

Research Article

Poly (2-Acrylamido 2-Methyl 1-Propane Sulphonic Acid) Hydrogel for the Sorption Studies of Brilliant Green Dye: Isotherm and Thermodynamic Studies

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Abstract

Poly (2-acrylamido-2-methyl-1-propane sulphonic acid) [PAMPS] hydrogel was synthesized via free radical polymerization using 2-Acrylamido 2-methyl 1-propane sulphonic acid (AMPS) monomer, N, N-Methylenebisacrylamide (MBAA) cross-linker and potassium per sulphate (KPS) as the initiator and evaluated as an efficient adsorbent for the removal of Brilliant Green (BG) dye from aqueous solutions. Batch sorption experiments were conducted to investigate the influence of key operational parameters, such as pH, temperature, initial concentration of dye and sorbent doses. Equilibrium data were analyzed using common adsorption isotherm models and sorption isotherm data was found to fit best with the Dubinin-Radushkevich model with the highest correlation ($R^2=0.9808$) at the temperature of 37.5 °C. Thermodynamic parameters such as Gibbs free energy (ΔG°), enthalpy (ΔH°), and entropy (ΔS°) were determined to elucidate the nature of the adsorption process. The positive Gibbs free energy (ΔG°) suggesting non-spontaneous process and a positive enthalpy change ($\Delta H^\circ= 0.003$ kJ/ mol), indicating an endothermic process. The maximum sorption capacity was observed at 37.5 °C with a removal efficiency up to 97.28% under optimized conditions. In addition, desorption studies using different types of solvents revealed the impact of the nature of the solvents on this sort of surface phenomenon. Overall, the findings demonstrate that PAMPS hydrogel is a promising and thermally responsive adsorbent for the effective removal of Brilliant Green dye, highlighting its potential application in wastewater treatment.

Keywords

Sorption, Hydrogel, Brilliant Green, PAMPS, Thermodynamics, Desorption Study

1. Introduction

The discharge of synthetic dyes from textile and related industries has proven as a critical environment concern according to their chemical stability, resistance to biodegradation and intense color. [1-4] Brilliant green dye is a cationic

dye [5] widely used in textile processing and biological staining; however, it is known for its toxicity and persistence in aquatic environments. [6-8]. It is generally released into natural water bodies not only degrades water quality but also

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harms public health and aquatic ecosystem [9, 10]. Therefore, improving effective and sustainable methods for removing such dyes from wastewater is prime significant. There are various dye removal techniques such as membrane separation [11, 12], reverse osmosis [13, 14], chemical flocculation [15, 16], adsorption [17, 18], microbial degradation [19, 20] and bioaccumulation [21, 22]. Among these various techniques, sorption has proven to be one of the most effective and economically friendly methods for dye removal [23]. The main advantages of this process is simplicity, low energy demand and high efficiency across a wide range of pollutant concentrations [24]. However, the performance of sorption system widely depends on the nature of the sorbent. Hydrogels particularly based on synthetic polymer have acquired increasing attention as dye sorbent due to their tunable porosity, high water retention and abundance of functional groups [25-28].

Poly (2-acrylamido-2-methyl-1-propane sulphonic acid) hydrogel is a superabsorbent polymer containing sulphonic acid ($-\text{SO}_3\text{H}$) groups, which occurs electrostatic interactions with cationic dye molecules such as brilliant green. Its excellent swelling properties and hydrophilic character make PAMPS hydrogel a strong candidate for aqueous-phase dye sorption [29]. In this study, PAMPS hydrogel was synthesized by free radical polymerization and investigated as a sorbent for brilliant green dye under various physicochemical conditions [30]. Batch sorption experiment was performed to find out the effects of pH, temperature, initial dye concentration, sorbent doses and equilibrium time on sorption efficiency. The hydrogel exhibited high removal efficiency under optimized conditions, achieving a maximum removal percentage. [31]. To acquire further insight into the nature and feasibility of the sorption process, thermodynamic parameters such as Gibbs free energy (ΔG°), enthalpy (ΔH°) and entropy (ΔS°) were calculated [32]. These parameters were used to assess the spontaneity, heat nature (endothermic or exothermic) and randomness changing during sorption. ΔG° indicates whether the process is spontaneous or non-spontaneous [33]. A positive ΔG° indicates that the sorption process is non-spontaneous, need any external energy input. ΔH° reveals the heat change involved [32].

A sorbents practical applicability in wastewater treatment is widely determined by its reusability [34, 35], Initial efficiency is determined by sorption performance but long term sustainable and cost effectiveness are also defined by the materials capacity to be efficiently regenerated and reuse over several cycles. To determine whether the structure and functional integrity of the sorbent was maintained how effectively sorbed pollutants can be extracted from the materials. Poor desorption may point to a stronger binding mechanism, high desorption efficiency usually indicates weak, reversible interaction like physisorption or electrostatic interaction [36].

The aim of this study is to evaluate the thermodynamic behavior of brilliant green dye removal through sorption and desorption using PAMPS hydrogel as a sorbent. This included investigating the spontaneity, heat exchange and reversibility

of the process as well as assessing the materials structure stability and reusability. The study also aims to determine the efficiency of dye removal under varying conditions and to analyze the potential of PAMPS hydrogel for.

2. Materials and Methods

All chemical used were of reagent grade. The PAMPS hydrogel was synthesized through a polymerization reaction involving the monomer, AMPS, source from Sigma Aldrich, Germany (ACS-99%), and the crosslinker MBAA also obtained from Sigma-Aldrich, Germany. The initiator, KPS was procured from Thermo Fisher scientific, USA, concentrated HCl was sourced from Pathumwan, Thailand. NaOH was collected from Merck, India. BG was obtained from Sigma Aldrich, Germany. A stock solution of brilliant green at 500 mg/L was prepared by dissolving 0.5g of brilliant green in a 1000 mL volumetric flask. The solution was then completed to the mark with deionized water. Ultimately the stock solution of BG was prepared.

Instruments such as pH meter (Model no: HI2211, Hanna Instrument, Romania) equipped with a combination electrode, accurate to ± 0.01 pH units, and a UV-visible spectrometer (UV-1800, Double beam, Shimadzu corporation, Japan) were utilized to determine the absorbance and concentration of the solution.

