REMOVAL OF CARCINOGENIC DYES FROM TEXTILE EFFLUENTS BY USING ACTIVATED CARBON PREPARED FROM AGRICULTURAL WASTE

T. V. NAGALAKSHMI[1], K. A. EMMANUEL[2], V.A.N.SATISH[3], K.JOHAR[4], D.S.PAVAN KUMAR[5], P.N.V.PRASADA RAO[6]

[1]Department of Chemistry, LakiReddy BaliReddy College of Engineering, Mylavaram -521230, A.P., India.

[2,3,4,5,6]Department of Chemistry, Sir C.R.Reddy Autonomous College, Eluru-534 007, A.P., India.
*E-mail address: mannava_laxmi@yahoo.co.in

ABSTRACT

In the present paper adsorption technique was employed for removal of Basic Blue 54 dye. Basic Blue 54 dye is a carcinogenic dye which comes in the effluents of textile industries during dyeing and rinsing processes. The technique was found to be very useful and cost effective for a better removal of dye. Although commercial activated carbon is a preferred sorbent for colour removal, its wide spread use is restricted due to high cost. Currently, the study of activated Jack fruit carbon as a low cost sorbent for removing dye has drawn attention of various researchers working in this field. In the present work, Jack fruit carbon (JC) in the form of powder was investigated for removing dyes taking Basic Blue 54 as a model system. The adsorbent was made from Jack fruit procured from Paderu and was investigated under variable system parameters such as agitation time and dose of adsorbent. An amount of 0.1 g/l of JC could remove 10 to 99 % of the dye from an aqueous solution of 50 ppm with the agitation time increasing from 20 min to 40 min. The interactions were tested for both pseudo first- order and second – order kinetics and it was observed that the interactions could be better explained on the basis of pseudo second order kinetics.

Keywords: Activated carbon, adsorption, effluents, Basic Blue 54, contact time, kinetics

I. INTRODUCTION

Colored wastewater could be generated from several industries such as textile, ceramic, rubber, paper, leather, printing, plastic, cosmetics, etc. These industries commonly use synthetic dyestuff as their colorant [1-3]. Discharge of this dye-containing-wastewater into environment can contaminate surface water and ground water system [4]. The presence of dyes even in very small amounts in water system is undesirable since dyes are highly visible and can result in a hazard to the aquatic life [5]. Furthermore, some of dyes have been reported to be mutagenic and carcinogenic especially for human [1, 6].

In the present study we used nitric acid as activating agent for activated carbon preparation using jackfruit (*Artocarpus heterophyllus*) peel waste as the precursor [7]. Here we used the activated carbon from jackfruit peel to remove Basic blue 54 from aqueous solution. The adsorption equilibrium and kinetic of Basic blue 54 onto activated carbon prepared from jackfruit peel waste were also studied. Basic blue 54 (BB 54) is one of frequently used dyes.

Material and Methods

Preparation of activated carbon

Jackfruit of pichiparai-1 variety was selected; its rind and pulp waste was washed with hot distilled water to remove dirt and dehydrated at 105°C until constant weight was obtained. This dried waste was then cut into small pieces and was mixed with K_2CO_3 solution at impregnation ratio 1. Impregnation ratio (IR) was given by weight of K_2CO_3 (g) in solution/weight of waste in g. It was dehydrated in an oven overnight at 105°C. The impregnated material was carbonized in uniform nitrogen flow at 600°C. The heating was provided at rate of 10°C min^{-1} from room temperature. The prepared carbon was cooled to room temperature and washed with hot distilled water to remove remaining chemical and filtered. The washing and filtration steps were repeated until the filtrate showed neutral pH. The activated carbon was sieved to 45mesh. They were subjected to liquid phase oxidation with 0.1N HNO_3 for 3hours individually. The filtered carbons were washed with distilled water until filtrate showed neutral pH. They were dehydrated in an oven overnight at 105°C.

Preparation of Adsorbate

All reagents used in this study are of analytical grade. The cationic textile dye, BB54, used in this experiment was supplied by SIGMA ALDRICH. It is directly taken to prepare stock solution without further purification. Stock solution (1000 mg l^{-1}) of dye was prepared by dissolving 1g dye into one liter double distilled water. The structure of the BB54 was shown in *Figure 1*.
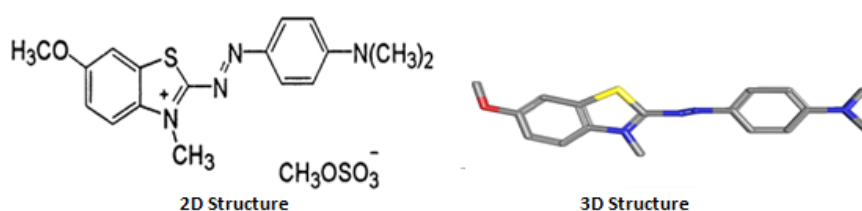

