



Removal of Methyl Orange from Aqueous Solution Using Guar Gum-g-Poly(acrylic Acid) Superabsorbent Composite

Musarrat Khan

Department of Chemistry, Jai Narain Vyas University, Jodhpur, Rajasthan, India

ABSTRACT :

The presence of synthetic dyes in industrial wastewater represents a significant environmental concern because of their persistence and adverse effects on aquatic systems. In the present study, a guar gum-g-poly(acrylic acid) superabsorbent composite was investigated as an adsorbent for the removal of methyl orange (MO) from aqueous solution. Batch adsorption experiments were performed to investigate the influence of adsorbent dosage, contact time and solution pH on dye removal. The residual dye concentration was determined by UV-Visible spectrophotometry. Increasing the adsorbent dosage resulted in a substantial improvement in methyl orange removal, reaching approximately 90% at the highest investigated dosage. The percentage removal also increased with contact time and approached equilibrium at approximately 50 min. The adsorption behavior was further evaluated using Freundlich and Langmuir isotherm models. The Freundlich plot exhibited an R^2 value of 0.96697, whereas the Langmuir plot showed an R^2 value of 0.99596 based on the relationships reported in the experimental source. The results demonstrate that the guar gum-g-poly(acrylic acid) superabsorbent composite has potential for the removal of methyl orange from aqueous media.

Keywords: Methyl orange; guar gum; poly(acrylic acid); superabsorbent composite; adsorption; wastewater treatment; adsorption isotherm.

1. Introduction

Synthetic dyes released from textile and related industrial processes are important water pollutants because of their intense coloration, chemical stability and resistance to conventional wastewater treatment processes. Even relatively low concentrations of dyes can impart visible colour to water and interfere with aquatic processes. Azo dyes constitute one of the largest classes of commercially used synthetic dyes, and their persistence has stimulated considerable interest in efficient treatment technologies.

Adsorption is among the commonly investigated approaches for dye removal because of its operational simplicity and the availability of a wide range of adsorbent materials. Conventional adsorbents include activated carbon, clays, modified clays and industrial waste-derived materials. Polymeric and hydrogel-based materials have also attracted attention because their functional groups and porous structures can provide active sites for interaction with dissolved pollutants.

Superabsorbent polymers are three-dimensional cross-linked polymeric materials capable of retaining substantial quantities of water. Their hydrophilic functional groups and polymeric network can also interact with dissolved contaminants. Incorporation of a natural polysaccharide such as guar gum into a poly(acrylic acid)-based network provides a material combining the renewable character of the polysaccharide with the functional properties of acrylic-acid-derived polymer chains.

Methyl orange is an anionic azo dye commonly used as a pH indicator. Its adsorption from aqueous systems depends on several experimental variables, including adsorbent dosage, contact time, initial dye concentration and solution pH. Previous work has investigated polymeric and hydrogel adsorbents for methyl orange removal. The present work evaluates guar gum-g-poly(acrylic acid) superabsorbent composite for methyl orange removal and examines the effects of adsorbent dosage, contact time and pH, followed by equilibrium analysis using Freundlich and Langmuir models.

2. Materials and Methods

2.1 Materials

The guar gum-g-poly(acrylic acid) superabsorbent composite used in this investigation was prepared in the laboratory. Methyl orange was obtained from Sigma-Aldrich. Hydrochloric acid and sodium hydroxide were used for pH adjustment. Other chemicals and reagents were of analytical grade. Double-distilled water was used throughout the experimental work.



Figure 1. Photograph of the prepared guar gum-g-poly(acrylic acid) superabsorbent composite (SAC 1).

2.2 Preparation of Methyl Orange Solution

A 100 mg/L stock solution of methyl orange was prepared by dissolving 100 mg of the dye in 1 L of double-distilled water. Working solutions with the required initial concentrations were prepared by appropriate dilution of the stock solution. The experimental source reports initial concentrations ranging from 10 to 90 mg/L.

2.3 Batch Adsorption Experiments

Batch adsorption experiments were performed to examine the influence of adsorbent dosage, contact time and solution pH on methyl orange removal. For the dosage study, the amount of superabsorbent composite was varied from 0.01 to 0.10 g. For the contact-time experiment, 20 mL of an 80 mg/L methyl orange solution was contacted with 0.1 g of adsorbent for different time intervals. The effect of solution pH was investigated by adjusting the dye solution using hydrochloric acid or sodium hydroxide.

