: the Langmuir, pseudo-first-order, and pseudo-second-order models.

2. EXPERIMENTAL INFORMATION

2.1 Materials and Methods

The effectiveness of a combination of styrene, maleic anhydride, and glycerin in removing Rh 6G from water was investigated. In order to determine what factors affect sorption, the researchers varied the following: pH, starting dye concentration, temperature, sorbent quantity, and dye-sorbent contact length. There were three models used to assess the equilibrium adsorption data: Freundlich, Dubinin-Radushkevich (D-R), and Langmuir. An explanation of the prospective sorption process was provided, along with graphs showing the thermodynamic and kinetic adsorption characteristics.



Recrystallization from benzene was used to eliminate impurities from MA before it was applied. The necessary temperature of 144-145°C was reached for the styrene (St) by distillation. Recrystallization from ethanol is necessary for the purification of azobisisobutyronitrile. The precipitate was Rh 6G chloride, a monovalent cationic dye. With the molecular formula C28H31ClN2O3, we have Rhodamine 6G powder. The formula and dye categorization of this color lead to its designation as C.I. Basic Red 1.

2.2. Preparation of Adsorbent

The functionality groups −COOH, OCO, −OH, and C=O are present in the alt-MA-St copolymer, which is produced in a two-step process. Lycerin (MSG) is associated with it. In a molar ratio of 1:1, 50 mL of benzene, 4.9 g of maleic anhydride, 4.16 g of styrene, and 0.1 g of AIBN were heated to 80 degrees Celsius. Dehydration of the copolymer (CPL) was achieved by subjecting it to a pressure oven at 40°C after freezing it in ethanol or heptane; this process resulted in 6.7 g, or 72.6% recovery. And then, for three hours, bring 4.08 grams of SPL and 5.0 grams of GL to a temperature of 120°C.

According to the chemical analysis, MA makes up 51.5% of SPL and St. accounts for 48.5%. The non-reactive GL and SPL were removed from the functional cross-linked polymer by rinsing it with double-distilled water and alcohol many times. Vacuum drying was performed on the polymer sorbent at 30°C. The adsorbent was manufactured and put together.

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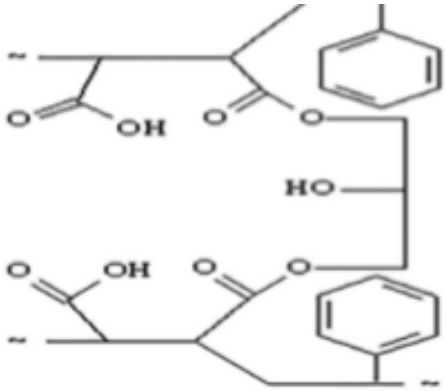

2.3. Adsorption Experiments

The dye was prepared in a stock solution of 500 mg L−1 using double-distilled water. Then, in order to create experimental solutions with the correct concentration, the stock solution was diluted. A mixture of 500 mg L−1 of dye stock solution and double-distilled water was used to achieve the necessary concentration for the investigations. Using the same methods as before, we investigated how the Rh 6G dye attached to a synthetic sorbent. We determined the capacity (mg g−1) and degree of sorption (%) of the sorbent by using equations (1) and (2).

$$Sorption\ \deg ree = \frac{(C_0 - C_e)}{C_0} \times 100\% \quad (1)$$

$$Sorption\ capacity = \frac{(C_0 - C_e) \times V_{sol}}{m_{sorb}} \quad (2)$$

Rh 6G initial and final concentrations (in milligrams per milliliter), sorbent mass, and dye solution volume absorbed are represented by Vsol, msorb, and Ce, respectively.