Figure 1. Structure of C.I. Basic Blue 54

Batch adsorption studies

All experiments were carried out in 250 ml conical flasks with 100 ml test solution at room temperature (25 ± 2°C). The flasks, along with test solution and 0.5g of the adsorbent for BB54 at neutral pH, were shaken in horizontal shaker at 120 rpm to study the equilibration time (10-100 min) for maximum adsorption of dye and to know the kinetics of adsorption process. At the end of the desired contact time, the samples were filtered using Whatman no. 42 filter paper and filtrates were analyzed for residual dye concentration. Test solution of dye of 50 mg l^{-1} concentration was prepared from fresh stock solution. All the experiments were carried out in 250 ml conical flasks with 100 ml test solution at room temperature (25 ± 2^{0}C). These flasks, along with test solution and adsorbent, were shaken in horizontal shaker at 120 rpm to study the various control parameters. At the end of desired contact time, the conical flasks were removed from shaker and allowed to stand for 2 min for settling the adsorbent. The adsorbent and dye solution were separated using filtration method. The samples were filtered using Whatman no. 42 filter paper, the first part of the filtrate was discharged to avoid the effects of adsorption on to the filter paper and the remaining filtrate was analyzed for residual dye concentration using UV visible spectrophotometer. To correct any adsorption of dye on containers, control experiments were carried out in duplicate.

$$\% \ removal = \frac{(C_i - C_e)}{C_i} X100 \ldots\ldots\ldots\ldots\ldots (1)$$

$$Amount \ adsorbed \ (q_e) = \frac{(C_i - C_e)}{m} V \ldots\ldots\ldots\ldots\ldots. (2)$$

Where C_i = initial concentration of dye solution in mg l^{-1} C_e = equilibrium concentration of dye solution in mg l^{-1} m = mass of the adsorbent in grams (g)

V = Volume of test solution in litres (l)

Effect of adsorbent dosage

The percentage removal of BB54 by adsorption onto JC_{HNO3} in the range 0.1 to 1g with 50 mg l^{-1} initial concentration of dye and agitation time of 60 min at pH 7 and at temperature (25±2^{0}C) was studied. The results are presented as percentage removal of dye versus adsorbent dosage in *Figure 2*.
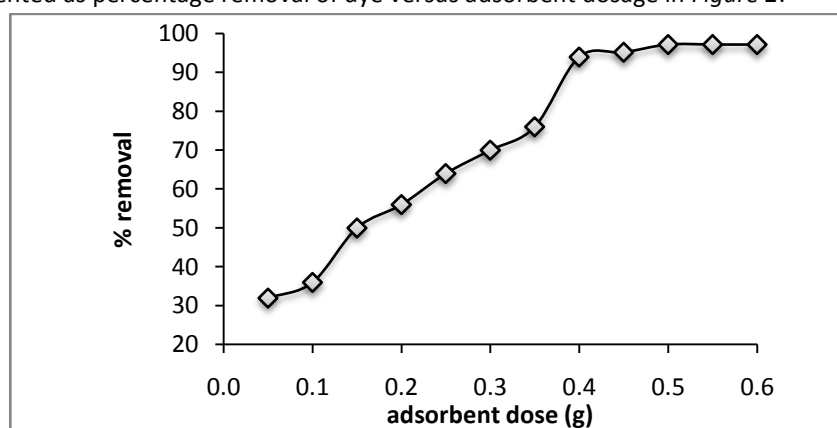

Figure 2. Effect of adsorbent dose on BB 54 dye removal

Effect of contact time

In order to study the effect of contact time which is related to kinetics of adsorption of dye by JC_{HNO3}, the adsorption experiments have been conducted in the extent of removal of dye at an optimum initial concentration of dye of 50 mg l^{-1} with optimum dose (0.5g) of adsorbent at pH 7 and at room temperature (25±2°C) by varying the agitation time from 5 to 60 min. The time profile of adsorption of dye onto adsorbent is presented in *Figure 3.*
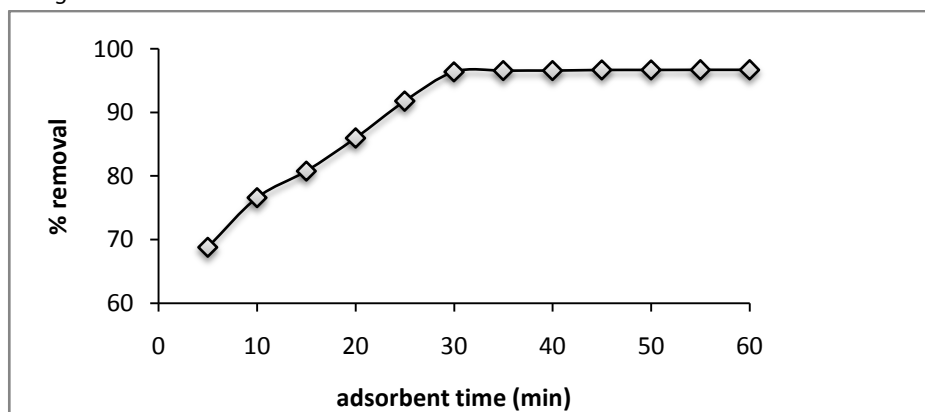