2.4 Determination of Dye Concentration

After adsorption, the dye-containing solution was separated from the adsorbent and the residual methyl orange concentration was determined using UV–Visible spectrophotometry. The experimental source reports a wavelength of 462 nm in the initial analytical procedure. A later equilibrium-procedure description reports 509 nm; this discrepancy requires confirmation from the original laboratory record before submission.

The percentage removal was calculated as:

$$\% \text{ Removal} = [(C_i - C_f) / C_i] \times 100$$

where C_i is the initial dye concentration and C_f is the final dye concentration.

The equilibrium adsorption capacity was calculated using:

$$q_e = [(C_0 - C_e)V] / W$$

where C_0 and C_e are the initial and equilibrium dye concentrations, respectively, V is the volume of dye solution and W is the mass of adsorbent.

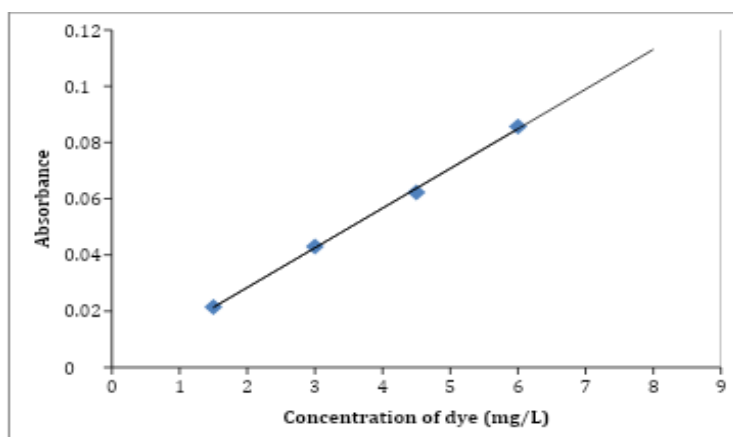


Figure 2. Calibration plot of methyl orange concentration versus absorbance reproduced from the experimental source.

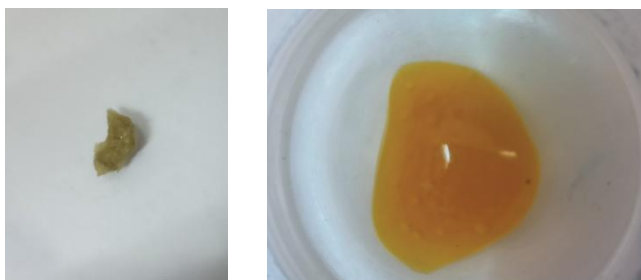


Figure 3A–B. Photographs associated with the methyl orange adsorption experiment.



Figure 3C. Comparison of methyl orange solution before and after adsorption.

3. Results and Discussion

3.1 Effect of Adsorbent Dosage

The influence of adsorbent dosage on methyl orange removal was investigated over the range of 0.01–0.10 g. An increase in the amount of superabsorbent composite resulted in a progressive increase in dye removal, with the reported removal increasing from approximately 30% to 90%. The enhancement in removal with increasing adsorbent dosage can be associated with the greater number of available adsorption sites and the increased total surface area available for interaction with dye molecules.

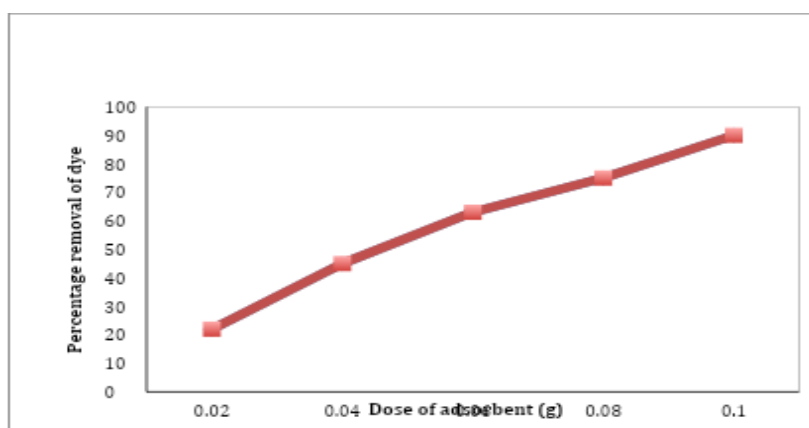


Figure 4. Effect of adsorbent dosage on percentage removal of methyl orange.