3. RESULTS AND DISCUSSION

3.1. Effect of Ph

The sorption degree of the Rh 6G dye was tested at 20°C, with 30 minutes of sorption, an initial dye concentration of 75 mg L−1, and a sorbent weight of 3.0 g L−1. The effects of pH on this degree were also investigated. Under these circumstances, the fluid's pH ranged from 3 to 9. According to the results, the sorption degree is 5.6% in an extremely acidic setting and 21.0% at a pH of 6. The degree of sorption, on the other hand, drops to 16.2% when the pH of the solution rises. Some people thought that the higher concentration of H+ ions in the solution was to blame for the reduced adsorption of Rh 6G at acidic pH. Due to the presence of extra H+ ions, which compete with the cationic groups on the dye for the active sites on the adsorbent, cationic dyes are less effective at adhering to very acidic media than other types of media. Surface charge density increases with increasing pH, which in turn reduces electrostatic repulsion between the adsorbent's positively charged surface and the positively charged dye. An improvement in adsorption could result from this. As the pH of the solution rises, the electrostatic repulsion between the cationic pigments, which are positively charged, and the adsorbent surface decreases, making the removal process more efficient. When the pH level is more than 3, the sorbent's negatively charged charge and the dye ions' positively charged charge interact electrostatically, leading to enhanced results. The synthesized adsorbent has a relatively good sorption capacity for Rh 6G at pH 6, thus that's where the subsequent tests were conducted.

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3.2. Effect of Sorbent Dosage

The dye recovery volume from water solutions as a function of sorbent concentration varied among experiments, as shown in Table 1. For the sorption approach, a sorbent concentration ranging from 1.0 to 4.0 g L<sub>1\/sub> was used. There is no significant link between the sorption level and the concentration of the sorbent, however the data shows that the clearance level drops significantly when the sorbent concentration gets close to 3.0 g L^-1. The optimal concentration of sorbent for these studies is 3.0 g L1. For the following experiments, 3.0 g L1 of sorbent was used.

3.3. Effect of Contact

Quicken the process. The amount of time a sorbate is in touch with an object changes its binding capacity relative to its original concentration. In a controlled setting, we measured the synthetic sorbent's ability to remove Rh 6G dye for 20 to 150 minutes (see Table 2). Researchers looked at how the length of time people were in contact affected this capacity. Based on the data, it was determined that the Rh 6G elimination process had stabilized. Following sorption, 3.7% of Rh 6G stayed attached for the first 20 minutes. After 120 to 150 minutes, the MSG's color will be stable. A drop of 28.8% to 29.5% in Rh 6G was achieved by the sorbent. It takes about 120 to 150 minutes for the Rh 6G dye to absorb water.

Table 1: The concentration of rhodamine 6G was examined after 30 minutes at 20°C with sorbent dosages of 200 mg L-1 and V=0.04 L.

Sorbent dosage, g L–1	1.0	1.5	2.0	2.5	3.0	3.5	4.0
Removal degree, %	1.5	5.5	10.2	12.3	12.6	13.0	13.1

Table 2: Dosage of sorbent 3.0 g L-1, temperature 20°C, starting concentration of rhodamine 6G 200 mg L-1, and volume (V)=0.04 L were the variables that determined the extent of sorption.

Time, min	20	30	40	60	80	100	120	150
Removal degree, %	3.7	12.6	14.6	19.1	22.3	25.5	28.8	29.5

3.4. Effect of Dye Concentration on Sorption Degree and Sorption Capacity

Steady-state experiments were conducted on dye solutions with initial concentrations of 75 mg per liter to investigate the impact of an increased Rh 6G concentration on the retention capacity and adhesiveness of the dye. An overview of the findings is provided in Table 3. As the sorbent's dye-absorbing capacity increases from 4.74 to 9.83 g g<-1</sup>, the clearance rate decreases from 19.0% to 11.8%. A perfect balance is achieved at a concentration of 200 mg L-1. As the sorbent's active sites are filled up with increasing dye concentration, the degree of sorption decreases. The sorbent has the ability to stable 9.83 grams of material, according to this.

3.5. Effect of Temperature

Various pH levels (6.0), contact lengths (30 minutes), dye concentrations (200 mg L₁), and temperatures (20 to 60°C) are shown in the following table as the adsorption of Rh 6G dye with MSG. According to Table 4, the sorption rate reaches 25.5% when the temperature is 60°C. Because dye molecules are more mobile and interact with the sorbent's active sites more effectively at higher temperatures, the sorption strength increases as the temperature rises. The temperature relation of the sorption degree for the MSG-Rh 6G dye shows that its adsorption process is endothermic.

