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Adsorption Efficiency of Natural Clay towards the Removal of Naphthol Green Dye from the Aqueous Solution: Equilibrium and Kinetic Studies

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Abstract

In this study, the adsorption characteristics of Naphthol Green from aqueous solution onto activated carbon prepared from Natural clay like Bentonite was investigated under various parameters like the adsorption capacity, initial dye concentration, contact time, effect of solution pH and adsorbent dosage were investigated in a batch mode. The adsorption isotherms data have been tested by applying both Frendlich and Langmuir isotherm models. The separation factor R_L value was found to be between 0 and 1 for the adsorbent, it indicate that the feasibility of adsorption. The result showed that this activated bentonite had a high adsorption capacity (Q_o = 253.14 mg/g). The kinetics data fitted to the pseudo-first- order model. The results indicate that natural clay like activated bentonite could be employed the removal of textile dyes from industrial effluents.

Keywords: Activated bentonite, naphthol green and adsorption isotherm.

Introduction

Presence of dyes and pigments in industrial effluent poses serious effect to the environment. They are discharged from various industries such as food, colouring, cosmetic, paper, textiles and carpet industries[1]. The complex aromatic structures of dyes make them more stable and more difficult to degrade[2]. Some of the benzidine based dyes, are toxic, carcinogenic[3] and also causes rapid decrease of dissolved oxygen affecting aquatic life species[4]. Therefore, removal of dyes is an important aspect of wastewater before discharge. Removing colour from waste water can be done via several methods namely chemical, biological and physical methods. Among these methods, adsorption is a widely used for removal of dyes from wastewater[5]. The most commonly used adsorbent for colour removal is activated carbon, because of its adsorption capacity for efficiently adsorbing a broad range of different types of adsorbate[6]. In this work, Acid Activated Bentonite (ABN) was applied for the removal of Naphthol Green dye from aqueous solution.

Material and Methods

Materials: The adsorbent used in the present study was Acid Activated Bentonite (ABN). The collected Bentonite was crushed well and activated by heating for 2 hours at 80ºC. This activated adsorbent was used in the adsorption process. 15grams of natural bentonite was activated by refluxing with 200 ml 50/50 (v/v) H_2SO_4 at 60ºC for 2h using round-bottom flask. The precipitate was cooled in air and filtered off and washed with double-distilled water and dried in an air oven at 120ºC for 2 h prior to use[7].

Methods of Analysis: The concentration of Naphthol Green dye solution was determined by using UV-VIS spectrophotometer (Systronics 2201). A standard solution of the dye was taken and the absorbance was determined at 714 nm [8].

Batch Adsorption experiments: In this study, the experiments were carried out by Batch adsorption process. To find out the percentage of removal of dye solution = $\left[\frac{C_0 - C_e}{C_0}\right] x\, 100$.

Where C_o and Ce are the initial and the final concentration of Naphthol Green respectively (mg/L)[9].

Results and Discussion

Effect of initial concentration of the dye solution: The adsorption experiment was carried out with varying the concentration of Naphthol Green over adsorbent such as ABN was investigated at different range of initial concentration, keeping contact time (30 min), initial pH of solution (7-7.5), and dose ($2gL^{-1}$). Figure -1 show that the amount of dye adsorbed increases with increase in concentration (97.1-93.92%) and also the extent of percentage removal decreases exponentially with increase in concentration (94.00-94.14%). This indicates that there exists a reduction in immediate solute adsorption owing to the lack of available active sites required for high initial concentration of dye [10].

Effect of contact time: In order to effect of contact time on the removal of Naphthol Green dye, experiments were conducted at different contact time (from 5-35 min.) at keeping the following concentration 200ppm, fixed dose of ABN (2g/L) and the room temperature. Figure-2 shows that the rate of removal of the adsorbate is higher in the beginning due to the large surface area of the adsorbent available for the adsorption of dye. A similar observation was reported (Hameed and Ahmad, 2009). After some time, only a very low increase in the dye uptake was observed because there are few active sites on the surface of sorbent. A same observation was reported for the adsorption of Malachite Green on oil trunk fibre (Hameed and Khaiary, 2008). Therefore, the optimum time of 30 minutes was selected for the adsorption of Naphthol Green dye for further studies.