3.2 Effect of Contact Time

Contact time is an important parameter because adsorption is generally rapid during the initial stage when a large number of vacant sites are available. In

the present study, methyl orange removal increased from approximately 25% to 90% with increasing contact time. The adsorption approached equilibrium at approximately 50 min, after which only a small change in removal was observed. The initial rapid uptake can be associated with the availability of unoccupied

active sites on the composite surface. With progressive occupation of these sites, the rate of adsorption decreases and eventually approaches equilibrium.

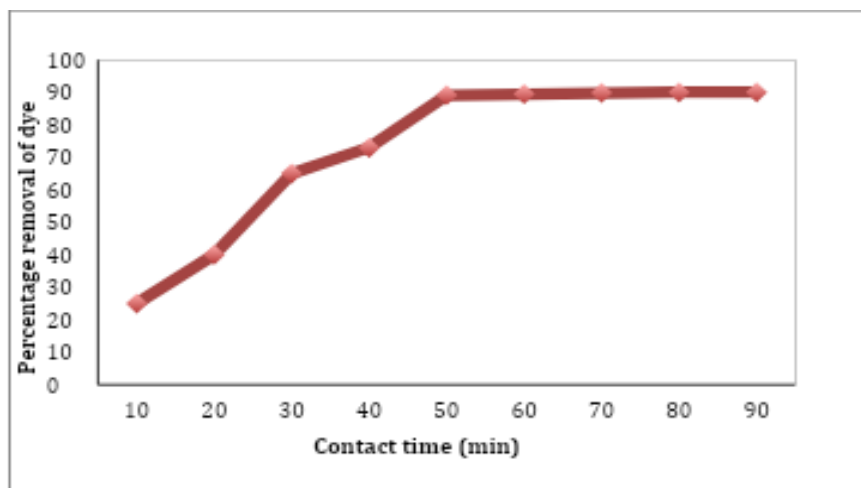


Figure 5. Effect of contact time on percentage removal of methyl orange.

3.3 Effect of Solution pH

Solution pH can strongly influence adsorption because it affects both the ionization state of the adsorbate and the surface charge of the adsorbent. The source data indicate relatively high methyl orange removal under acidic conditions and a decline in removal as the pH increases. The proposed explanation involves electrostatic attraction between negatively charged dye species and favorable adsorption sites on the adsorbent under acidic conditions. Competition from hydroxide ions at higher pH may contribute to the observed decrease in dye uptake.

The detailed source text states that high removal was observed in the acidic range, particularly pH 1–6, and that removal decreased at pH values above 7. The plotted source figure contains values from pH 1 to 10; this range should be checked against the original experimental notebook before final submission.

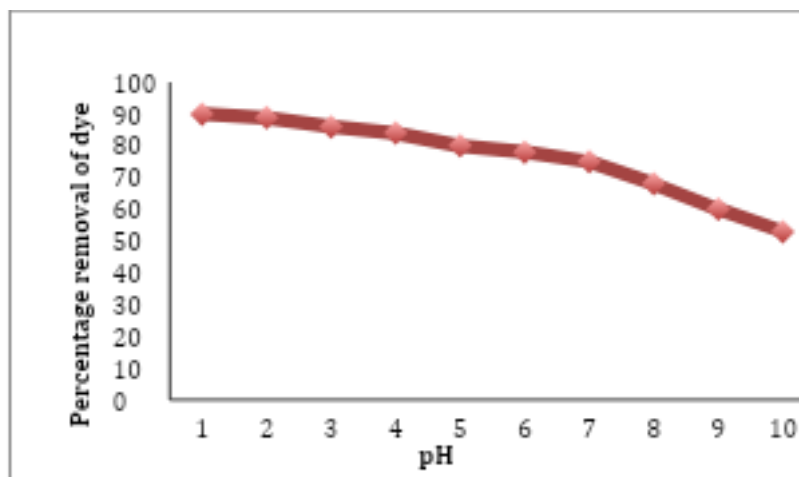


Figure 6. Effect of solution pH on percentage removal of methyl orange.

3.4 Adsorption Isotherm

Equilibrium adsorption experiments were performed using 0.1 g of composite with methyl orange solutions having initial concentrations of 20, 30, 40, 50, 60, 70 and 80 mg/L. The source reports a contact period of 200 min at pH 10. The equilibrium data were analyzed using Freundlich and Langmuir models.

3.4.1 Freundlich Isotherm

The linear Freundlich equation can be expressed as:

$$\log q_e = \log KF + (1/n) \log C_e$$

The reported linear relationship was $\log q_e = 0.7311 \log C_e + 0.8368$, with $R^2 = 0.96697$. Thus, $1/n = 0.7311$ and $n \approx 1.37$. The intercept corresponds to $K_F \approx 6.87$ in the units associated with the concentration and capacity scales used in the source.