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3.6. Langmuir, Freundlich, and DR Isotherms

When doing monolayer adsorption, the Langmuir isotherm value is assumed to be constant across all adsorption sites

Table 3: The Langmuir isotherm value is assumed to be constant across all adsorption sites during monolayer adsorption.

Initial concentration, mg L^{-1}	75	100	125	150	175	200	225	250
Sorption degree, %	19.0	18.0	15.8	14.5	13.2	12.6	12.1	11.8
Sorption capacity, g g L^{-1}	4.74	6.0	6.58	7.26	7.7	8.4	9.07	9.83

Table 4: (Rh 6G initial concentration: 200 mg L-1, volume = 0.04 L, duration = 30 min) The effect of temperature on the extent of sorption

Temperature, °C	20	30	40	50	60
Removal degree, %	12.6	15.0	19.1	23.0	25.5

Considering the fact that absorption rates vary throughout space. Shown by Equation (3) is the Langmuir isotherm in action.

$$C_e/q_e = 1/(q_{max} K_L)+C_e/q_{max} \quad (3)$$

Rh 6G is visibly present in Ce at a measured concentration (mcg L-1). The amount of adsorption is represented by the value of qe. Qmax is the maximum concentration of MSG that can be absorbed by the MSG monolayer in this particular situation. In the end, KL shows that the Langmuir equilibrium constant holds. Since various surfaces have different energies at different sites, the Freundlich isotherm equation shows that site energy determines adsorption. In relation to the Freundlich isotherm, we have Equation (4).

$$\log q_e = \log K_F+(1/n) \log C_e \quad (4)$$

The Freundlich constant KF and the variability factor 1/n are both provided. To assess the experimental data about equilibrium, the Freundlich and Langmuir isotherm models were used. The equilibrium concentration is shown in Figures 1 and 2 at a temperature of 20°C, a volume of 0.04 L, a pH of 6, and a sorbent dosage of 3.0 g L-1. Rh 6G linear selective sorption in solution is the initial step. The values for the Freundlich and Langmuir isotherms were determined with the help of the slope intercepts of the plot, which are presented in Table 5. According to the Langmuir equation, the highest equilibrium sorption capacity is 14.73 mg g<<-1</sup>. The experimental result of 9.83 mg g-1 shows that this amount is more in line with the mark.

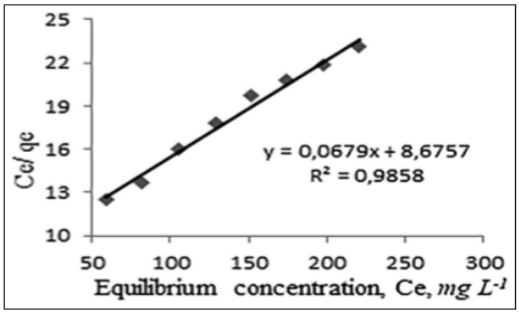

Figure 1: Langmuir plot for the rhodamine 6G sorption

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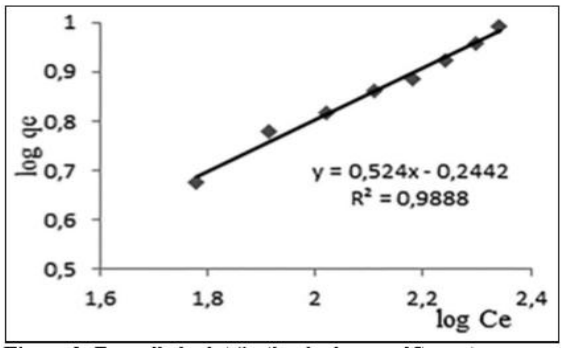

Figure 2: Freundlich plot for the rhodamine 6G sorption:

Table 5: 75-250 mg L-1 of Rh 6G, 0.04 L of volume, 3.0 g L-1 of sorbent, 30 minutes at 20°C, and the parameters of the Freundlich, D-R, and Langmuir models.

