



Removal of Methylene Blue from Aqueous Solution Using Guar Gum-g-Poly (Acrylic Acid)/Zeolite Superabsorbent Composite

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ABSTRACT

The present study investigated the removal of methylene blue (MB) dye from aqueous solution using a guar gum-g-poly(acrylic acid)/zeolite superabsorbent composite. Batch adsorption experiments were carried out to study the effects of adsorbent dose, contact time and pH. The residual dye concentration was determined by UV-Visible spectrophotometry. Increasing the adsorbent dose from 0.01 to 0.1 g increased dye removal from 25% to 93%. Increasing contact time from 20 to 200 min increased removal from 20% to 90%. The effect of pH showed maximum methylene blue removal of 92% at pH 10. The Langmuir and Freundlich isotherms were applied to the equilibrium data. The Langmuir plot showed $R^2 = 0.9826$, while the Freundlich plot showed $R^2 = 0.9520$. From the slope of the Langmuir plot, the calculated maximum adsorption capacity was 5.19 mg/g. The results demonstrate the applicability of the prepared superabsorbent composite for methylene blue removal from aqueous solution.

Keywords: Methylene blue; guar gum; poly(acrylic acid); zeolite; superabsorbent composite; adsorption; Langmuir; Freundlich

1. Introduction

Industrial effluents are discharged into land and water from industries without proper treatment, leading to complex environmental pollution and health problems. Textile industries generate large quantities of toxic effluents containing residual dyes and salts that can harm the environment. The presence of coloured wastewater reduces light penetration and photosynthesis and can increase the toxicity of receiving water. Organic dyes are difficult to treat because of their synthetic origin and mainly aromatic structures. Among several physical and chemical methods, adsorption is one of the effective techniques employed for colour removal from wastewater.

Superabsorbent polymers and composites have attracted attention as adsorbent materials because their polymeric networks contain functional groups and porous structures capable of interacting with dissolved dye molecules. Previous studies have reported the use of superabsorbent hydrogels and polymer/clay composites for dye removal. In the present work, a guar gum-g-poly(acrylic acid)/zeolite superabsorbent composite was used for the removal of methylene blue from aqueous solution.

2. Materials and Methods

2.1 Materials

The superabsorbent composite based on guar-gum-g-poly(acrylic acid)/zeolite was prepared in the laboratory. Methylene blue dye was purchased from Sigma Aldrich Pvt. Limited. Hydrochloric acid and sodium hydroxide were used to adjust pH. All other reagents used were of analytical grade and prepared in double-distilled water.

2.2 Preparation of dye solution and adsorption studies

A stock solution of methylene blue (100 ppm) was prepared by dissolving 100 mg methylene blue dye in 1 L of double-distilled water. Desired initial concentrations ranging from 10 to 90 ppm were obtained by dilution. For adsorption experiments, dye solution was taken in a flask and magnetically stirred at 100 rpm for a specified period. The pH was adjusted using HCl or NaOH. Aliquots were withdrawn at suitable intervals until equilibrium was attained. After filtration, the residual dye concentration was measured using a UV-Visible spectrophotometer at $\lambda_{\text{max}} = 664 \text{ nm}$. A calibration curve was prepared using known concentrations.

The adsorption capacity was calculated using:

$$Q_e = (C_o - C_e) \times V / W$$

where C_0 is the initial concentration of dye (mg/L), C_e is the equilibrium concentration of dye (mg/L), V is the volume of dye solution, and W is the weight of composite used (g).

Percentage removal was calculated as:

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

where C_i is the initial concentration of dye and C_f is the final concentration of dye at the end of the adsorption process.

2.3 Batch adsorption experiments

Batch adsorption experiments were carried out at room temperature to investigate the effects of adsorbent dose, contact time and pH on methylene blue adsorption. The adsorbent dose was varied from 0.01 to 0.1 g. Contact-time experiments were conducted using 30 mL of 100 mg/L methylene blue solution with 0.1 g adsorbent at different time intervals from 20 to 200 min. The pH effect was studied over pH 2 to 12. The experimental data were used to prepare the adsorption isotherms.