2.1. Preparation of PAMPS Hydrogel

The second phase was involved the preparation of PAMPS hydrogel and the investigation of BG dye sorption on the hydrogel. The hydrogel, PAMPS, was synthesized through a polymerization reaction involving the AMPS monomer, MBAA as a crosslinker and KPS as initiator. To prepare the stock solution (100 mL), the required concentration of the monomer, initiator and crosslinker was measured and a specific amount of this solution was placed into a vial to achieve final concentration 2M for AMPS, 16mM for MBAA, 1.6mM for KPS. The polymerization was conducted in a water bath at 60 °C for 25 minutes. Once the gel has fully formed, it was extracted from the vial. The prepared gel was submerged in a beaker filled with a sustainable volume de-ionized water and left for 48 hours to attain a state of equilibrium swelling. After this period, the gel was kept for sorption studies.

2.2. Sorption Studies

Initially the sorption studies were carried out at different physicochemical condition to investigate pH optimization, equilibrium time of brilliant green on PAMPS hydrogel. For performing batch sorption studies the optimum pH value (pH 6.00) and equilibrium time (180 min or 3 hours) were initially found out at different conditions. BG solution of concentration 50 mg/L and volume of 40 mL was taken into 100 mL reagent bottle thereafter shaking with 0.5 g dried PAMPS

hydrogel for 5 hours at room temperature (27.5 °C) to find out the optimum pH and equilibrium time was carried out by changing initial concentration, pH and temperature. Different values of pH and different proportions of concentration, sorbate amount, temperature was taken to find out some factors such as initial concentration, contact time, dose.

2.3. Sorption Isotherms

Brilliant green solution of different concentration 10, 20, 30, 40, 50, 60, 70, 80 mg/L was prepared in 50 mL volumetric flask. The pH of the solution was adjusted at 6.00. After adjusting the pH of the solution 40mL of each solution was poured into well stopper clean reagent bottle each. Then 3 g of PAMPS hydrogel was discharge in each bottle. The bottles were then mounted on shaking machine previously set at

temperature 27.5 ± 0.5 °C and 120 rpm. The shaking was continued for 3 hours. After three hours shaking pH of each solution was adjusted at pH 6.00 and then analyzed. UV-visible spectrum of each solution was taken where absorbance was measured at 625 nm. The initial concentration was justified by taking UV-visible spectrum with respect to standard curve constructed at pH 6.00. The isotherm data were fitted with different models to investigate the adsorption behavior of brilliant green dyes solution onto PAMPS hydrogel.

2.4. Desorption Studies

The desorption studies of brilliant green dye on PAMPS hydrogel were carried out by using several reagents with same proportion of brilliant green solution to find out the percentage of desorption and regeneration of PAMPS hydrogel.

3. Results and Discussions

3.1. Sorption Studies

3.1.1. Absorption Spectrum of Brilliant Green

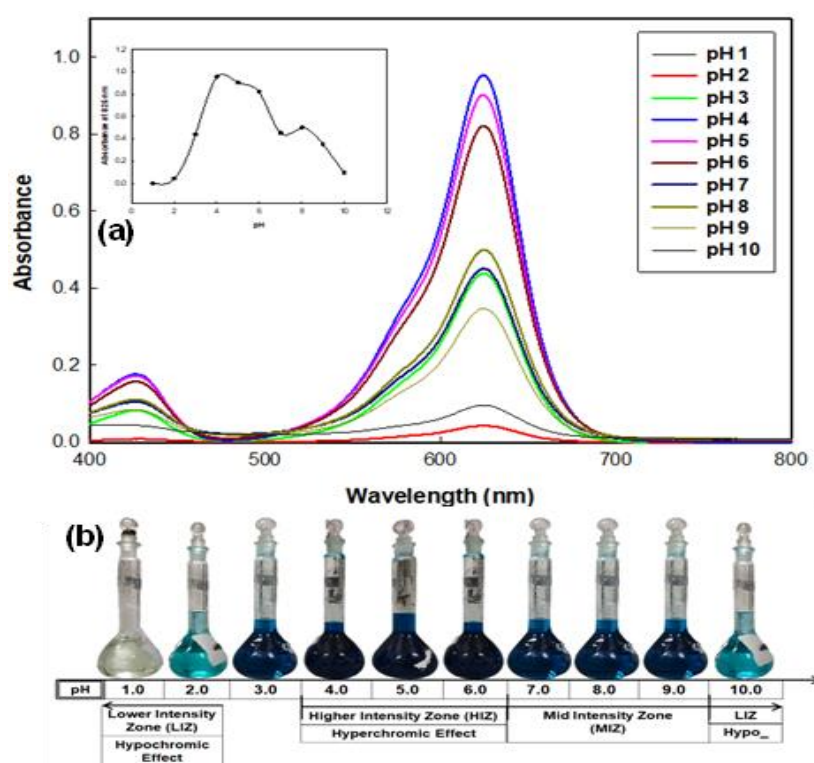


Figure 1. (a) Absorption Spectra of BG Dye of 50 mg L⁻¹ at Different pH Values. Inset Figure Variation of Absorbance with pH at λ_{max} 625 nm and (b) pH Dependent Chromaticity of BG dye.

The absorption spectrum of brilliant green (BG), was obtained at 625 nm. The absorption spectrum of BG was investigated at different pH levels whether there is any shift of the

spectrum. Though there was no shift of the wavelength the chromaticity was observed to be affected remarkably based on the acidity or basicity of BG solution (Figure 1). Based on

the pH level spectrum of BG can be segregated in three different zones- (1) higher intensity zone (HIZ); (2) lower intensity zone (LIZ) and (3) mid intensity zone (MIZ). The higher intensity zone (HIZ) (hyperchromic effect) in the spectrum of BG was found at pH 4.00-6.00. Hypochromic effect (lower intensity zone (LIZ)) was observed at highly acidic (pH 1.00-2.00) and highly basic media (pH 10.00). The third intensity zone which was found neither at HIZ nor at LIZ rather it appeared for the BG solutions at pH 3.00 and 7.00-9.00.