Effect of initial pH of the dye solution: The pH is one of the important parameters controlling the uptake of Naphthol Green dye from aqueous solution by the adsorbent like ABN. Figure -3 shows that the adsorption of Naphthol Green dyes was pH dependent. In case of Naphthol Green, at lower pH range 2-4, increased percentage removal was observed (99%) and at higher pH percentage removal decreased. The acidic medium is favourable for the adsorption process of Naphthol Green. High adsorption capacity of dye at low pH indicates that, the surface of active carbons seems to be acidic which increase the protonation at their surfaces due to neutralization of negative charges, resulting in easier diffusion. This provides more active surface of the adsorbents and result into more adsorption at their surfaces. On increasing pH, deprotonation takes place, which decreases the diffusion and adsorption[11-12].

Effect of dose variation of adsorbents: The removal of the Naphthol Green dye was studied with different dose of ABN (0.5-3.5g/L) at the concentration of 200ppm with fixed contact time (30min) and pH (2-4). Figure-4 shows that the percentage removal of the Naphthol Green, increased with increase in the dose of adsorbent. This may be due to the availability of surface activities resulting from the increased dose and conglomeration of the adsorbent.

Adsorption Isotherm: The most important models used for the adsorption equilibrium of the dyes are Frendlich and Langmuir[13]. The Langmuir model assumes that the adsorption of the Naphthol Green dye occurs on a homogeneous surface by mono- layer adsorption without any interaction between the dyes. But, the Freundlich isotherm assumes that the adsorption of the dye occurs on heterogeneous surface by mono-layer adsorption[14]. The correlation analysis of Freundlich and Langmuir isotherm data was presented in table -1. The applicability of the isotherm data was best explained by Langmuir model. Figure -5 and Figure -6 indicate that the adsorption of Naphthol Green dye follows the monolayer adsorption. In this case, R_L value found to be less than 1. Hence, the nature of adsorption process is favourable and the monolayer adsorption capacity (Q_o= 253.14mg/g) of adsorbent in Naphthol Green.

Kinetic of the adsorption: In order to find out the nature and order of kinetics of adsorption in the present study the applicability of the Natarajan and Khalaf equation is tested[15]. The equations are based on the fact that the adsorption follows first order kinetics. A linear relationship is found out with each equation as shown in figure -7. Hence, it is concluded that the adsorption follow the first order kinetics (The rate constant value below one that is 0.0952).

Table-1
Adsorption isotherms of Naphthol Green dye

Adsorbent	Freundlich isotherm			Langmuir isotherm			
	1/n	Kf	R	Qo(mg/g)	b(g.L^{-1})	R_L(L/mg)	R
ABN	0.59	1.41	0.989	253.16	0.053	0.070	0.922

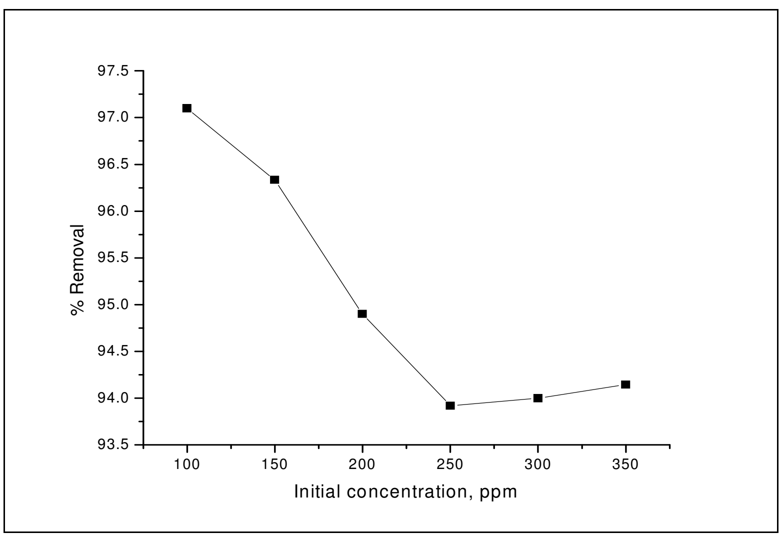

Figure-1
Various concentration on the percentage removal of Naphthol Green by ABN (dose 2g/L, Time 30min, pH 7-7.5)