3. Results and Discussion

3.1 Calibration curve

The calibration curve was prepared using known methylene blue concentrations. The experimental concentration and absorbance values used in the experimental data are presented in Table 1 and shown in Figure 1.

Concentration (mg/L)	Absorbance
1	0.0215
2.5	0.0430
3.8	0.0623
5.22	0.0856
7.5	0.1200

Table 1. Calibration data for methylene blue.

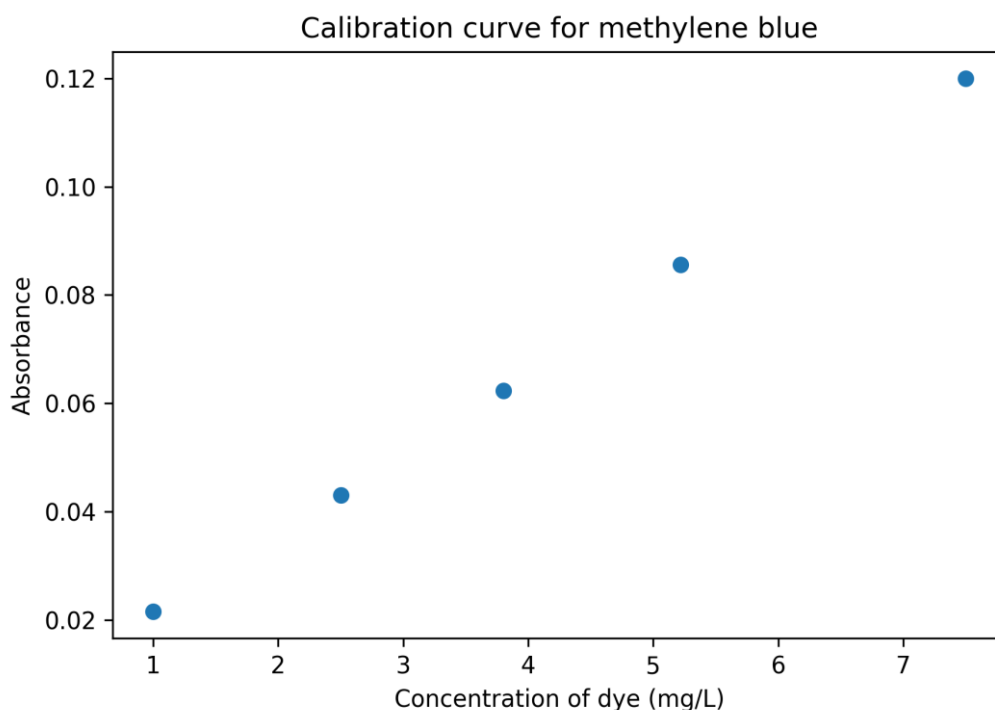


Figure 1. Calibration curve for methylene blue.

3.2 Effect of adsorbent dose

The effect of adsorbent dose was studied by varying the amount of composite from 0.01 to 0.1 g. The percentage removal increased from 25% to 93% with increasing adsorbent dose. The increase in removal can be associated with the increase in available adsorption sites as the amount of adsorbent is increased.

Adsorbent dose (g)	Removal (%)
0.01	25
0.02	33
0.03	42
0.04	49
0.05	55
0.06	68
0.07	72
0.08	85
0.09	89
0.10	92

Table 2. Effect of adsorbent dose on methylene blue removal.