3.1.2. Variable Factors for Thermodynamic Studies

The sorption of brilliant green (BG) onto PAMPS hydrogel was affected by the pH of the solution. The study was examined this effect across a pH range of 2.00 to 9.00. Maximum BG removal occurred at pH 6. As the pH was increased beyond 6.00, the amount sorbed decreased. The sorption of brilliant green (BG) onto PAMPS hydrogel was analyzed by varying the initial dye concentration. Maximum sorption capacity was achieved at 80 mg/L across all tested temperatures. At a BG dye concentration of 50–60 mg/L, a

slight retardation in uptake was observed at all temperatures due to the mass transfer driving force between the solution and the sorbent. This governs the optimum condition for the dye uptake. The sorbent dose was reflected the capacity of PAMPS hydrogel to remove dye at fixed initial concentration. As the dose of the sorbent was gradually increased from 6.25 g/L to 62.5 g/L, the amount of brilliant green sorbed also increased. The highest sorption was observed at 75 g/L. Beyond this dose, no significant improvement in sorption was noted. Therefore 75 g/L was chosen as the optimal dose for further experiment. Sorption isotherms of brilliant green on PAMPS hydrogel showed the sorption increased as the temperature was raised from 17.5°C to 37.5°C. However, at higher temperature the sorption amount decreased. This reduction may be due to increased segmental motion in the PAMPS polymer chains, leading to dispersion in the gel matrix, which hinders proper dye sorption. The higher in entropy at higher temperatures further supports that elevated temperatures are unfavorable for effective sorption, a common trend on heterogeneous surfaces.

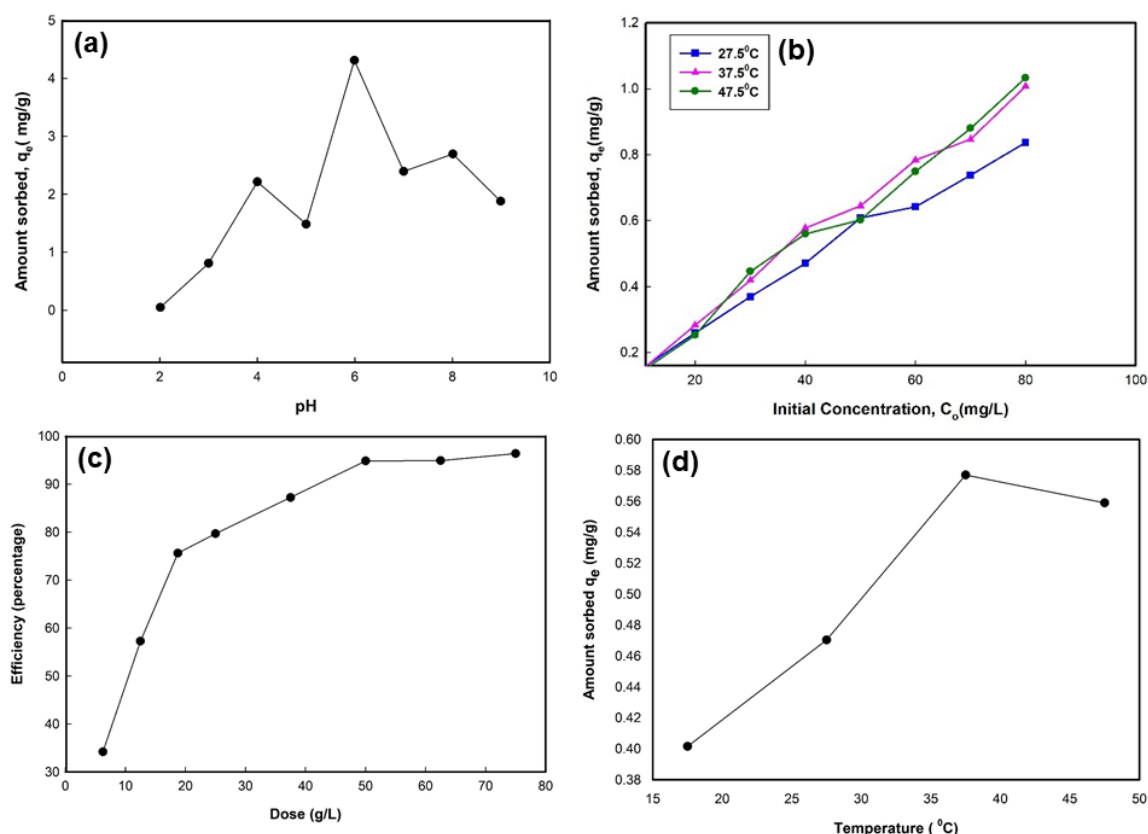


Figure 2. Variable Factors Such as (a) pH, (b) Initial Concentration, (c) Dose, (d) Temperature That Can Affect on Thermodynamic Studies.

3.2. Sorption Isotherms

The temperature can affect the sorption of brilliant green

(BG) onto PAMPS hydrogel. Sorption increased while the temperature was raised from 17.5°C to 37.5°C which indicates that the higher temperature initially enhanced dye uptake. However, at 47.5°C, the sorption decreased indicating

that high thermal energy disrupts dye-polymer interaction. This may be due to increased segmental motion of the hydrogel polymer chains, leading to reduced sorption efficiency.

3.3. Model of Isotherms

In this study, the sorption behavior of brilliant green on PAMPS hydrogel was analyzed using different four models of isotherm: Langmuir, Freundlich, Temkin and Dubinin-Radushkevich. These models help understand the interaction of BG on PAMPS hydrogel surface. The Langmuir isotherm assumes monolayer adsorption on a homogenous surface with uniform energy level. It shows that once a dye molecule occupies a site, no further adsorption can occur at that site. The Langmuir model also helps to calculate the maximum adsorption capacity of the hydrogel. A good fit with this model suggests uniform sorption sites in PAMPS hydrogel [37].

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

$$\frac{1}{q_e} = \frac{1}{q_{max} K_L} \times \frac{1}{C_e} + \frac{1}{q_{max}} \quad (2)$$

Where, q_e is the amount sorbed at equilibrium (mg/g), C_e is the equilibrium concentration of dye (mg/L), q_{max} is the maximum adsorption capacity (mg/g) and K_L : Langmuir constant related to adsorption energy (L/mg).

The Freundlich isotherm assumes that heterogeneous surface with varying adsorption energies. It suggests multilayer adsorption which indicates the BG dye can form layers on the surface. The value of $1/n$ from the Freundlich model reflects the favorability of adsorption. If $1/n < 1$, the process is con-

siderable favorable [38].

$$q_e = K_F C_e^{\frac{1}{n}} \quad (3)$$

$$\log q_e = \log K_F + \frac{1}{n} \log C_e \quad (4)$$

Where, K_F is the Freundlich constant (adsorption capacity), N is the adsorption intensity ($1/n < 1$ —favorable adsorption).

