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Research Article

Equilibrium and Isothermal Studies on Decolourization of Bismarck Brown Dye Using Titanium Nanoparticles

[*a]Raju, Ch. A.I., [b]Anitha, J., [b]Kalyani, R.M., [a]Tukaram Bai, M. and [c]Mani Deepa, I.

[a]Professor, [b]Teaching Assistant, Department of Chemical Engineering, A.U. College of Engineering (A), Andhra University, Visakhapatnam – 530003, Andhra Pradesh, India
[c]Assistant Professor, Department of Microbiology, Vignan Degree College, Palakaluru Road, Guntur, Andhra Pradesh, India
*Corresponding Author Email: chairaju@gmail.com

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Abstract
Rapid industrialisation has increased the use of dyes in a variety of industrial applications in order to meet rising consumer demand. The toxicity level of a dye is important since it impacts both the environment and living things. Adsorption and photocatalysis are two prominent dye removal techniques that have received a great deal of attention in recent years. The current experiment shows the maximum adsorption of BB dye (67%) on Ti NPs. Equilibrium experiments provide the ideal time, pH, concentration, dosage, and temperature for colour removal.
Keywords: Titanium Nanoparticles, pH, Time, Dosage, Temperature.

1. Introduction

People on Earth may survive without food, sleep, power, and other requirements on occasion, but they cannot go a single day without water, highlighting the importance of water in our existence. The Earth's water content is 71%, with 97% of it contained in seas that cannot be used for drinking, washing, cleaning, farming, and so on. Of the 3% of fresh water, 2.5% is trapped in glaciers, polar ice caps, the atmosphere, and soil, and it is highly contaminated. So only 0.5% of pure water is used in our daily life, and it is polluted [1-5].

Dyes are another type of contaminant that is becoming increasingly prevalent in freshwater bodies. Dyes are chemical substances that can adhere to fabrics or surfaces to add colour. Most dyes are complex chemical molecules that must withstand a variety of conditions, including the weather and the action of detergents. Synthetic dyes are widely used in a variety of modern technology fields, including textiles, leather tanning, paper production, food technology, agricultural research, light-harvesting arrays, photo electrochemical cells, and hair coloring [6-8].

Dyes can be characterized as acidic, basic, direct, reactive, dispersion, or metal-complex based on how they are applied to cloth. All dyes share the ability to absorb visible light. Acidic, direct, and reactive dyes are anionic; basic dyes are cationic; and disperse dyes are neutral molecules. Synthetic dyes are composed of complex aromatic molecule structures designed to resist fading when exposed to sweat, soap, water, light, and oxidizing chemicals [9-10]. Reactive dyes are made comprised of azo or anthraquinone-based chromophores with a variety of reactive groups. The development and implementation of cost-effective dye uprooting/recovery processes is crucial to improving the competitiveness of industrial processing operations. Disadvantages, combined with the need for more cost-effective and efficient methods of extracting colors from wastewaters, have resulted in the development of alternative separation technologies [11-14].

2. Experimental Procedure

2.1 Preparation of the Nanoparticle Solution

Collect the leaves from the neighboring *Quisqualis indica* plant, properly wash to eliminate dust, and boil in distilled water to make a broth solution. To create nanoparticles, the broth solution collected from the leaves is combined with the 0.05 M TiO_2 solution and heated at 60°C for 15 minutes.

2.2 Preparation of Dye Solution

To make the first solution, combine 1 g of dye powder with 1000 ml of distilled water to create a dye solution with a concentration of 1000 ppm, then utilize a concentration of 20 ppm throughout the operation. A periodic equilibrium analysis was conducted to remove the BB dye and measure its bioadsorption capability.

2.3 Preparation of the 1000mg/L of Bismarck Brown Solution

All necessary solutions are made using analytical reagents and double-distilled water. In a 1 L volumetric flask, 1.0 g of Bismarck Brown is completely dissolved in distilled water to produce 1000 ppm (mg/L) of Bismarck Brown stock solution.