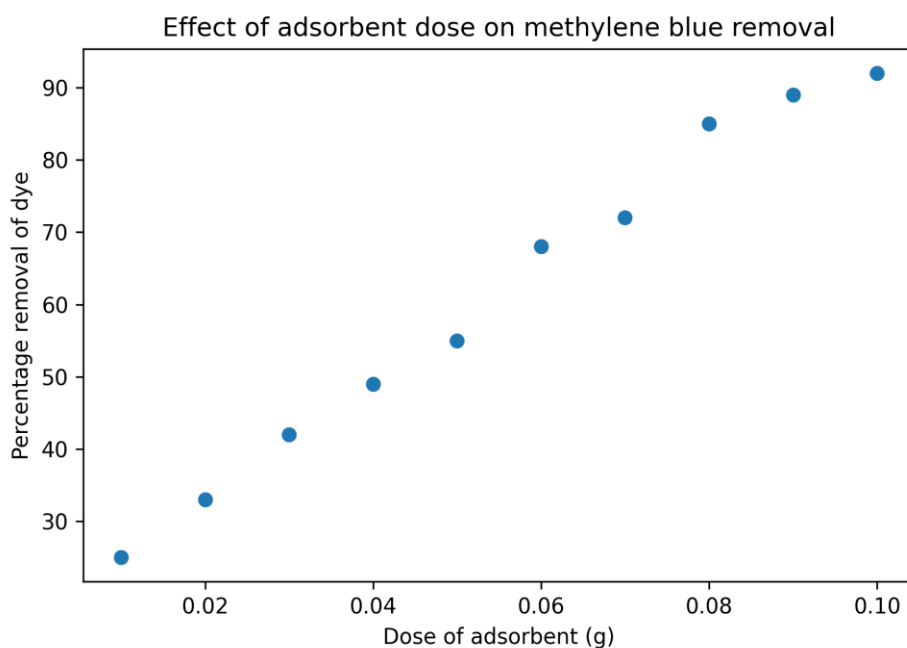


Figure 2. Effect of adsorbent dose on percentage removal of methylene blue.

3.3 Effect of contact time

The percentage removal of methylene blue increased from 20% to 90% as contact time increased from 20 to 200 min. The adsorption increased rapidly during the initial period and approached a higher removal value with increasing contact time.

Contact time (min)	Removal (%)
20	20
40	27
60	35

Contact time (min)	Removal (%)
80	39
100	45
120	54
140	62
160	75
180	86
200	90

Table 3. Effect of contact time on methylene blue removal.