Langmuir equation				Freundlich equation				D-R equation			
q_{max}, mg g^{-1}	K_L, L mg^{-1}	R_L	R^2	1/n	n	K_F	R^2	K_D, kJmol^{-1}	B_{DR}, mmol g^{-1}	E, kJmol^{-1}	R^2
14.73	0.00783	0.63-0.338	0.9858	0.524	1.908	3.342	0.9888	0.0334	0.0254 (12.17 mg/g)	5.472	0.9695

Adsorption feasibility is evaluated by plugging the values of the equilibrium constant (KL) and the separation coefficient (RL) into the Langmuir isotherm equation. Equation (5) is used to find the RL, or dimensionless separation coefficient.

$$R_L = 1/(1+K_L\ Co) \qquad (5)$$

The starting RL value of 0 cannot be surpassed by any variation in the adsorbate concentration. A range of 1 > RL > 0 is considered suitable, RL > 1 is considered insufficient, while RL = 1 indicates linearity [18]. For Rh 6G initial concentrations ranging from 75 to 250 mg L-1, the calculated RL values of 0.630-0.338 show that the dye adsorbs well with MSG. When trying to distinguish between physical and chemical adsorption, the D-R isotherm (Equation 6) is a popular tool to use.

$$ln\ q_e = -K_D \varepsilon^2 + lnB_{DR} \qquad (6)$$

The Polanyi potential, the equilibrium adsorption capacity (qe), the D-R equation constant (KD), the BDR theoretical isotherm saturation capacity (mol g-1), and other relevant parameters are defined by Equation (7).

$$\varepsilon = RT\ ln\ (1+1/Ce) \qquad (7)$$

The Polanyi potential, the equilibrium adsorption capacity (qe), the saturation capacity (mol g-1) of the BDR theoretical isotherm, and the D-R equation constant (KD) are defined by Equation (7).

$$E_D = 1/(2\ K_D)^{½} \qquad (8)$$

An ED of at least 16.0 KJ mol-1 is necessary for chemical adsorption, for example, and this value may be indicative of the type of adsorption. According to [19], physical adsorption takes place when the ED falls below 8.0 kJ mol-1. You may see a function representing the D-R equation, lnqe = f (2), in Figure 3. To achieve the best results, you need to know the following: pH = 6, contact time = 30 minutes, sorbent dosage at 20°C, V = 0.04 L, concentration = 3.0 g L-1, and Co = 75-250 mg L-1. The computed values are displayed in Table 5. The sorbent's (BDR) ability to retain 0.0254 mmol g-1 (12.17 mg g-1) can be calculated using the D-R equation. When it comes to physically adsorbing Rhodamine 6G (Rh 6G), a synthetic polymer sorbent with an ED value of 5.472 kJ mol-1 and 8.0 kJ mol-1 is the way to go.

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3.7. Sorption Kinetics and Thermodynamic

Time periods of 20–150 minutes were used for kinetic testing in an ideal setting. In terms of kinetic data, the linear Lagergren pseudo-first-order and pseudo-second-order models performed exceptionally well. This model of first-order hyperbolic kinetics is defined by the following equations:

$$log\ (q_e - q_\tau) = log q_e - 0.434 K_1 \qquad (9)$$

At equilibrium, the sorption capacity is represented as q (mol g-1), and as time progresses, it is denoted as qe. This pseudo-first-order kinetic model has a rate constant K1 (min-1). By examining Equation 10, we may better understand the pseudo-second-order kinetic model.

$$\tau/q_\tau = 1/(K_2 q_e^{\ 2}) + \tau/q_e \qquad (10)$$

K2, the pseudo-second-order equilibrium rate constant expressed in moles per minute, qe, the sorption capacity at a given instant, and q are the three variables that we have. The equations for the pseudo-first model and the pseudo-second model are shown in Figures 4 and 5, correspondingly. Storing the sorbent at 20°C in a 0.04-liter container at a pH of 6 requires 3.0 g L^{-1}. Information on the kinetic parameters is shown in Table 6. When it comes to the Rh 6G dye binding process with MSG, the pseudo-second-order model does a better job than the pseudo-first-order model, which has a lower correlation coefficient.