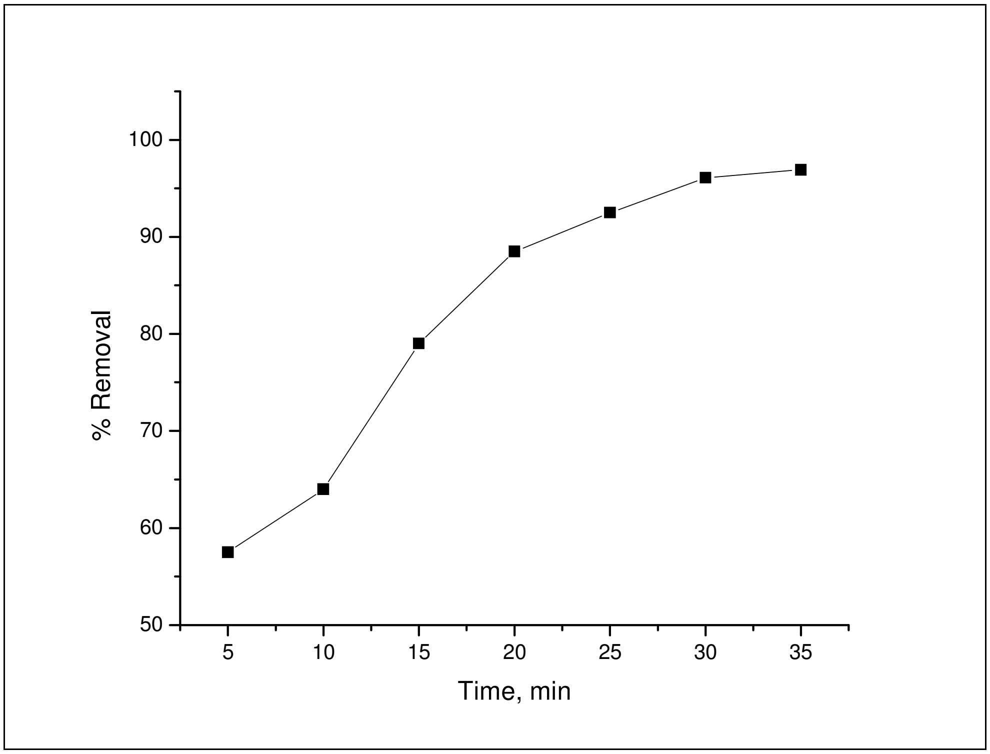

Figure-2
Effect of contact time on the percentage removal of Naphthol Green by ABN (Optimum concentration 200ppm, dose 2g/L, pH 7-7.5)