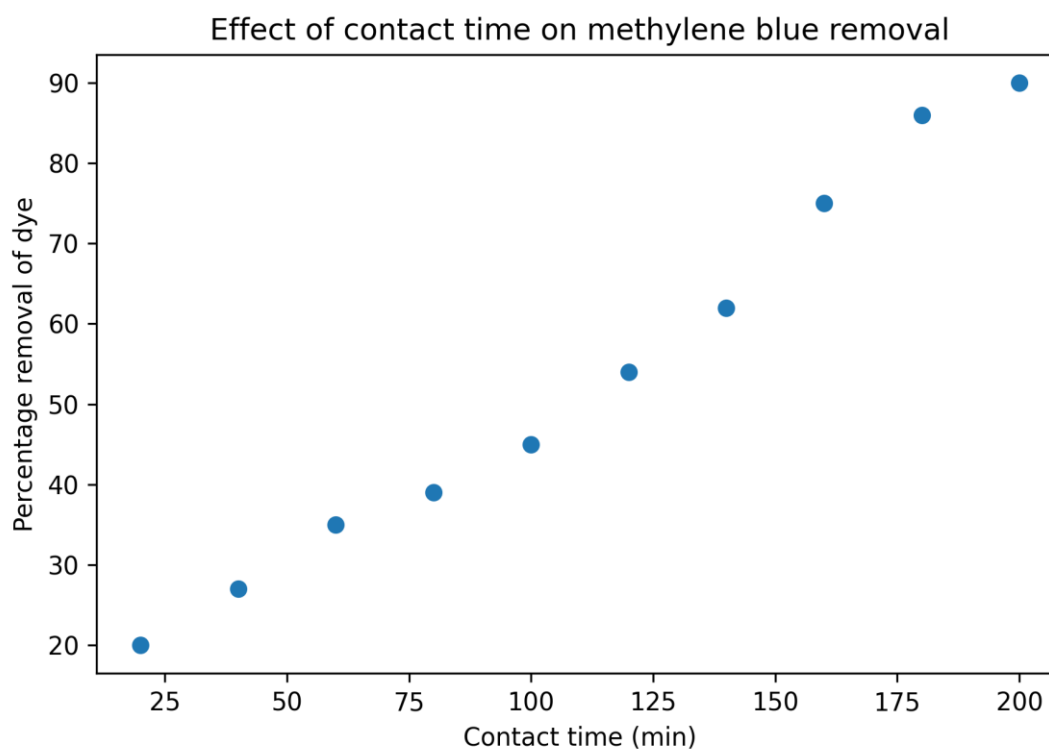


Figure 3. Effect of contact time on percentage removal of methylene blue.

3.4 Effect of pH

The effect of pH on methylene blue removal was studied by changing pH from 2 to 12. The results showed lower removal in acidic medium and increased removal under basic conditions. The maximum methylene blue removal was 92% at pH 10.

pH	Removal (%)
2	35
4	58
6	70
8	84
10	90
12	82
14	79

Table 4. Effect of pH on methylene blue removal.

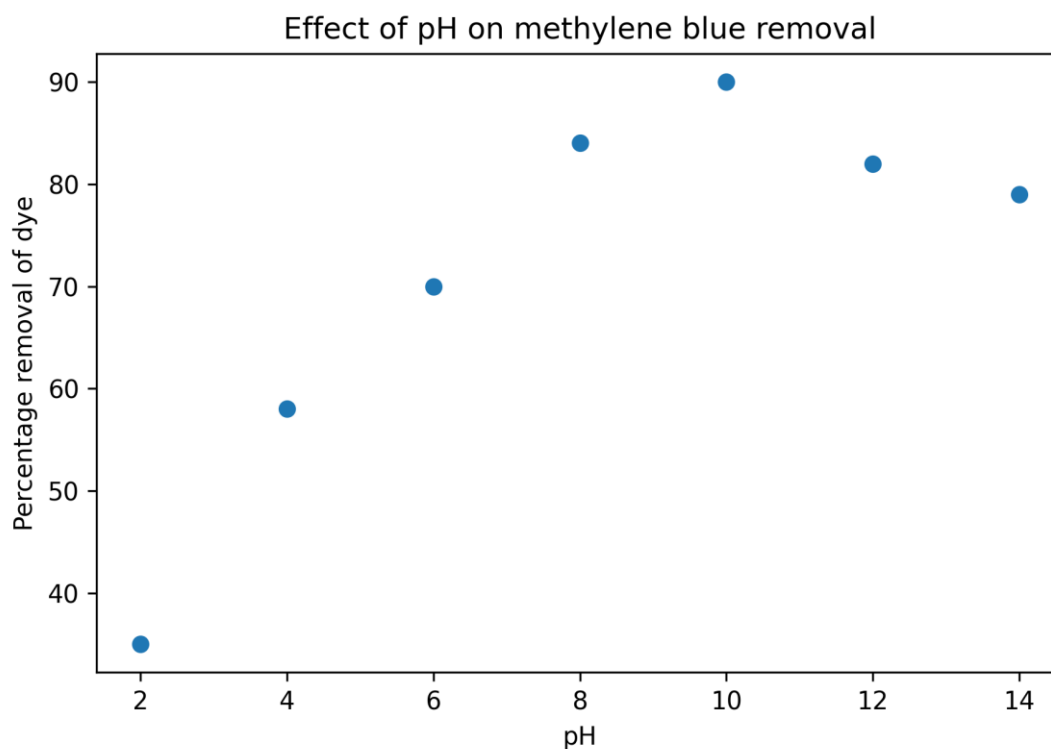


Figure 4. Effect of pH on percentage removal of methylene blue.