Comparing the adsorption measurements of the Rh 6G dye from the produced sorbent MSG with the results of additional tests yieldedTable 7. Using thermodynamic metrics such as standard Gibbs free energy (ΔG°), standard entropy change (ΔS°), and standard enthalpy change (ΔH°), we research the temperature-dependent variations in Rh 6G adsorption on MSG. To find these values, use Equations 11–13.

Table 6: Key variables for the kinetic models' regression analysis: sorbent dosage 3.0 g L-1, temperature 20°C, initial concentration of Rh 6G 200 mg L-1, and volume = 0.04 L.

Kinetic model parameters					
Pseudo-first order			Pseudo-second order		
q_e, mg g^{-1}	K_1, min^{-1}	R^2	q_e, mg g^{-1}	K_2, min^{-1}	R^2
32.48	0.003	0.8892	31.545	0.00071	0.9894

Table 7: Comparison of alternative adsorbents with statistical analysis of Rh 6G dye absorption

Sorbent	q_{max}, (mg g^{-1})	pH	Adsorbent, (g L^{-1})	Model	Source
Activated carbon	44.7	7	0.02	Langmuir	[24]
Palm shell powder	105.0	5.75	0.4	Langmuir	[23]
Biological sludge	16.3	7	10.0	Langmuir	[22]
Coffee ground	17.37	—	1.0	Langmuir	[8]
Trichoderma harzianum mycelial biomass	3.40	8	2.0	Langmuir	[24]
Chitosan-g-(N-vinylpyrrolidone)/ montmorillonite hydrogel	36.6	10	0.05	Freundlich	[5]
Bentonite clay	111.11	6	4.0 g	Langmuir	[11]
Cross-linked maleic anhydride-styrene copolymer	14.73	6	3.0	Langmuir	In this study

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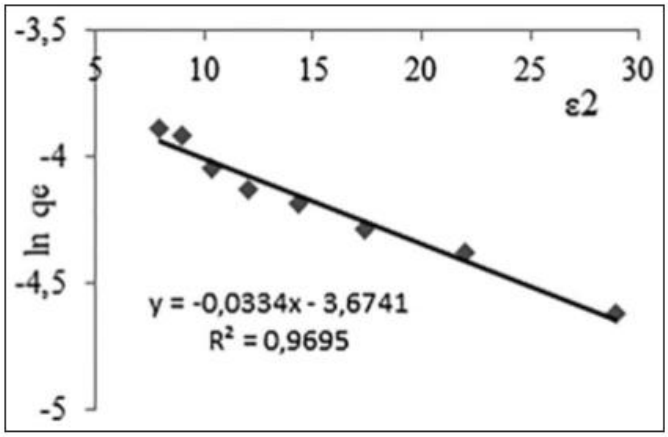

Figure 3: The rhodamine 6G sorption is represented by the Dubinin-Radushkevich plot.

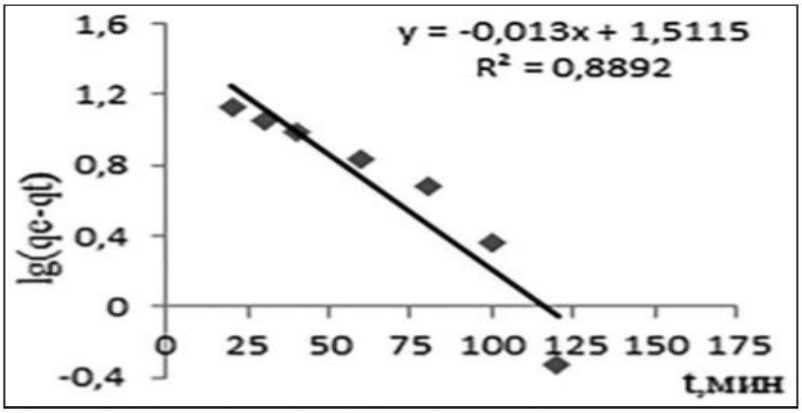

Figure 4: Plots of pseudo-first-order models.

