

Adsorption of Brilliant Cresyl blue from Aqueous Solution by Superadsorbent Hydrogel Nanocomposite

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Abstract

Superadsorbent hydrogel nanocomposite, using a free radical polymerization process of Brilliant Cresyl Blue (BCB) dye, were produced and employed as adsorbents for adsorption. XRD and FE-SEM were used to characterize the nanocomposite. The thermodynamic adsorption studies suggested that the adsorption process was spontaneous and exothermic for nanocomposite. The adsorption process of BCB dye on the surface nanocomposite follows the Freundlich isotherm model. The interesting properties and practical possibilities of nanocomposite as a highly effective adsorbent in the removal of BCB dye from an aqueous solution are revealed in this study.

Keywords: adsorption, nanocomposite, BCB dye, Freundlich, thermodynamic

1. Introduction

Adsorption can be defined as the phenomenon of a substance collecting in the form of particles, atoms, or ions on the surface of another substance or is the physical or chemical association of substance molecules with the active sites of a surface through Vander Waals' weak forces or the formation of chemical bonds with effective sites on the surface. Adsorption is an important technique in removing pollutants, especially removing dye pollution [1]. Dyes from organic materials polluted with water sources are important and widespread in various sectors, including textiles, printing, and photography colors, as well as oil industry additives and several other fields [2].

Hydrogels are networks of hydrophilic homopolymers or copolymers that swell when exposed to water. The cross-links can be produced by covalent or ionic bonding, which is three-dimensional. Weaker forces like van der Waals and hydrogen bonds are frequently used as cross-links, resulting in swelling networks that act like hydrogels [3]. Many synthetic and natural aqueous gel materials have been studied and tested for various biomedical device applications due to their apparent biocompatibility. Many of the physical features of such gels, particularly their interfacial properties, are strongly reliant on the arrangement of water inside and on the surface of the hydrogel [4]. Due to their excellent adsorption characteristics, hydrogels have been used to remove several contaminants, including dyes, heavy metals, and organic pollutants [5].

This research looks at the adsorption of BCB in an aqueous solution using the Superadsorbent hydrogel nanocomposite. This study aims to suggest that BCB be removed using a low-cost nanocomposite. Characterization of the materials was done using XRD and FESEM. The use of nanocomposite as adsorbents for extracting BCB dye from an aqueous media was examined fully. Adsorption isotherms were used to evaluate the adsorbents adsorption processes.

2. Experimental

Chemicals and materials

Chitosan (CS, MACKLIN), Itaconic acid (IA, MACKLIN), Acrylic Acid (AAc, CDH), N,N- Methylene bisacrylamide (MBA, MACKLIN), Potassium persulfate (KPS, MACKLIN), Brilliant Cresyl Blue (BCB, Fluka), glacial acetic acid (ALPHA).

Preparation of Superadsorbent hydrogel nanocomposite

The nanocomposite was created by dissolving 1g from chitosan in 40 mL of acetic acid and adding KPS, Itaconic acid, Acrylic Acid, and MBA with nitrogen gas. After the nanocomposite was produced, it was cut into small pieces and washed with distilled water to remove the interactive material.

Characterization of nanocomposites

XRD was used to study the crystal properties of prepared materials. The properties of the Morphology of surface nanocomposites, such as form, size, and construction nature, were studied using FESEM, which was measured using 200KV voltages and secondary electrons (SEs) detector with a power of 40-2.5KX enlargement.

Preparation Surface of nanocomposite

Grinding the composite and isolating grains of various sizes using conventional sieves, where 100µm measured particles were chosen and all tests were carried out in this research.

Contact Time of Adsorption System

Hydrogel nanocomposite and BCB dye solution in a vibrator at 120 rpm at 25°C. Samples of the solution were taken at various times (1-180 min). The absorption was determined after the centrifuge separation operation was completed at 6000 rpm for 10 min.

Effect of Temperature

To set isotherm adsorption was placed (0.05g) from the surface and then was add (10ml) of BCB dye in focus (50-400) ppm, and then these solutions were put into a device Shaker and controlling temperature grade (at different

thermal degrees is (15-30) °C and duration time (120 min). After the time of equilibrium, the Absorption of solutions was measured by the simplicity of the optical-ultraviolet spectrometer (UV-VIS) at the λ_{max} of the BCB dye.