3.5 Adsorption isotherm

Adsorption isotherm studies were used to evaluate the adsorption characteristics of the prepared composite. The linear forms of the Freundlich and Langmuir isotherms were applied to the equilibrium data. The equilibrium data used for the Langmuir and Freundlich plots are reproduced from the experimental data.

Langmuir linear equation:

$$C_e/Q_e = 1/(Q_{max} K_L) + C_e/Q_{max}$$

The plot of C_e/Q_e versus C_e gave a straight line with slope 0.1927565 and intercept -0.3316901 , with $R^2 = 0.9826301$. From the slope, Q_{max} calculated as $1/\text{slope}$ is approximately 5.19 mg/g.

Ce (mg/L)	Ce/Qe (g/L)
5	0.5
10	1.5
15	2.7
18	3.5
23	4
27	4.7

Table 5. Equilibrium data used for the Langmuir plot.

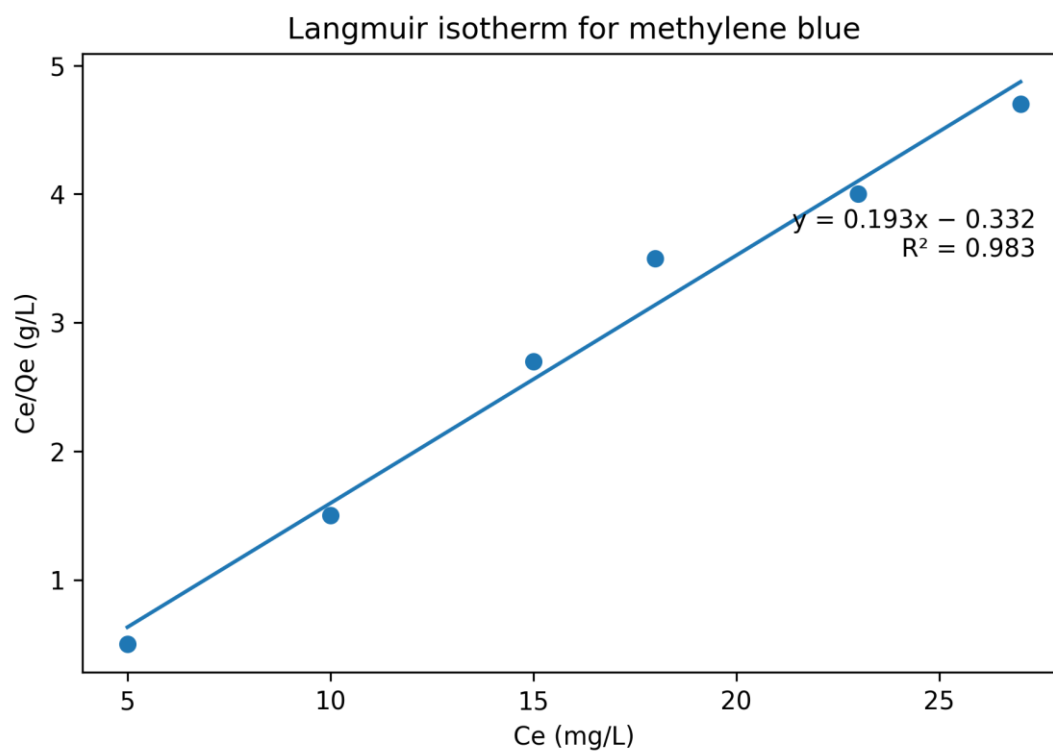


Figure 5. Langmuir isotherm for adsorption of methylene blue dye onto superabsorbent composite.

Freundlich linear equation:

$$\log Q_e = \log K_f + (1/n) \log C_e$$

The Freundlich plot showed a slope (1/n) of 2.0245232, intercept of -0.5282016 and $R^2 = 0.9520384$.

log Ce	log Qe
0.69	1
1	1.3
1.17	1.8
1.25	2
1.36	2.2
1.43	2.5

Table 6. Equilibrium data used for the Freundlich plot.