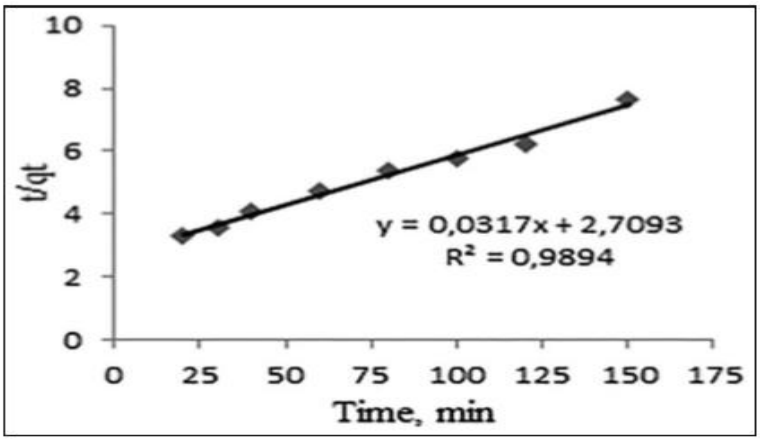

Figure 5: Plots of pseudo-second order.

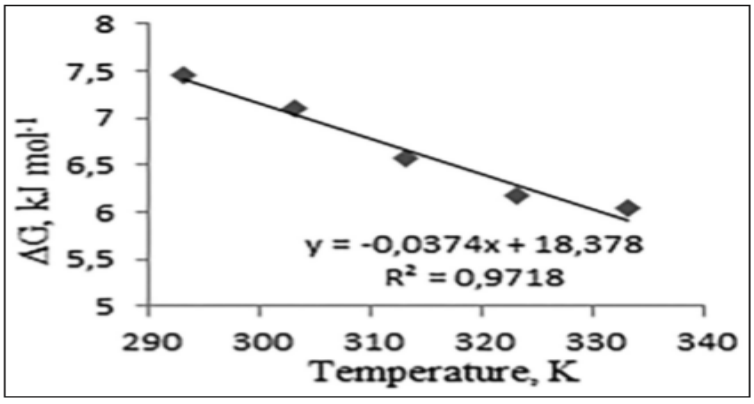

Figure 6: Plot of ΔG° versus T.

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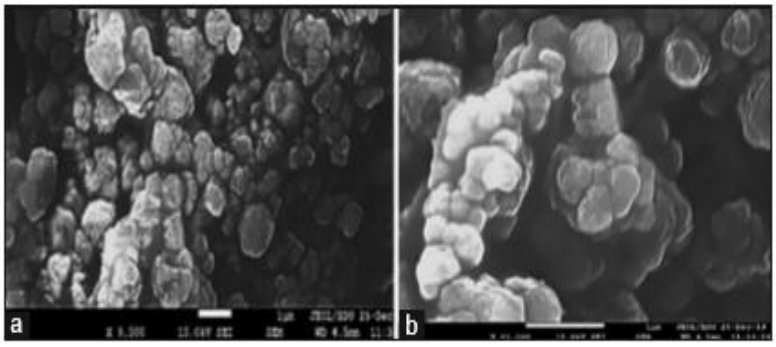

Figure 7: The rhodamine (Rh) 6G-loaded sorbent's SEM picture shows the adsorbed Rh 6G dye at light locations (a) ×9500 and (b) ×25,000.