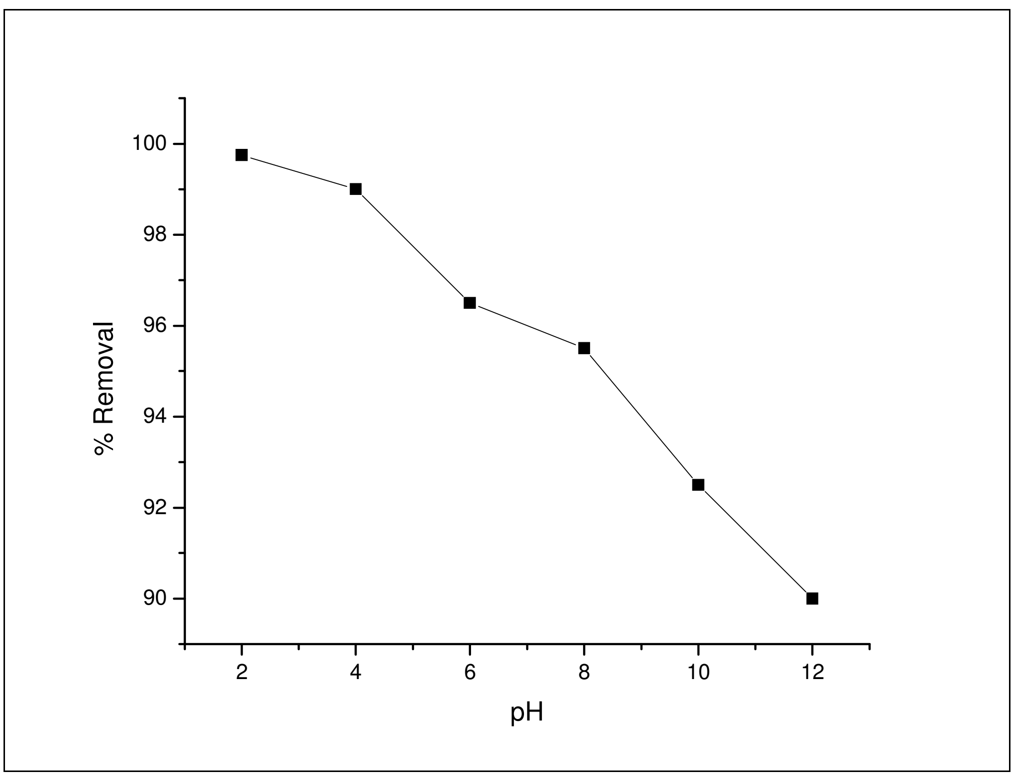

Figure-3
Effect of pH on the percentage removal of Naphthol Green by ABN (optimum concentration 200ppm, dose 2g/L, Time 30min)

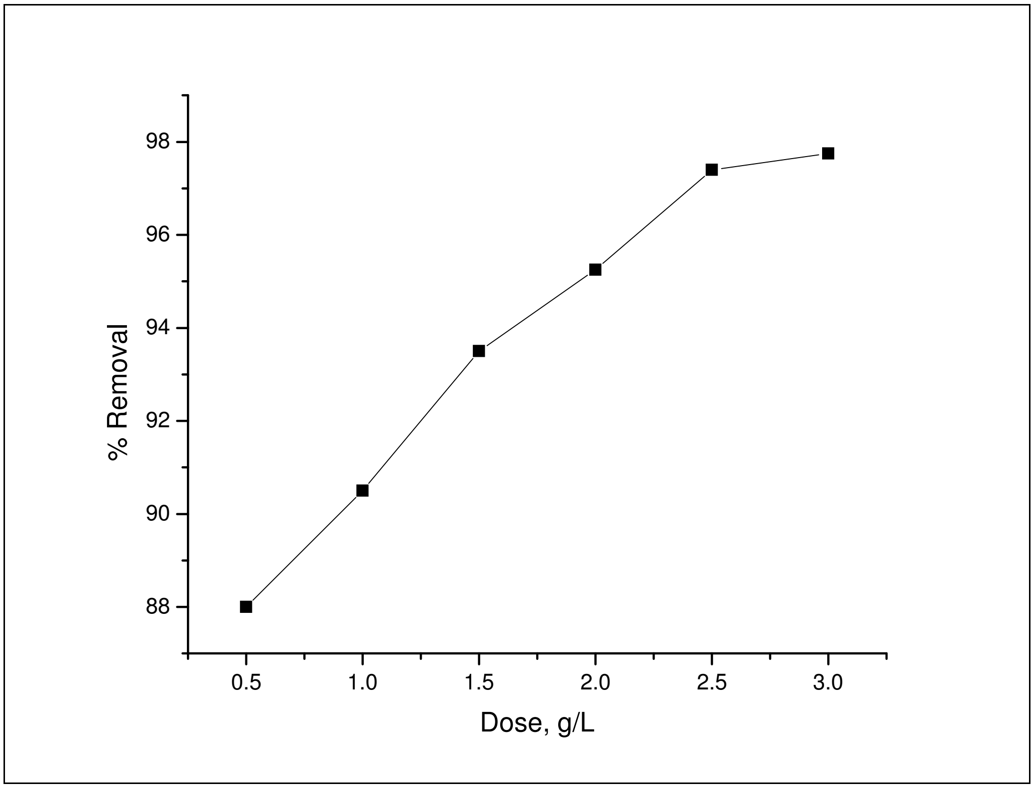

Figure-4
Effect of Dose variation on the percentage removal of Naphthol Green (optimum concentration 200ppm, Time 30min, pH 7-7.5)