The Temkin isotherm accounts for interaction between dye molecule and hydrogel surface. It assumes that the heat of adsorption decreases linearly as coverage increases. This model provides insight into how adsorbent-adsorbate interaction affects the adsorption process [38].

$$q_e = B \ln A + B \ln C_e \quad (5)$$

Where, $B = \frac{RT}{b}$, A is the Temkin equilibrium binding constant (L/g), B : constant related to heat of adsorption (J/mol) and B is the Temkin isotherm constant.

The Dubinin-Radushkevich isotherm is more theoretical and used to differentiate between physical and chemical adsorption. It does not assume a homogenous surface and involves a Gaussian energy distribution. If $E < 8$ kJ/mol, it suggests physical adsorption while higher values indicate chemical adsorption [39].

$$q_e = q_m \exp(-B \varepsilon^2) \quad (6)$$

where, $\varepsilon = RT \ln(1 + \frac{1}{C_e})$; q_m is the theoretical saturated capacity (mg/g), B is the activity coefficient (mol^2/J^2), E is the $1/\sqrt{2B}$: mean free energy (kJ/mol).

Table 1. Data for the Co-efficient of Different Models of Isotherm for the Sorption of Brilliant Green onto PAMPS Hydrogel.

Isotherm Models	Coefficients	Temperature (°C)			
		17.5	27.5	37.5	47.5
Langmuir	q_m (mg/g)	-4.512	4.4623	2.1413	-1.403
	K_L (L/mg)	-0.009	0.0868	0.2569	-0.112
	R^2	0.000	0.1323	0.5556	0.0898
Freundlich	K_F (mg/g)	0.0362	0.3490	0.4044	0.1657
	N	0.8764	1.0506	1.1679	0.7287
	R^2	0.5160	0.9180	0.8824	0.8560
Temkin	K_T	0.3705	3.3153	3.8660	1.3246
	B_T (kJ/mol)	0.5096	0.3606	0.3774	0.5630
	R^2	0.7014	0.9071	0.9596	0.7557
Dubinin-Radushkevich	q_s (mg/g)	1.6874	1.5370	1.692	2.515

Isotherm Models	Coefficients	Temperature (°C)			
		17.5	27.5	37.5	47.5
	E (kJ/mol)	10.619	25.00	26.73	18.26
	β (mol ² /kJ ²)	0.3069	0.0008	0.0007	0.0015
	R ²	0.8814	0.9587	0.9808	0.9221

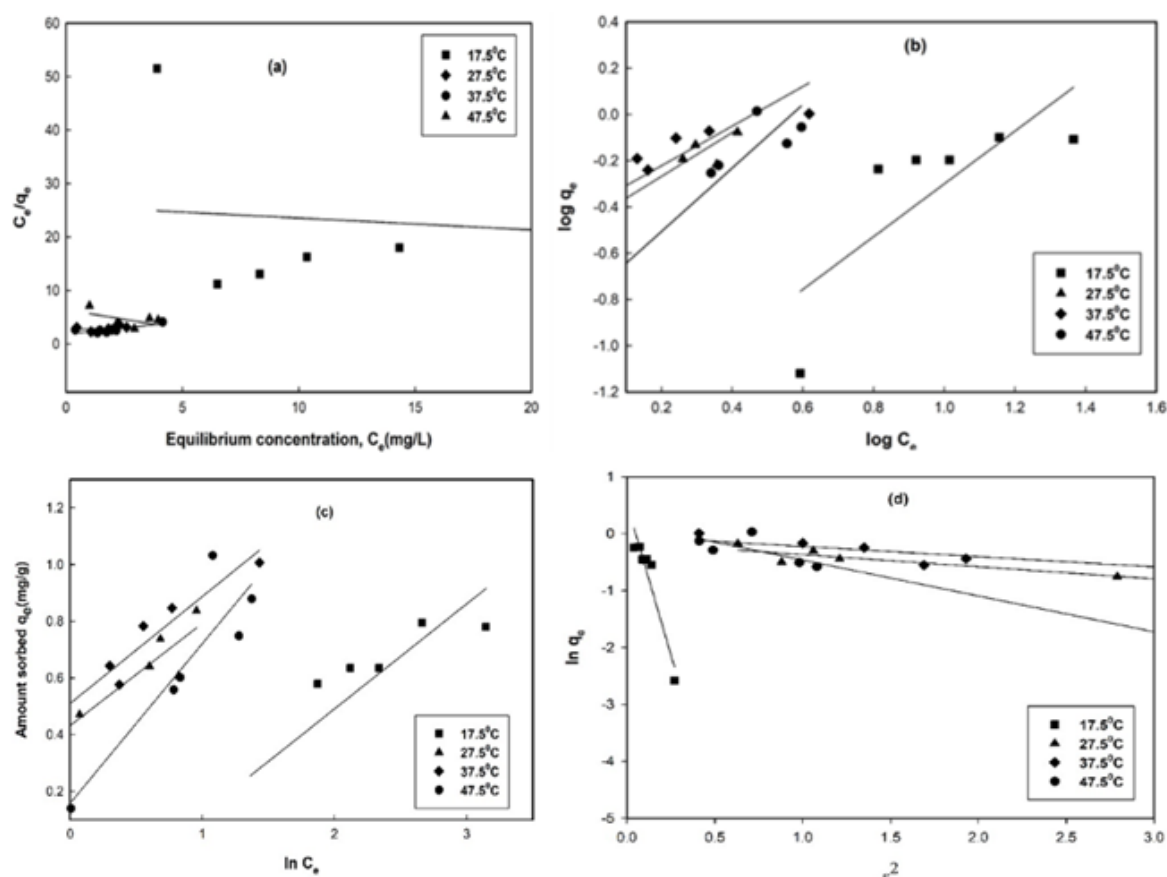


Figure 3. Fitting of Isotherm Data with (a) Langmuir Isotherm, (b) Freundlich Isotherm, (c) Temkin Isotherm and (d) Dubinin-Radushkevich Isotherm Models for the Sorption of BG Dye onto PAMPS Hydrogel at Different Temperatures.