2.4 Studies on Equilibrium Biosorption

To execute the biosorption in a batch operation, a pre-weighed amount of coconut shell powder was introduced to a certain volume of aqueous solution for a predetermined amount of time in an orbital shaker. The following procedures are utilized to evaluate the various parameters: temperature, pH, beginning lead concentration in aqueous solution, biosorbent size, biosorbent dose, and agitation duration.

3. Results and Discussion

3.1 Effect of Agitation Time

The removal rate of Bismarck Brown is plotted against the stirring time in Figure 1. From the plot, we can see that the uprooting rate increases continuously in the first 60 minutes of stirring. After a stirring time of 60 minutes, the change in BB dye uprooting rate is fairly constant. Therefore, the equilibrium stirring time is 60 minutes.

In the current study, the stirring time for 50 ml of aqueous BB dye solution by adding 0.04g of bacterial culture and 0.01 g of nanoparticles, the % uprooting obtained from 16% to 67% from 5 to 60 minutes [15-16].

3.2 Effect of pH

Figure 2 is plotted between the uprooting rate of Bismarck Brown and the pH of the aqueous solution. Increasing the pH from 2 to 6 observes a sharp increase in the uprooting rate of BB, and above pH 6 further, a decrease in the uprooting rate is observed. In the current pH test the uprooting rate increased from 51% to 76% and the dye uptake was 10.2 to 15.2 mg/g in the pH range of 2-6. It has dropped on increase in the pH value above 6 [17-18].

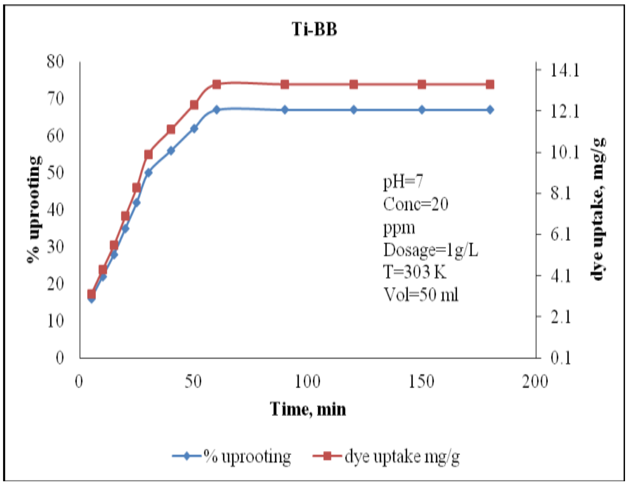

Figure 1. Effect of time on % removal of dye.

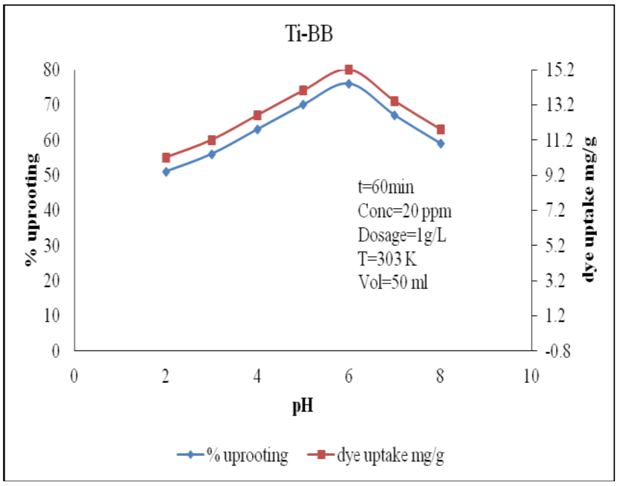

Figure 2. Effect of pH on % removal of Bismarck Brown dye.