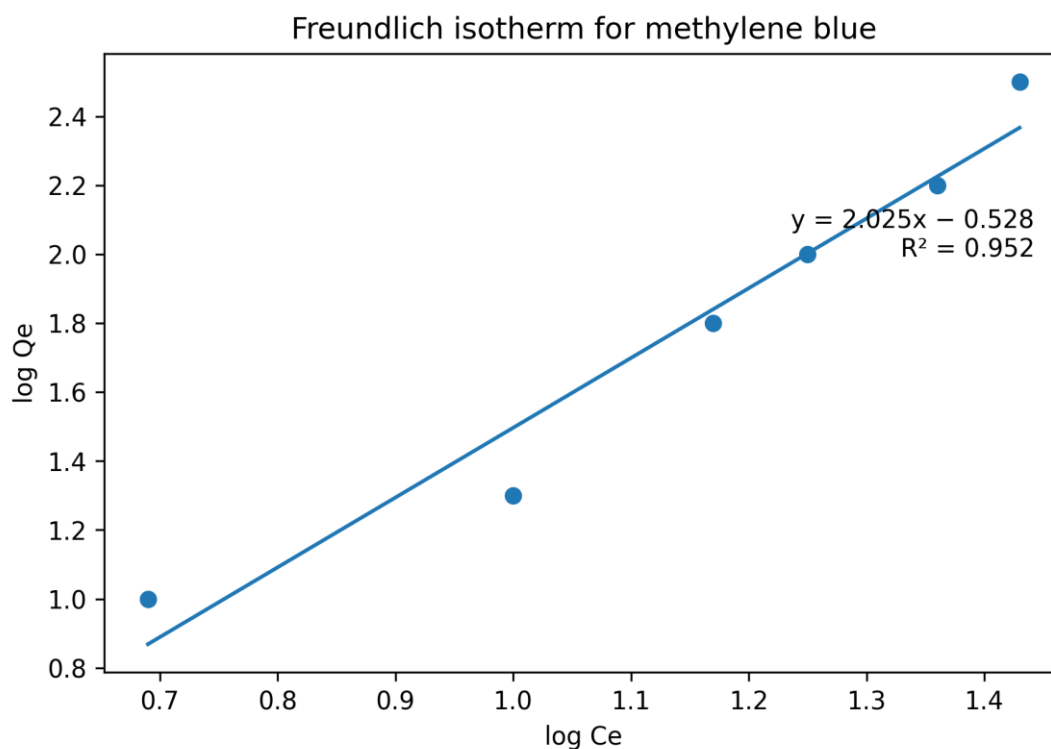


Figure 6. Freundlich isotherm for adsorption of methylene blue dye onto superabsorbent composite.

3.6 Photographic observation

The prepared composite and its interaction with methylene blue are shown in Figure 7. The original photographs from the experimental data are retained here as the visual record of the prepared composite and dye adsorption experiment.