3.4. Sorption Thermodynamic Parameters

Temperature plays a crucial role in the sorption behavior of PAMPS hydrogel by influencing molecular kinetic energy. In endothermic process, increasing temperature enhances sorption capacity while in exothermic process, sorption decreases with the increment of temperature. Thermodynamic feasibility and nature of the sorption can be evaluated using Gibbs free energy ΔG , enthalpy ΔH , entropy ΔS . these are

determined by the following equations,

$$\Delta G = RT \ln K_D \quad (7)$$

where R (8.314 Jmol⁻¹ K⁻¹) is universal gas constant, T is temperature in Kelvin scale and K_D (q_e/C_e) is the distribution coefficient. ΔH and ΔS can be calculated from the linear of $\ln K_D$ and $1/T$ obtained from the linear equation.

$$\ln K_D = \frac{\Delta H}{RT} + \frac{\Delta S}{R} \quad (8)$$

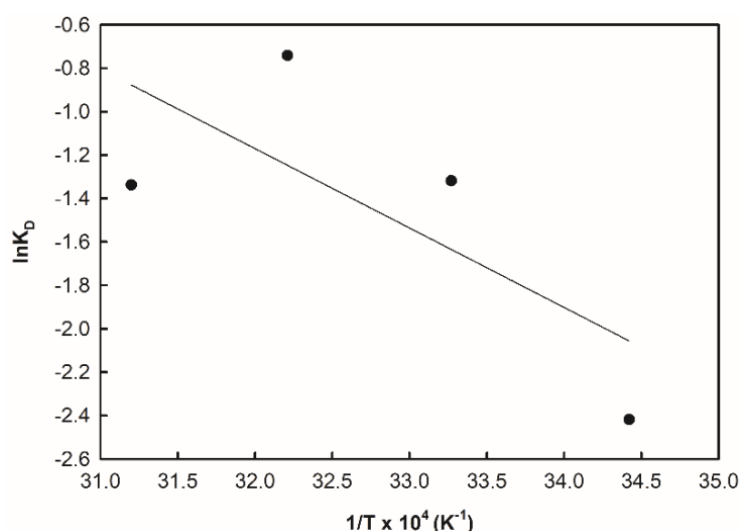


Figure 4. A Plot of $\ln K_d$ vs $1/T$ for the Sorption of Brilliant Green onto PAMPS Hydrogel at pH 6.

Table 2. Thermodynamic Parameters for Brilliant Green Sorption on the PAMPS Hydrogel.

Temperature (K)	K_d	ΔG (kJmol ⁻¹)	ΔH (kJmol ⁻¹)	ΔS (JK ⁻¹ mol ⁻¹)	R^2	Reference
290.5	0.089136	5.839				
300.5	0.267665	3.292	0.003	87.62	0.783	Current Research
310.5	0.47642	1.912				
320.5	0.262553	3.458				
288	6.7	-16.2			0.998	
298	6.9	-17.1	20.1	29.9	0.997	[37]
313	7.1	-8.51			0.988	
323	7.3	-19.6			0.989	
298	8.0631	-6.413				
308	13.153	-7.8514	36.439	143.8	-	[38]
318	20.218	-9.2890				
328	33.281	-10.584				
298	11.3	6.05				
308	13.3	6.63	27.92	113.1	-	[39]
318	19	7.78				
328	32.3	9.48				

$$\Delta G = \Delta H - T\Delta S \quad (9)$$

$$-RT \ln K_D = \Delta H - T\Delta S \quad (10)$$

The thermodynamic studies for the sorption of brilliant green on PAMPS hydrogel was performed from experimental data carried out at different temperature such as 290.5,

300.5, 310 and 320.5 K. Thermodynamic parameters, such as Gibb's free energy (ΔG), entropy (ΔS), enthalpy (ΔH) was calculated at the positive values of ΔG (5.839, 3.292, 1.912, 3.458 kJ/mol) indicates the sorption of brilliant green dye on PAMPS hydrogel was non-spontaneous and more favorable at higher temperature. The positive value of the enthalpy change, ΔH (0.003 kJ/mol) indicate that the sorption process was an endothermic in nature. The positive entropy changes,

ΔS (87.62 J/K/mol) value indicates decreased order and increased randomness in the system.

Table 3. Desorption Studies of Brilliant Green Dye By Adsorbed PAMPS Hydrogel at pH 6.

Reagents	(%) Desorption	(%) Regeneration	Transparency of Gel	Physical Structure of Gel	Appearance of Gel
Water	2	-	Coloured	Not deformed	
NaCl (0.1M)	8	-	Coloured	Not deformed	
HCl (0.1 M)	-	-	Transparent but slightly yellowish in colour	Slightly deformed	
NaOH (0.1M)	-	-	Opaque	Slightly deformed	
Acetone (0.1M)	-	-	Slightly transparent	Not deformed	
Ethanol (0.1M)	-	-	Slightly transparent	Not deformed	

3.5. Desorption Studies

The desorption studies of brilliant green dye on PAMPS hydrogel were carried out using several reagents Table 3. But within those reagents it was found that water is slightly appropriate for desorption but NaCl salt is more appropriate to use for desorption studies. We know PAMPS contains sulphonic acid group which is highly charged and can bonded with brilliant green dye solution. When NaCl is introduced, the sodium ion (Na^+) can compete with the positively charged dye molecules for the negatively charged sulphonic group and promote desorption. NaOH at pH 6.00 is not effective for desorption because the alkali is not strong enough to disrupt the interaction between dye and hydrogel at that pH. HCl protonates the PAMPS hydrogel and neutralizes the sulphonic acid and reduces the interaction between cationic brilliant green dye which facilitates desorption and the gel structure is changed for this interaction and the adsorbed gel

turns into transparent. In alkaline medium gel turns into opaque but when acetone and ethanol are used the gel turns into slightly transparent after desorption studies [40, 41].

3.6. Percent Removal

At this present work, it was found that the percent removal of brilliant green from aqueous solution onto PAMPS hydrogel was influenced by pH of the adsorbate solution. The percent removal of BG onto PAMPS hydrogel was found to increase with pH. Though at the early stage (from equilibrium time experiment) the sorption was observed to rise with pH the removal became similar at high pH values (pH 6 and 8) while the system reached the equilibrium Figure 5. Considering the facts such as contact time, pH and initial concentration of dye solution, dose of PAMPS and temperature the overall percent removal of BG sorbed onto PAMPS hydrogel was calculated as 97.28%.