3. Results and Discussion

XRD and FE-SEM analyses

XRD analysis of the hydrogel reveals no crystal peaks (20.75, 34). In the case of the nanocomposite, XRD reveals crystalline peaks (21.09,36.6,61,88), indicating that the nanocomposite is crystalline. By comparing XRD data, the nature of hydrogel can be seen inside the structure of superadsorbent hydrogel nanocomposite [5]. Fig.1.

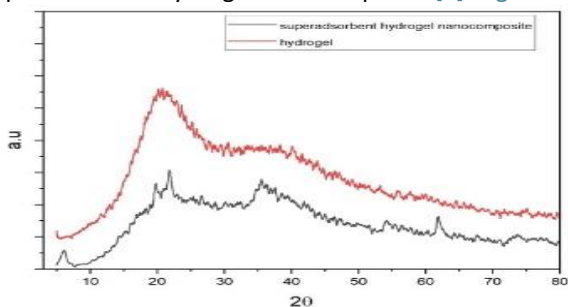


Fig.1.XRD for hydrogel and superadsorbent hydrogel nanocomposite

The image of the FESEM exhibited in shape after BCB dye adsorption, the surface of the superadsorbent hydrogel nanocomposite is rough and porous, with a sponge-like structure and a network of stacked layers [6]. Fig.2

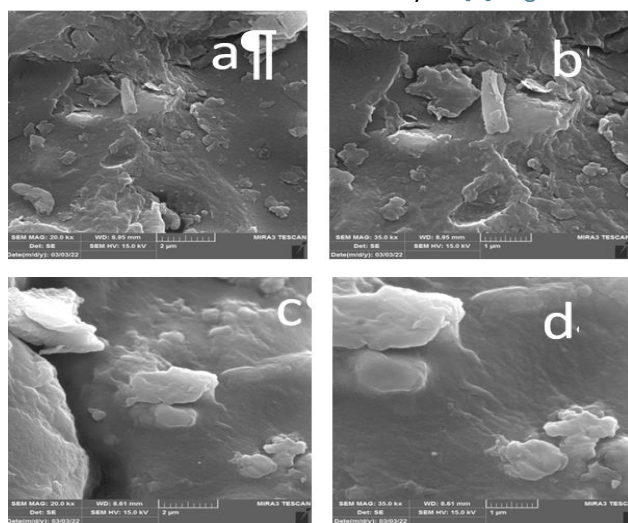


Fig.2. SEM images at different zoom forces of a.b superadsorbent hydrogel nanocomposite. c.d superadsorbent hydrogel nanocomposite after adsorption.

Effect of the weight of the adsorbate surface on adsorption

The rate of removal (Re%) of the BCB dye will increase with the increase in the weight of the adsorbent as a result of the increase in the surface area and thus increase

the number of effective sites of the adsorbent and thus increase the percentage of removal as for the quantity of the adsorbed material. It is reduced sharply to an almost constant amount with an increase in the weight of the adsorbent material. This is due to a decrease in the number of dye particles adsorbed at the expense of the surface area when increasing the mass of the adsorbent material resulting in a decrease in the amount of the adsorbent material on the surface, The preferred weight in adsorption of experiments is (0.05 gm) [4].Fig.3

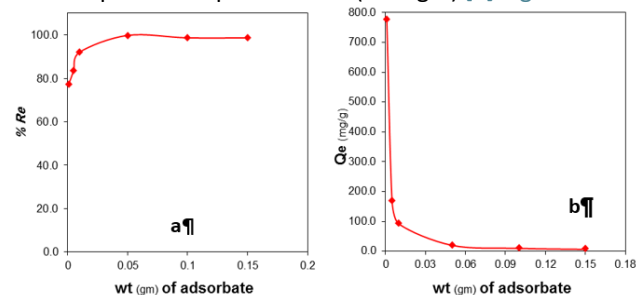


Fig.3. a. the amount of the adsorbent material on the surface. b. The rate of removal (Re%) of the BCB dye

Effect of contact time

At a concentration of 100 ppm and a temperature of 25 °C, the time required to reach equilibrium with the BCB dye was studied at 120 min. This is because the effective sites on the surface are primed for adsorption until they are occupied at the start of time [7]. Fig.4