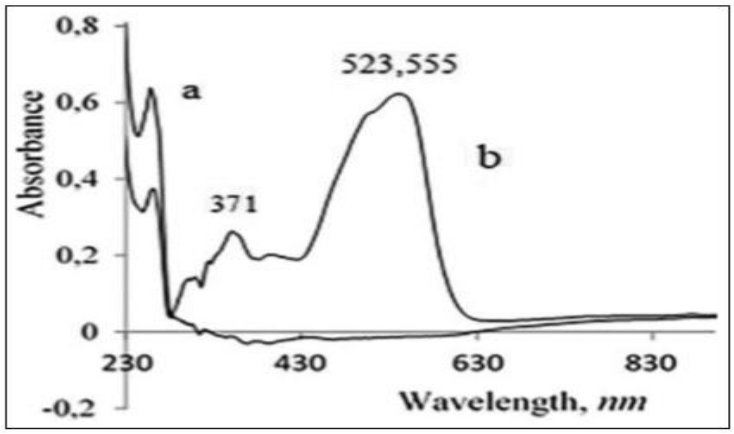

Figure 8: MSG's UV-visible spectra: (a) prior to and (b) upon sorption

$$\Delta^\circ = -2{,}3\ RT\ log K_d \quad (11)$$

$$K_d = q_e/C_e \quad (12)$$

$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ \quad (13)$$

T is the precise temperature, and R is the gas constant, which is 8.314 J mol^{-1} K^{-1}. Kd is the equilibrium constant at temperature T. The slope and intercept values of the G° vs. T plots are shown in Figure 6, together with the values of H° and S°. All of these things are in Table 8. It is clear that the adsorption process is endothermic because the positive enthalpy change (H°) is 18.209 kJ mol-1. When S° is positive, namely 0.3691 kJ mol-1 K-1, the stability of the adsorption process is diminished.

Table 8: The following are the thermodynamic characteristics of sorption: starting concentration Co = 0.365 mmol L^{-1}, volume V = 0.04 L, sorbent dosage 3.0 g L^{-1}, pH 6, duration 30 min.

Temperature, TK	Thermodynamic parameters		
	ΔG°, k J mol^{-1}	ΔH°, k J mol^{-1}	ΔS°, k J $mol^{-1}K^{-1}$
293	7.45		
303	7.11		
313	6.57	18.378	0.0374
323	6.19		
333	6.04		

3.8. Mechanism of the Adsorption

The process of Rh 6G dye absorption by MSG was examined using a scanning electron microscope (SEM) image and the ultraviolet (UV) band observed in the adsorbent after sorption. Figure 7, a scanning electron micrograph, shows that the Rh 6G dye molecules

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appear to cluster on the uneven surface of the sorbent. The UV spectra of MSG are shown in Figure 8 both before and after absorption. Figure 8b shows that the sorbent's UV spectroscopy showed that the dye-sorbent complex adhered at 371 nm, while the Rh 6G dye binds to surfaces throughout the 523 to 555 nm range.

The possible interactions of Rh 6G with acidic polymers, including maleic acid copolymers, have been the subject of numerous investigations. Copolymers of phenolic acids that include Rh 6G complexes are responsible for the peaks observed between 350 and 370 nm. Electrostatic adsorption of the Rh 6G dye transpires at MSG active sites, according to the sorbent post-sorption SEM and UV spectroscopic investigations, the dye's kinetic and thermodynamic properties, and other evidence. Sorption energies ranging from 5.472 kJ mol-1 to 8.0 kJ mol-1 show that Rh 6G is physically linked to a polymer sorbent.

4. CONCLUSION

The optimal parameters for the sorption of Rh 6G dye from water to MSG were investigated in this work. The variables of interest were initial dye concentration, pH, contact duration, sorbent dosage, and temperature. Using the equilibrium sorption data, the Freundlich, Dubinin-Radushkevich, and Langmuir models were fitted. According to Langmuir's equation, the maximum sorption capacity at equilibrium is 14.73 mg g-1. The RL values for the separation factor varied from less than 1 to greater than 0, indicating significant adsorption at various starting concentrations of Rh 6G. For sorption processes, the pseudo-second-order model worked well.

The sorption process is considered endothermic if the heat release is more than 18.378 kJ mol-1, denoted by H°. With a positive S° value (0.0374 kJ mol-1 K-1), adsorption becomes less reliable. Evidence from surface plasmon resonance (SEM) microscopy, ultraviolet (UV) spectra of the sorbent before and after sorption, thermodynamic and kinetic characteristics, and electrostatic interactions shows that the Rh 6G dye binds to the active sites of MSG. The average sorption energy of Rh 6G (ED = 5.472 kJ mol-1 to 8.0 kJ mol-1) is indicative of a chemical bond with a polymer sorbent. Glycerin and the cross-linked alt-MA-St copolymer effectively absorb the color of Rh 6G from water-based solutions.

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