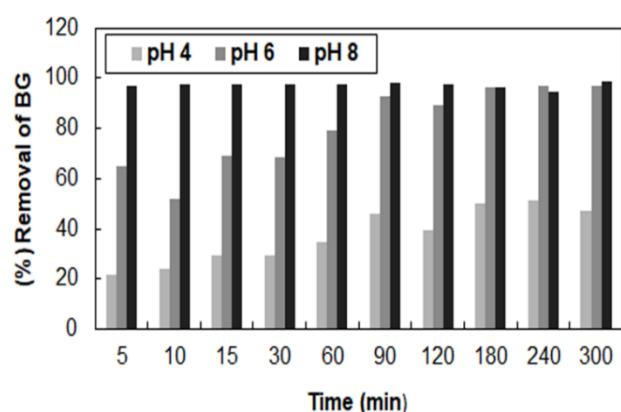


Figure 5. Percent Removal of BG Onto PAMPS With Time at Different pH Levels.

4. Conclusions

This study assures that PAMPS hydrogel is highly effective adsorbent for removing Brilliant green dye from water. It achieved a removal efficiency of up to 97.28% under optimized conditions. Sorption data best fitting the Dubin-in-Radushkevich isotherm model. Thermodynamic analysis expressed that was non-spontaneous and endothermic process and indicate physisorption mechanism. These results show PAMPS hydrogel potential as a cost effective and sustainable material for waste-water treatment applications.

Abbreviations

PAMPS	Poly (2-Acrylamido-2-Methyl-1-Propane Sulphonic Acid)
AMPS	2-Acrylamido 2-Methyl 1-Propane Sulphonic Acid
MBAA	N, N-Methylenebisacrylamide
KPS	Potassium Persulphate

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Author Contributions

Sakib Hasan: Data curation, Formal analysis, Investigation, Writing – original draft

Md. Anamul Haque: Methodology, Visualization

Md. Towsif-Ur-Rahman: Data curation, Visualization, Writing – original draft

Nafees Ahmed: Conceptualization, Data curation, Funding acquisition, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – review & editing

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Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflicts of interest.

References

- [1] Slama, H. B., Chenari Bouket, A., Pourhassan, Z., Alenezi, F. N., Silini, A., Cherif-Silini, H., Oszako, T., Luptakova, L., Golińska, P. and Belbahri, L, Diversity of synthetic dyes from textile industries, discharge impacts and treatment methods. *Applied Sciences*, 2021, 11(14), p. 6255. <https://doi.org/10.3390/app11146255>
- [2] Ali, H, Biodegradation of synthetic dyes—a review. *Water, Air, & Soil Pollution*, 2010, 213(1), pp. 251-273. <https://doi.org/10.1007/s11270-010-0382-4>
- [3] Singh, K. and Arora, S., Removal of synthetic textile dyes from wastewaters: a critical review on present treatment technologies. *Critical reviews in environmental science and technology*, 2010, 41(9), pp. 807-878. <https://doi.org/10.1080/10643380903218376>
- [4] Vigneshpriya, D., Krishnaveni, N., Renganathan, S. and Sri Sakthi Priyadarshini, R., Impact of untreated and Sargassum wightii-treated brilliant green dye exposure on Indian major carp, *Labeo rohita* Ham.: hematology, biochemistry, enzymology and histopathology. *International Journal of Phytoremediation*, 2010, 22(8), pp. 819-826. <https://doi.org/10.1080/15226514.2019.1710816>
- [5] Singh, S., Gupta, H., Dhiman, S. and Sahu, N. K., Decontamination of cationic dye brilliant green from the aqueous media. *Applied Water Science*, 2022, 12(4), p. 61. <https://doi.org/10.1007/s13201-022-01596-5>
- [6] Abdel-Fadeel, M. A., Aljohani, N. S., Al-Mhyawi, S. R., Halawani, R. F., Aljuhani, E. H. and Salam, M. A., A simple method for removal of toxic dyes such as Brilliant Green and Acid Red from the aquatic environment using Halloysite nanoclay. *Journal of Saudi Chemical Society*, 2022, 26(3), p. 101475. <https://doi.org/10.1016/j.jscs.2022.101475>