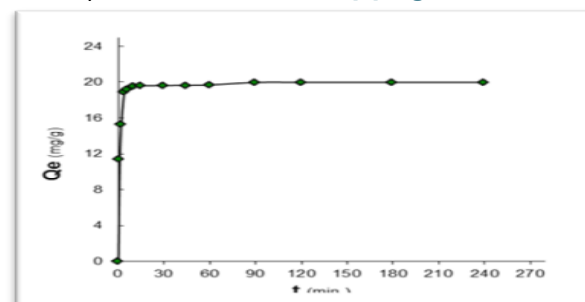


Fig.4. Contact time

Adsorption isotherms studies

Adsorption isotherm models are crucial for predicting the type of adsorbate-adsorbent interactions and the distribution of adsorbates between adsorbents and aqueous phases in the adsorption process. The supporting information goes through the details of the specified isotherm models. Fig.5. and Table 1 illustrate the results. The greatest R2 values were used to compare the applicability of various models. The adsorption is shown by isothermal forms to be S3 of Giles classification. The adsorption isotherm results best explain the Freundlich isotherm model. the Freundlich isotherm model better described the BCB dye adsorption by superadsorbent hydrogel nanocomposite. The Freundlich isotherm model had the highest R2 value of 0.977. The R2 values decreased in the order: Freundlich > Temkin > Langmuir [8].

Model	Equation	slope	inter.		
Langmuir	$y = 0.0029x + 0.0053$ $R^2 = 0.5385$	0.0029	0.0053	Qm	KL
				344.8275862	0.54717

Freundlich	$y = 0.9155x + 2.1653$ $R^2 = 0.985$	0.9155	2.1653	N	Kf
				1.09229929	146.319
Temkin	$y = 31.167x + 91.204$ $R^2 = 0.9438$	31.167	91.204	B	kT
				31.167	18.6585

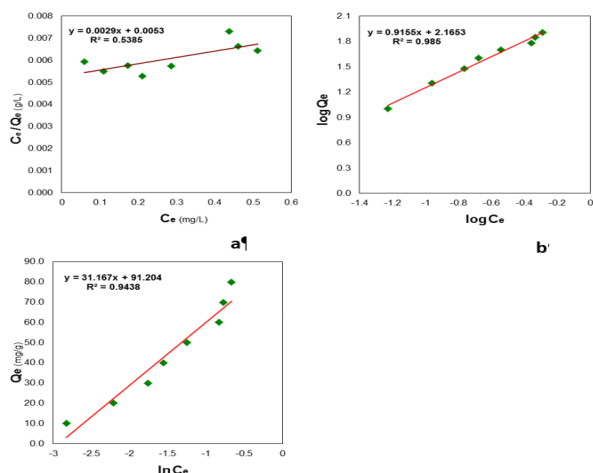


Fig. 5 a Langmuir, b Freundlich, and c Temkin isotherm

Thermodynamic parameter values for BCB dye Table.2.				
Temp.(°C)	ΔH	ΔG	ΔS	Equilibrium Constant(K)
15	-82863.975	-18297.58957	-224.188839	868.055556
20		-17627.54224	60.1622602	
25		-16763.88571	56.25465003	
30		-14835.69504	48.96268989	
	ΔH(kJ/mol.)	ΔG(kJ/mol.)	ΔS(kJ/K.mol.)	Equilibrium Constant(K)
	-82.864	-16.764	56.255	868.056

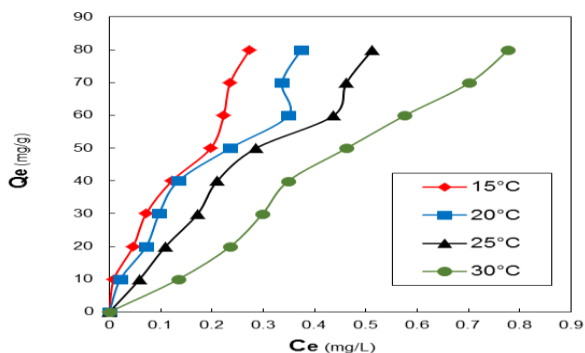


Fig.6 Effect of temperature change on adsorption of BCB dye on the surface of nanocomposite

4. Conclusion

superadsorbent hydrogel nanocomposite was used as an adsorbent to remove BCB dye from aqueous solutions. The adsorption process of BCB dye on the superadsorbent hydrogel follows the Freundlich isotherm model, and adsorption thermodynamic analyses indicated that the adsorption process for nanocomposite was spontaneous exothermic.