3.3 Effect of Initial Concentration of Bismarck Brown Dye

Figure 3 shows the influence of the initial concentration of Bismarck Brown in aqueous solution on the uprooting rate at the optimum stirring time. By increasing the BB dye concentration from 20 to 100 mg/L, the uprooting rate gradually decreases from 76% to 55.5% and the dye uptake goes from 15.2 mg/g to 55.5 mg/g. In general, increasing the initial dye concentration usually increases the uprooting rate because it provides the driving force that causes the dye to move to the surface of the bioadsorbent particles [19-20].

3.4 Effect of Biosorbent Dosage

The change in Bismarck Brown uprooting rate from aqueous solution with bio solvent dose is demonstrated in Figure 4. Increasing the dose from 0.04 organisms + 0.01 g nanoparticles to 0.16 g organisms + 0.05 g nanoparticles increases the uprooting rate from 76% to 95%. This is because increasing the dose of bio adsorbent increases the number of active centers available for dye uptake. The increase in uprooting rate is not noticeable (94-95%) as the dose increases from 0.04 + 0.05 to 0.16 + 0.05. Therefore, for all other remaining studies, the dose is assumed to be 0.04 + 0.05 [21-22].

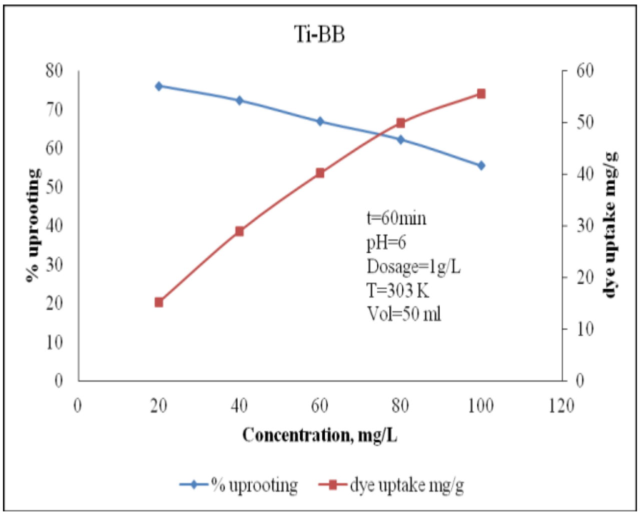

Figure 3. Effect of initial concentration on % removal of Bismarck Brown dye.

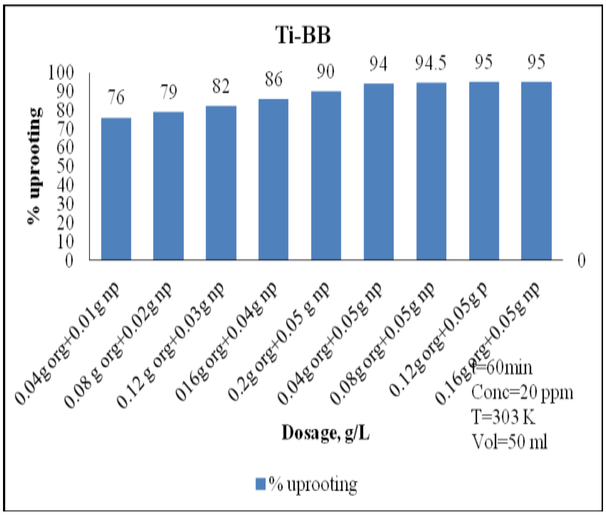

Figure 4. Effect of dosage on % removal of Bismarck Brown dye.

3.5 Effect of Temperature

The equilibrium dye uptake was significantly impacted by temperature. Figure 5 illustrates how temperature variations affect the absorption of the Bismarck Brown dye. Bismarck Brown dye absorption rose with temperature when the temperature was below 303 K, whereas the opposite was true when the temperature was above 303 K. This reaction suggested that the dye and the ligands on the cell wall interacted differently. Physical biosorption processes were often exothermic below 303 K, hence the amount of biosorption typically remained constant as the temperature increased the removal rate increased from 88% to 95% [23-24].