- [7] Akter, T., Protity, A. T., Shaha, M., Al Mamun, M. and Hashem, A., The impact of textile dyes on the environment. In Nanohybrid materials for treatment of textiles dyes 2023, pp. 401-431. Singapore: Springer Nature Singapore.
- [8] Yildirim, O. A., Bahadir, M. and Pehlivan, E., Detrimental effects of commonly used textile dyes on the aquatic environment and human health—a review. *Fresenius Environ Bull*, 2022, 31, pp. 9329-45.
- [9] Mehra, S., Singh, M. and Chadha, P. J. T. I., Adverse impact of textile dyes on the aquatic environment as well as on human beings. *Toxicol. Int*, 2021, 28(2), p. 165
<https://doi.org/10.18311/ti/2021/v28i2/26798>
- [10] du Plessis, A., Primary water quality challenges, contaminants and the world's dirtiest places. In *Water as an Inescapable Risk: Current Global Water Availability, Quality and Risks with a Specific Focus on South Africa 2018* (pp. 79-114). Cham: Springer International Publishing.
https://doi.org/10.1007/978-3-030-03186-2_5
- [11] Aggour, Y. A., Kenawy, E. R., Magdy, M. and Elbayoumy, E., Multifunctional copolymers for brilliant green dye removal: adsorption kinetics, isotherm and process optimization. *Environmental Science: Advances*, 4(5), 2025, pp. 787-808.
<https://doi.org/10.1039/D4VA00404C>
- [12] Moradihamedani, P. J. P. B. Recent advances in dye removal from wastewater by membrane technology: a review. *Polymer Bulletin*, 2022, 79(4), pp. 2603-2631.
<https://doi.org/10.1007/s00289-021-03603-2>
- [13] Aziz, A. A., Mokhter, M. A., Ghazali, A. I. and Hanaffi, N. Removal of Remazol brilliant blue R dye from water using eggshell mixed matrix membrane through filtration and adsorption. *Journal of Applied Membrane Science & Technology*, 2024, 28(3), pp. 17-31.
- [14] Garud, R. M., Kore, S. V., Kore, V. S. and Kulkarni, G. S., A Short Review on Process and Applications of Reverse Osmosis. *Universal Journal of Environmental Research & Technology*, 2011, 1(3).
- [15] Muniasamy, S. K., AlObaid, A. A., Warad, I. and Ravindiran, G., 2023. Removal of Brilliant Green dye in aqueous solution using synthetic coagulation and flocculation technique. *Desalination and Water Treatment*, 2023, 314, pp. 231-240.
<https://doi.org/10.5004/dwt.2023.30093>
- [16] Aqeel, K., Mubarak, H. A., Amoako-Attah, J., Abdul-Rahaim, L. A., Al Khaddar, R., Abdellatif, M., Al-Janabi, A. and Hashim, K. S., 2020, July. Electrochemical removal of brilliant green dye from wastewater. In *IOP Conference Series: Materials Science and Engineering* (Vol. 888, No. 1, p. 012036). IOP Publishing. <https://doi.org/10.1088/1757-899X/888/1/012036>
- [17] Nandi, B. K., Goswami, A. and Purkait, M. K., Adsorption characteristics of brilliant green dye on kaolin. *Journal of hazardous materials*, 2009, 161(1), pp. 387-395.
<https://doi.org/10.1016/j.jhazmat.2008.03.110>
- [18] Mane, V. S., Mall, I. D. and Srivastava, V. C., Kinetic and equilibrium isotherm studies for the adsorptive removal of Brilliant Green dye from aqueous solution by rice husk ash. *Journal of environmental management*, 2007, 84(4), pp. 390-400.
- [19] Tripathi, P., Tiwari, S., Sonwani, R. K. and Singh, R. S., A step towards enhancing the efficiency of biofilm mediated degradation of brilliant green dye in packed bed bioreactor: Statistical and toxicity analysis. *Process Safety and Environmental Protection*, 2023, 170, pp. 1228-1239.
<https://doi.org/10.1016/j.psep.2022.12.066>
- [20] Zabłocka-Godlewska, E. and Przysaś, W., Fed-batch decolorization of mixture of Brilliant Green and Evans Blue by bacteria species applied as pure and mixed cultures: influence of growth conditions. *Water, Air, & Soil Pollution*, 2020, 231(2), p. 75. <https://doi.org/10.1007/s11270-020-4441-1>
- [21] González, V., Abalde, J. and Torres, E. Discoloration and biosorption of Brilliant green dye in seawater using living biomass of the microalga *Phaeodactylum tricornutum*. *Journal of Applied Phycology*, 2024, 36(4), pp. 1823-1835.
- [22] Kaushik, P. and Malik, A., Comparative performance evaluation of *Aspergillus lentulus* for dye removal through bioaccumulation and biosorption. *Environmental Science and Pollution Research*, 2013, 20(5), pp. 2882-2892.
<https://doi.org/10.1007/s11356-012-1190-8>
- [23] Mane, V. S. and Babu, P. V., Studies on the adsorption of Brilliant Green dye from aqueous solution onto low-cost NaOH treated saw dust. *Desalination*, 2011, 273(2-3), pp. 321-329.
- [24] Zolgharnein, J., Bagtash, M. and Shariatmanesh, T., Simultaneous removal of binary mixture of Brilliant Green and Crystal Violet using derivative spectrophotometric determination, multivariate optimization and adsorption characterization of dyes on surfactant modified nano- γ -alumina. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, 2015, 137, pp. 1016-1028. <https://doi.org/10.1016/j.saa.2014.08.115>
- [25] Darban, Z., Shahabuddin, S., Gaur, R., Ahmad, I. and Sridewi, N., Hydrogel-based adsorbent material for the effective removal of heavy metals from wastewater: A comprehensive review. *Gels*, 2022, 8(5), p. 263.
- [26] Godiya, C. B., Ruotolo, L. A. M. and Cai, W, Functional biobased hydrogels for the removal of aqueous hazardous pollutants: current status, challenges, and future perspectives. *Journal of Materials Chemistry A*, 2020, 8(41), pp. 21585-21612.
- [27] Shalla, A. H., Bhat, M. A. and Yaseen, Z., Hydrogels for removal of recalcitrant organic dyes: A conceptual overview. *Journal of environmental chemical engineering*, 2018, 6(5), pp. 5938-5949.
- [28] Lim, J. Y., Goh, S. S., Liow, S. S., Xue, K. and Loh, X. J., Molecular gel sorbent materials for environmental remediation and wastewater treatment. *Journal of Materials Chemistry A*, 2019, 7(32), pp. 18759-18791.
- [29] Demirci, S., Ari, B., Aktas, N. and Sahiner, N., pH-responsive amphoteric p (APTMAcI-co-AMPS) hydrogel as effective multiple dye sponge network from aqueous media. *Frontiers in Materials*, 2022, 9, p. 837701.
<https://doi.org/10.1039/C9TA05782J>