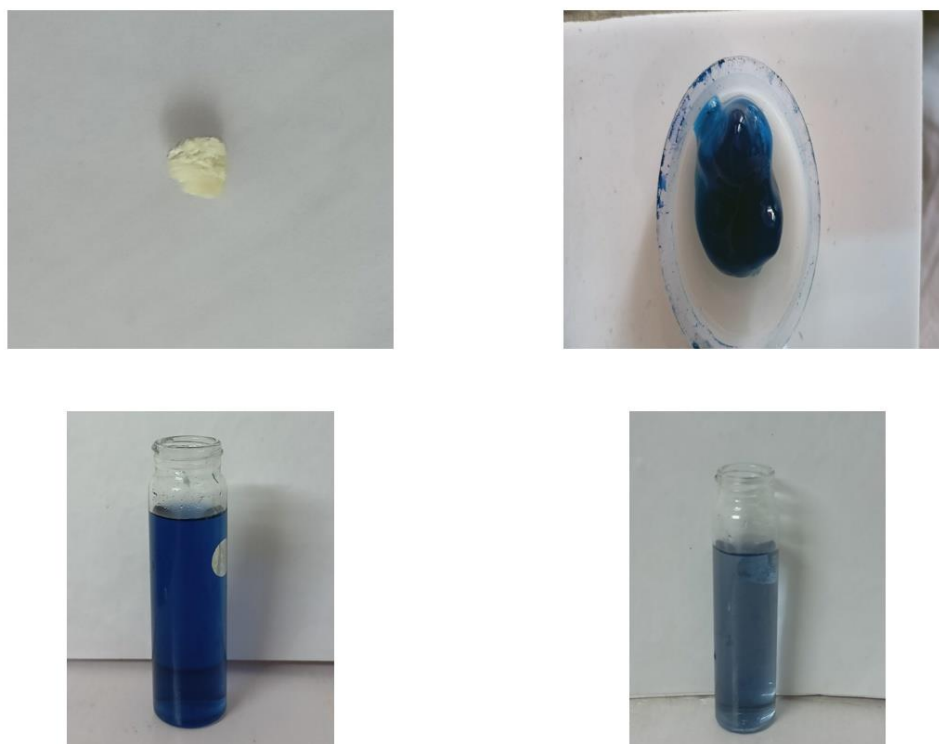


Figure 7. Photographs associated with the methylene blue adsorption experiment: dry composite, methylene-blue-adsorbed composite, and dye solution before/after adsorption.

4. Conclusion

The guar gum-g-poly(acrylic acid)/zeolite superabsorbent composite was investigated for the removal of methylene blue from aqueous solution using batch adsorption experiments. The percentage removal increased with adsorbent dose from 0.01 to 0.1 g, reaching a maximum removal of 92% at pH 10. Increasing contact time from 20 to 200 min increased removal from 20% to 90%. The pH study showed maximum methylene blue removal of 92% at pH 10. The Langmuir and Freundlich models produced R^2 values of 0.9826 and 0.9520, respectively. The Langmuir slope corresponds to a calculated Q_{max} of approximately 5.19 mg/g. These results indicate that the prepared superabsorbent composite can be used as an adsorbent material for methylene blue removal from aqueous solution.

References

- Paulino, A. T. et al. (2006). Removal of methylene blue from water using a superabsorbent hydrogel prepared from modified gum arabic, polyacrylate and polyacrylamide.
- Wang, Y., Zheng, L., Ren, X., Song, H. and Wang, A. (2010). *Journal of Environmental Sciences*, 22(1), 7–14.
- Kumar, P. S., Ramalingam, S., Senthamarai, C., Niranjana, M., Vijayalakshmi, P. and Sivanesan, S. (2010). *Desalination*, 261(1–2), 52–60.
- Haghseresht, F. and Lu, G. (1998). Adsorption characteristics of phenolic compounds onto coal-reject-derived adsorbents. *Energy & Fuels*, 12, 1100–1107.
- Sokker, H. H., Abdel-Kareem, M., Zohdy, K. and Younes, M. M. (2010). *Journal of Radiation Research and Applied Sciences*, 3(4), 1107–1124.
- Wang, H., Yuan, X. Z., Wu, Z. B. et al. (2014). Removal of basic dye from aqueous solution using *Cinnamomum camphora* sawdust; kinetics, isotherms, thermodynamics and mass transfer processes. *Separation and Purification Technology*, 49, 2689–2699.
- Weber, T. W. and Chakravorti, R. K. (1974). Pore and solid diffusion models for fixed-bed adsorbers. *AIChE Journal*, 20, 228–238.
- Zheng, H. and Lu, F. (2011). *Food Chemistry*, 128(4), 1087–1093.