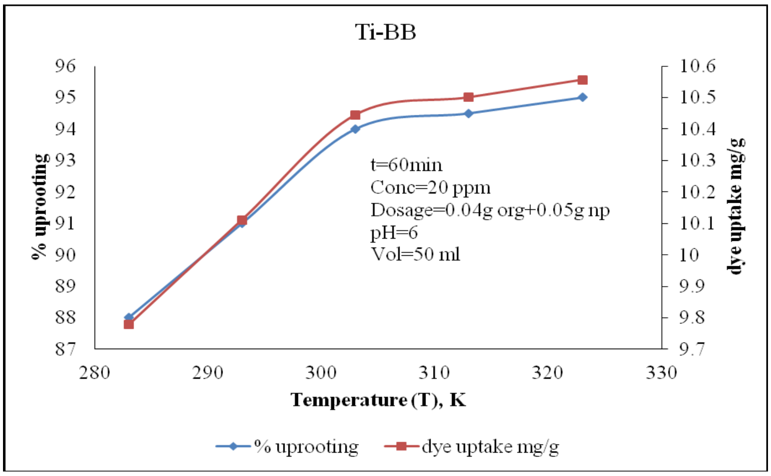

Figure 5. Effect of temperature on % removal of Bismarck Brown dye.

3.6 Isothermal Studies

3.6.1 Langmuir Isotherm

The Langmuir isotherm is drawn in Figure 6 for current data.

The resulting formula is given in equation 1

Ce / qe = 0.0122 Ce + 0.2516 ..... (1)

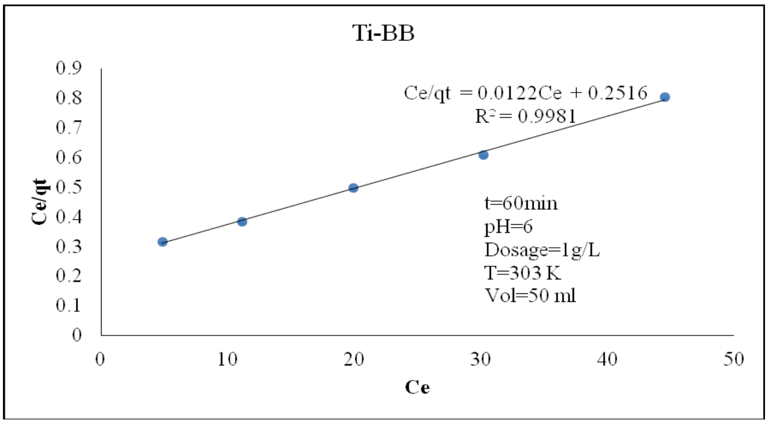

Figure 6. Langmuir isotherm for BB dye.

(correlation coefficient 0.9981) confirms the strong binding of Bismarck Brown ions to the surface of the Ti NPs [25].

3.6.2 Frendlich Isotherm

The Freundlich isotherm is drawn between lnCe and lnqe in the Figure 7. As a result the following equation 2 was obtained.

ln qe = 0.5892ln Ce + 1.8704 ..... (2)

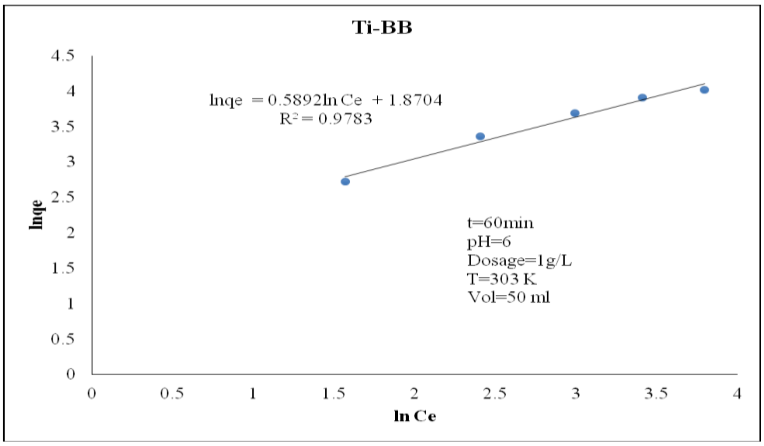

Figure 7. Frendlich isotherm for BB dye.