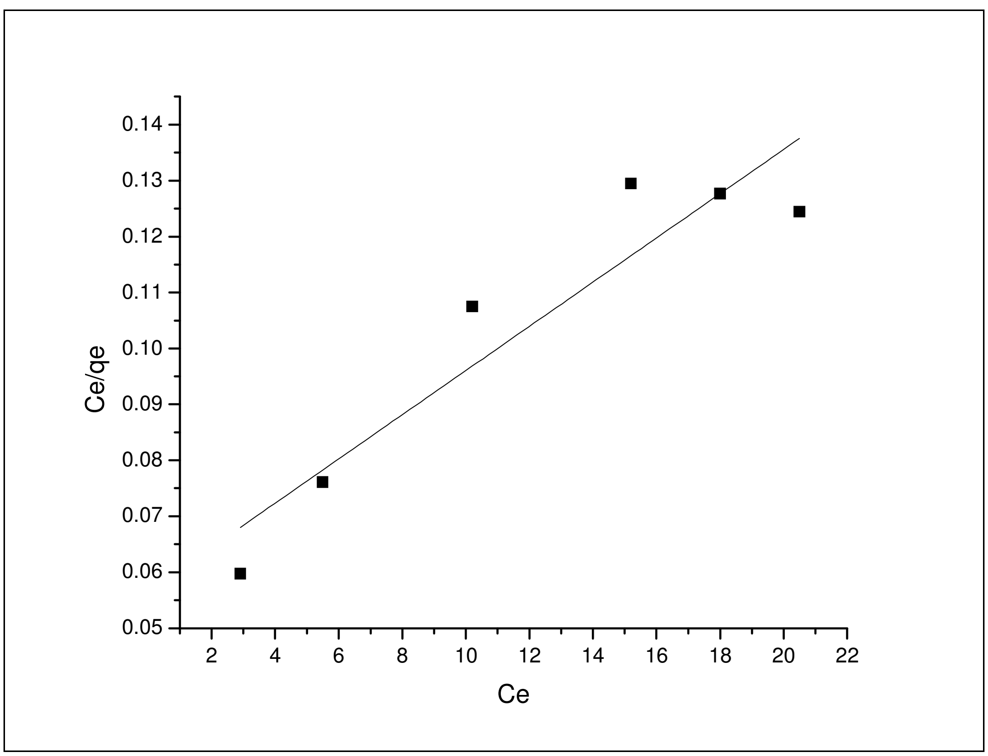

Figure-5
Application of Langmuir isotherms for the removal of Naphthol Green using ABN