- [30] Phonlakan, K., Meetam, P., Chonlaphak, R., Kongseng, P., Chantarak, S. and Budsombat, S., Poly (acrylic acid-co-2-acrylamido-2-methyl-1-propanesulfonic acid)-grafted chitosan hydrogels for effective adsorption and photocatalytic degradation of dyes. *RSC advances*, 2023, 13(44), pp. 31002-31016. <https://doi.org/10.1039/D3RA05596E>
- [31] Zhou, G., Luo, J., Liu, C., Chu, L., Ma, J., Tang, Y., Zeng, Z. and Luo, S., A highly efficient polyampholyte hydrogel sorbent based fixed-bed process for heavy metal removal in actual industrial effluent. *Water research*, 2016, 89, pp. 151-160. <https://doi.org/10.1016/j.watres.2015.11.053>
- [32] Krishnan, M., Michal, F., Alsoughayer, S., Almohsin, A. and Alsharaeh, E., October. Thermodynamic and kinetic investigation of water absorption by PAM composite hydrogel. In *SPE Kuwait Oil and Gas Show and Conference* (p. D043S022R002). 2019, SPE.
- [33] Omer, A. M., Sadik, W. A. A., El Demerdash, A. G. M., Tamer, T. M., Khalifa, R. E., Mohyeldin, M. S. and Abdelwahed, N. A., 2021. Fabrication of semi-interpenetrated PVA/PAMPS hydrogel as a reusable adsorbent for cationic methylene blue dye: isotherms, kinetics and thermodynamics studies. *Polymer Bulletin*, 78(11), pp. 6649-6673. <https://doi.org/10.1007/s00289-020-03456-1>
- [34] Kumar, N., Mittal, H., Alhassan, S. M. and Ray, S. S., Bi-onanocomposite hydrogel for the adsorption of dye and reusability of generated waste for the photodegradation of ciprofloxacin: a demonstration of the circularity concept for water purification. *ACS Sustainable Chemistry & Engineering*, 2018, 6(12), pp. 17011-17025. <https://doi.org/10.1021/acssuschemeng.8b04347>
- [35] Mustafa, A., Yaqoob, N., Almas, M., Kamal, S., Zia, K. M. and Rehman, S., Adsorptive removal of Drimarene Brilliant Blue by thermo stable and eco-friendly graphene oxide reinforced polyvinyl alcohol hydrogels with high reusability potential. *Journal of Polymer Research*, 2022, 29(8), p. 332. <https://doi.org/10.1007/s10965-022-03140-0>
- [36] Poplewska, I., Strachota, B., Strachota, A., Poplewski, G. and Antos, D., Thermo-and pH-responsible gels for efficient protein adsorption and desorption. *Molecules*, 2024, 29(20), p. 4858.
- [37] Ragab, A., Ahmed, I. and Bader, D., The removal of brilliant green dye from aqueous solution using nano hydroxyapatite/chitosan composite as a sorbent. *Molecules*, 2019, 24(5), p. 847. <https://doi.org/10.3390/molecules29204858>
- [38] Abbas, M., Removal of brilliant green (BG) by activated carbon derived from medlar nucleus (ACMN)–Kinetic, isotherms and thermodynamic aspects of adsorption. *Adsorption Science & Technology*, 2020, 38(9-10), pp. 464-482. <https://doi.org/10.3390/molecules24050847>
- [39] Kismir, Y. and Aroguz, A. Z., 2011. Adsorption characteristics of the hazardous dye Brilliant Green on Saklikent mud. *Chemical Engineering Journal*, 172(1), pp. 199-206. <https://doi.org/10.1016/j.cej.2011.05.090>
- [40] Karim, A. B., Mounir, B., Hachkar, M., Bakasse, M. and Yaacoubi, A., 2017. Adsorption/desorption behavior of cationic dyes on Moroccan clay: equilibrium and mechanism. *Journal of Materials and Environmental Science*, 8(3), pp. 1082-1096.
- [41] Malekbala, M. R., Khan, M. A., Hosseini, S., Abdullah, L. C. and Choong, T. S., 2015. Adsorption/desorption of cationic dye on surfactant modified mesoporous carbon coated monolith: equilibrium, kinetic and thermodynamic studies. *Journal of Industrial and Engineering Chemistry*, 21, pp. 369-377. <https://doi.org/10.1016/j.jiec.2014.02.047>

Biography



Sakib Hasan is an early-career researcher in environment, physical and analytical chemistry, with his academic training from Jagannath university, where he completed B. Sc. and M. Sc. program. His undergraduate thesis focused on dye sorption, specially investigating the sorption behavior of Brilliant green dye using PAMPS hydrogel. Through this work, he gained strong expertise in sorption kinetics, thermodynamics, equilibrium modeling and batch experimental technique. He is skilled in applying model such as pseudo-first order, pseudo-second order. His interest lies in hydrogel-based adsorbent, polymer materials, and the removal of organic pollutants from aqueous systems. Motivated and research-oriented, he aims to pursue a PhD in environment chemistry, materials science or coordination chemistry with the long-term goal of developing innovative adsorption materials for sustainable water treatment.



Md. Anamul Haque is currently working as an Associate Professor in the Department of Chemistry, University of Dhaka (DU) since February 2020. Prior, he served in the same institute as Lecturer and Assistant Professor from August 2013 and September 2014, respectively. Earlier in his academic achievement, he has been awarded the B. Sc. (Hons) and the M.S. from DU in 2005 and 2007, respectively. Dr. Haque was awarded Ph.D. degree in 2011 in Material Science from Hokkaido University, Japan and continued his postdoctoral research in the same institute for one and a half year. His research interests are the removal of textile dyes by hydrogel as a recyclable absorber, mimicking natural nacre, stimuli-sensitive photonic gels, mechanics of soft materials and gels, hydrogel composite

based on solid waste and waste-water treatment. He has published 1 book chapter and 27 international and national peer-reviewed journal articles.



Md. Towsif-Ur-Rahman is a Masters student in the Department of Chemistry, Jagannath University, Dhaka, Bangladesh. He completed his Bachelor degree in Chemistry from the same institution in 2023. His undergraduate thesis focused on dye sorption, specially investigating the sorption behavior of Crystal dye using PAMPS hydrogel. His research interest includes surface chemistry, electrochemistry, material science and nanochemistry. Some of his recent works are based on the removal of organic pollutants from aqueous systems by hydrogel-based adsorbent.



Nafees Ahmed is a Professor of Chemistry at Jagannath University, Dhaka, Bangladesh. Professor Ahmed completed his B. Sc. (Hons) and M. Sc. in chemistry from the Department of Chemistry, University of Dhaka in 2006 and 2008 respectively. He was rewarded Ph.D. in polymer science from the Division of Biological Sciences, Graduate School of Science, Hokkaido University, Japan in 2011. He began his teaching career from Stamford University of Bangladesh in 2012 and then joined the Department of Chemistry, Jagannath University as Lecturer. Professor Ahmed started his research in Physical Chemistry in this institution besides teaching. His research interest covers the area of physical chemistry, surface chemistry, polymer chemistry, material science and environmental chemistry.

He has got published 21 research articles in nationally and internationally reputed journals and attended numerous scientific conferences at home and abroad. Besides scientific activities he is involved in curriculum designing and institutional quality assurance program.

Research Field

Sakib Hasan: Physical Chemistry, Electrochemistry, Environment chemistry, Material Science, polymer Chemistry.

Md. Anamul Haque: Physical Chemistry, Material Science, Electrochemistry and Environmental Science.

Md. Towsif-Ur-Rahman: Electrochemistry, Material Science, Polymer Chemistry, Surface Chemistry, Nanochemistry.

Nafees Ahmed: Physical Chemistry, Surface Chemistry, Material Science, Polymer Chemistry, Environmental Chemistry.