The correlation coefficient for this equation is 0.9783. A 'n' value of 0.589 indicates a preferred distance that satisfies condition 0<n<1 [26].

3.6.3 Temkin Isotherm

Figure 8 shows the diagram between qe and lnCe. The formula for the distance from Bismarck Brown is equation 3 [27].

qe= 18.506 lnCe – 14.545 ..... (3)

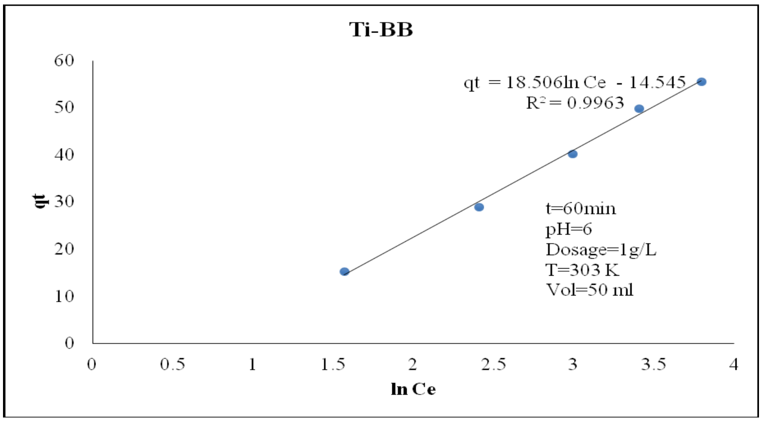

Figure 8. Temkin isotherm for BB dye.

Table 1. Equations and isotherm constants for BB dye.

Equations and isotherm constants for BB dye	Langmuir isotherm	Freundlich isotherm	Temkin isotherm
Equation	Ce/ qe = 0.0122Ce +0.2516	lnqe = 0.5892lnCe + 1.8704	qe= 18.506 lnCe – 14.545
Constant 1	qm = 81.967 mg/g	Kf = 6.490 mg/g	AT = 0.455 L/mg
Constant 2	KL = 0.047	n = 0.5892	bT = 136.125
Constant 3	RL = 0.813	-	-
R^2	R^2 = 0.998	R^2 = 0.978	R^2 = 0.996

4. Conclusions

This investigation aims to determine the suitability of Titanium nanoparticles as a biosorbent for the removal of Bismarck Brown dye from aqueous solutions for biosorption of BB dye experimentally and theoretically, resulting in the following conclusions:

- ✓ The equilibrium stirring time for BB dye sorption is 60 minutes.
- ✓ The optimum dosage for sorption is 1.8 g/L.
- ✓ Maximum extent of sorption is noted at pH = 6.
- ✓ The maximum uptake capacity of 10.444 mg/g is obtained at 303 K.
- ✓ The experimental data are well represented by Langmuir (R^2 = 0.9981), Freundlich (R^2 = 0.9783) and Temkin (R^2 = 0.9963) isotherms.

Declarations

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Author Contributions: CAIR: Conceived and supervised the study, designed the experimental methodology, interpreted the results, reviewed and edited the manuscript, and approved the final version; JA: Conducted laboratory experiments, performed data collection, prepared nanoparticle and dye solutions, carried out equilibrium and adsorption studies, analyzed experimental data, and contributed to manuscript drafting; RMK: Assisted in data processing, literature review, interpretation of adsorption and isothermal studies, preparation of tables and figures, and manuscript revision; MTB: Contributed to study planning, technical guidance, critical review of the manuscript, interpretation of findings, and final approval of the manuscript; IMD: Contributed to literature review, data interpretation, manuscript editing, critical revision for intellectual content, and approved the final manuscript.

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