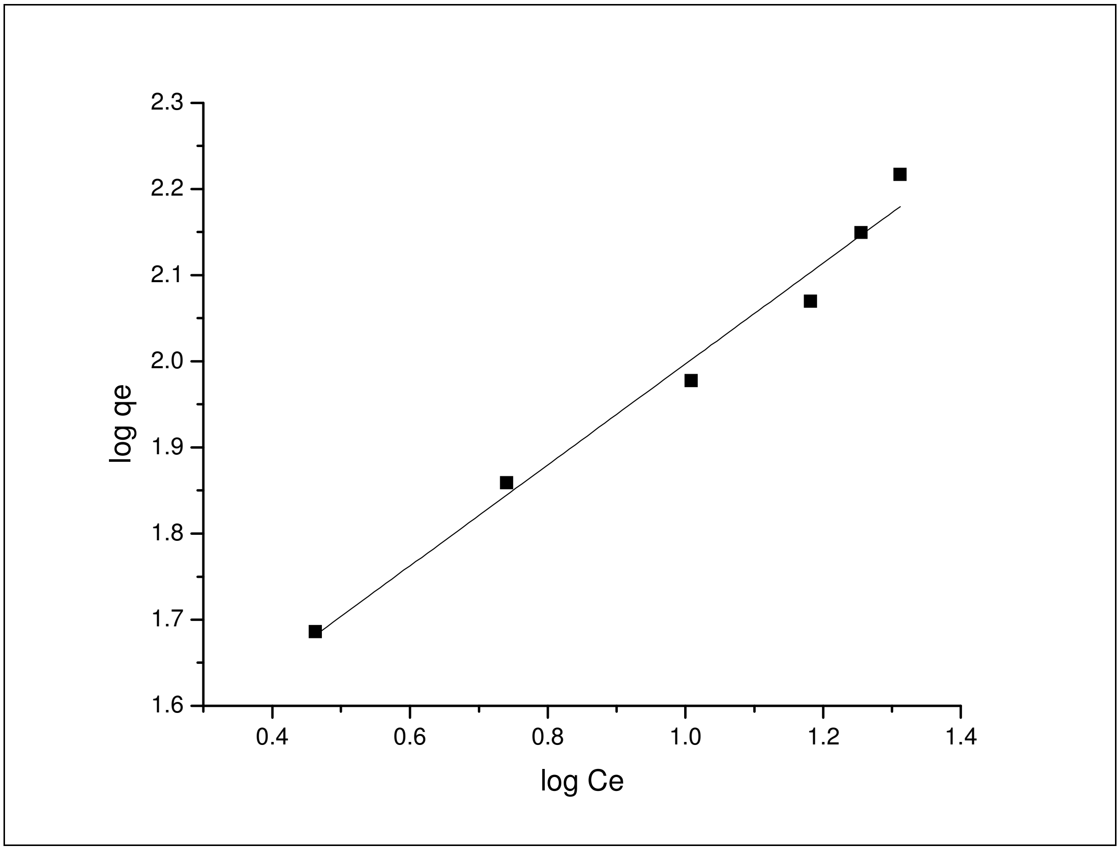

Figure-6
Application of Freundlich isotherms for the removal of Naphthol Green by using ABN

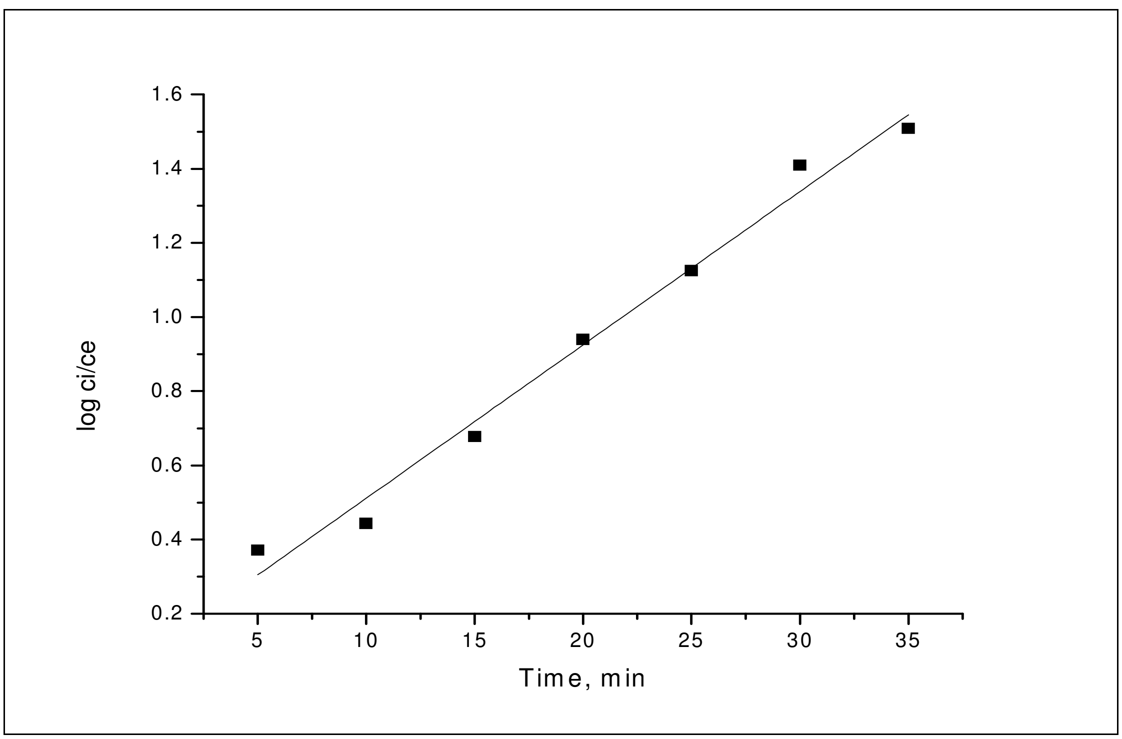

Figure-7
Nataragan and Khalf equation for the removal of Naphthol Green dye by using ABN

Conclusion

This study showed that Acid activated Bentonite (ABN) acts as a very effective adsorbent for the removal of Naphthol Green dye from the aqueous solution. This result indicates that the adsorption process reached to 30 minutes and the dye removal was 96.1% with the optimum dye concentration of 200ppm, dose 2g/L and pH 2. The linearity of the curve and correlation coefficient value of isotherms such as Freundlich and Langmuir shows that the system covered monolayer adsorption.

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