References

1. Ali I, Asim M, Khan TA. Low cost adsorbents for the removal of organic pollutants from wastewater. Journal of environmental management. 2012;113:170-83. <https://doi.org/10.1016/j.jenvman.2012.08.028>
2. Yagub MT, Sen TK, Ang H. Equilibrium, kinetics,

models for superadsorbent hydrogel nanocomposite

Adsorption thermodynamics studies

Experiments were carried out at different temperatures ranging from (15-30) °C to investigate the nanocomposites adsorption thermodynamics during the BCB adsorption. The results are given in Table 2. The obtained values of ΔH° (-82.864kJ/mol) and ΔS° (56.255kJ/mol/K) for nanocomposite indicate an exothermic reaction with the higher disorder. In this case, the adsorption process may involve the formation of an adsorption layer with the thickness of several particles [9]. The value of ΔG°(-16.764kJ/mol) indicates the spontaneous nature of the adsorption process [10]. Fig. 6 and Table 2 illustrate the results.

and thermodynamics of methylene blue adsorption by pine tree leaves. Water, Air, & Soil Pollution. 2012;223(8):5267-82. <https://doi.org/10.1007/s11270-012-1277-3>

3. Aljeboree AM, Radia ND, Jasim LS, Alkaim AF. Removal of Pharmaceutical by Adsorption Process; Study Effect of Various Parameters and Determination of Pharmaceutical by Oxidative Coupling Reaction. adsorption. 2021;1000:1. Available from: <http://impactfactor.org/PDF/IJDDT/11/IJDDT,Vol11,Issue 3,Article44.pdf>

4. Aljeboree AM, Mahdi MA, Jasim LS. Synthesis And Characterization Of NTADCIP/P (AA-Co-AM) Composite: Adsorption And Removal Studies Of Drug From Aqueous Solutions. Systematic Reviews in Pharmacy. 2021;12(1):282-9. <http://doi.org/10.31838/srp.2021.1.45>

5. Jawad MA, AJK NDR, Radia ND. Role of Sodium Alginate-g-poly (Acrylic acid-fumaric acid) Hydrogel for Removal of Pharmaceutical Paracetamol from Aqueous Solutions by Adsorption. International Journal of Pharmaceutical Quality Assurance. 2021;12(3):202-5. Available from: <https://impactfactor.org/PDF/IJPQA/12/IJPQA,Vol12,Issue3,Article7.pdf>

6. Hadi ZA, Aljeboree A, Alkaim A. Adsorption of a cationic dye from aqueous solutions by using waste glass materials: isotherm and thermodynamic studies. Int J Chem Sci. 2014;12(4):1273-88.

7. Bhattacharyya R, Ray SK. Removal of congo red and methyl violet from water using nano clay filled

composite hydrogels of poly acrylic acid and polyethylene glycol. *Chemical Engineering Journal*. 2015;260:269-83.

<https://doi.org/10.1016/j.cej.2014.08.030>

8. Dai H, Huang Y, Huang H. Eco-friendly polyvinyl alcohol/carboxymethyl cellulose hydrogels reinforced with graphene oxide and bentonite for enhanced adsorption of methylene blue. *Carbohydrate polymers*. 2018;185:1-11.

<https://doi.org/10.1016/j.carbpol.2017.12.073>

9. Wright E, Partt N. *Current chemical Papers*. J Chem Soc Faraday Trans. 1961;70:1461.

10. Melo BC, Paulino FA, Cardoso VA, Pereira AG, Fajardo AR, Rodrigues FH. Cellulose nanowhiskers improve the methylene blue adsorption capacity of chitosan-g-poly (acrylic acid) hydrogel. *Carbohydrate polymers*. 2018;181:358-67.

<https://doi.org/10.1016/j.carbpol.2017.10.079>