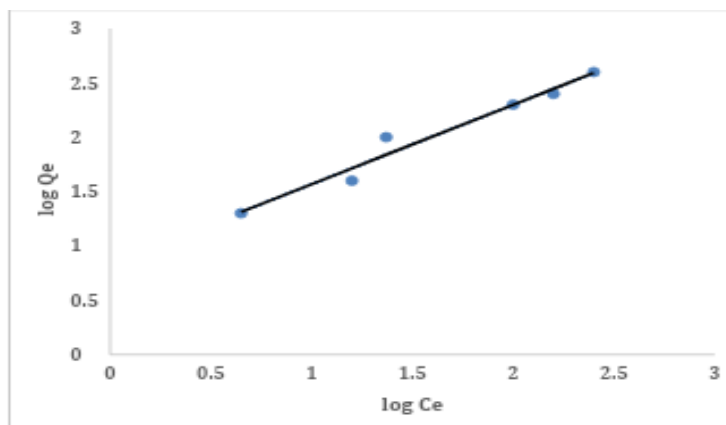


Figure 7. Freundlich isotherm for adsorption of methyl orange onto the superabsorbent composite.

3.4.2 Langmuir Isotherm

The Langmuir model describes monolayer adsorption on a finite number of adsorption sites. The reported linear relationship was $C_e/q_e = 0.85274C_e - 2.20978$, with $R^2 = 0.99596$. The high correlation coefficient indicates a strong linear correlation for the reported plot.

However, the negative intercept in the reported equation produces a physically inconsistent value when the conventional linear Langmuir equation is used to calculate the adsorption capacity. Therefore, the Langmuir constants and maximum adsorption capacity are not reported here as final numerical values until the original equilibrium data are verified.

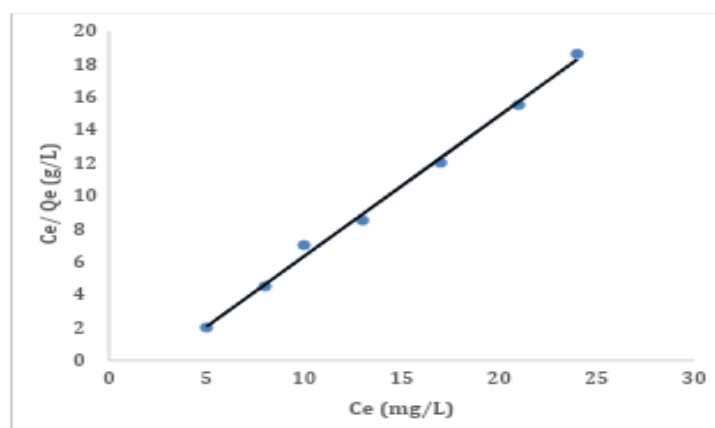


Figure 8. Langmuir isotherm for adsorption of methyl orange onto the superabsorbent composite.

3.5 Proposed Adsorption Mechanism

Methyl orange is an anionic azo dye containing a sulfonate group. Under favorable acidic conditions, electrostatic interactions between negatively charged dye species and positively charged or protonated sites on the adsorbent may contribute to adsorption. Hydrogen bonding and other physicochemical interactions involving functional groups of the guar gum/poly(acrylic acid) network may also contribute to dye retention. The decrease in removal at higher pH may be related to changes in surface charge and competition from hydroxide ions for available adsorption sites. The precise mechanism would require additional characterization, such as zeta-potential analysis and FTIR comparison before and after adsorption.

4. Conclusion

Guar gum-g-poly(acrylic acid) superabsorbent composite was investigated as an adsorbent for the removal of methyl orange from aqueous solution. The adsorption performance was influenced by adsorbent dosage, contact time and solution pH. Increasing the adsorbent dosage enhanced methyl orange removal, reaching approximately 90% under the reported experimental conditions. The adsorption process also showed rapid initial uptake followed by an approach to equilibrium at approximately 50 min.

Equilibrium analysis showed good correlation with both Freundlich and Langmuir representations, with the reported Langmuir plot showing the higher

correlation coefficient. Nevertheless, the numerical Langmuir constants require verification because the reported linear equation gives a physically inconsistent intercept. Overall, the results indicate that the guar gum-g-poly(acrylic acid) superabsorbent composite has potential as a polymeric adsorbent for methyl orange removal from aqueous systems.

5. REFERENCES

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