Figure 3. Effect of contact time on BB 54 dye removal by JC_{HNO3}

Effect of initial concentration of dye

The effect of initial concentration of dye on the extent of removal of dye in terms of percent removal and amount of the dye adsorbed on prepared JC_{HNO3} has been studied by varying the initial concentration of dye (range: 10 – 120 mgl^{-1}) and keeping the other control parameters at their optimum conditions. The effect of initial concentration of BB54 on adsorption is shown in Figure 4.
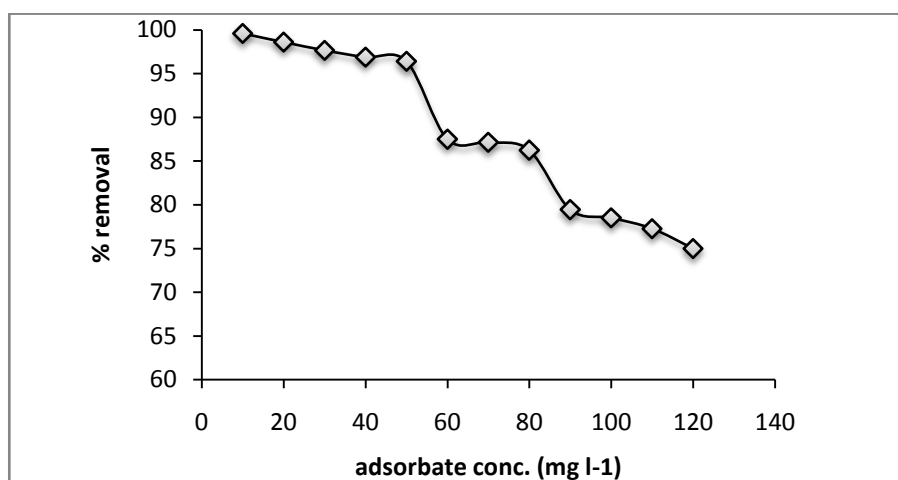
Figure 4 Effect of adsorbate concentration on BB 54 dye removal by JC$_{HNO3}$

Effect of pH

The effect of pH on adsorption was studied by varying the pH from 3 to 11 under constant process parameters i.e., the initial concentration of the standard dye solution which is 50 mg l^{-1}, the dose of adsorbent is 0.5 g and contact time of 40 min and at room temperature (25±2°C). The results were depicted in Figure 6.
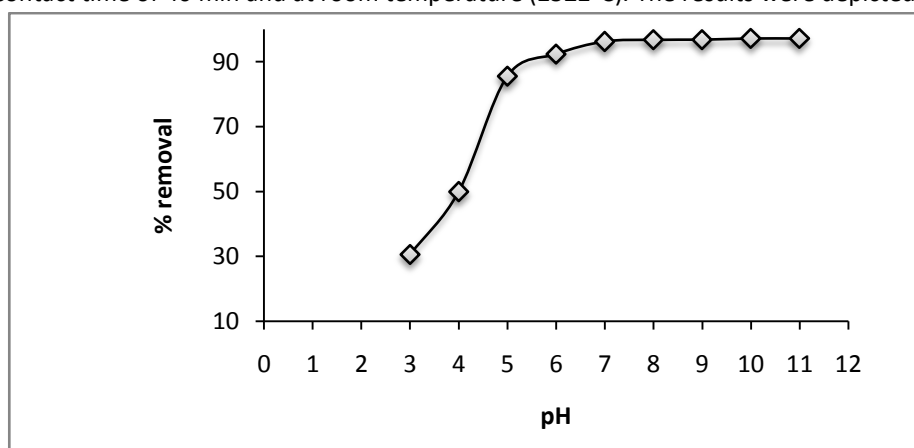

Figure .5 Effect of solution pH on BB 54 dye removal by JC$_{HNO3}$

Adsorption kinetics

To study the adsorption kinetics five kinetic models were used which include pseudo-first-order [8] pseudo-second order [9], Weber and Morris intraparticle diffusion [10], Bangham's pore diffusion [11] and Elovich models [12]. The relevant equations and results are tabulated in *Table 1*.

Table 1. *The adsorption kinetics of BB 54 on JCHNO3*							
Pseudo first-order							
Adsorbent	Adsorbate	$q_{e(expt.)}$ (mg g^{-1})	$k_1 \times 10^{-1}$ (min^{-1})	$q_{e(Cal.)}$ (mg g^{-1})	SSE	R^2	
JC$_{HNO3}$	BB 54	9.640	0.8452	4.7087	0.26168	0.9362	
Pseudo second-order							
Adsorbent	Adsorbate	$q_{e(expt.)}$ (mg g^{-1})	$k_2 \times 10^{-1}$ (g mg^{-1}min^{-1})	$q_{e(Cal.)}$ (mg g^{-1})	SSE	R^2	
JC$_{HNO3}$	BB 54	9.640	0.3213	10.2669	0.00423	0.9975	
Intraparticle diffusion							

Adsorbent	Adsorbate	$q_{e(expt.)}$ (mg g^{-1})	k_{ip}X10^{-1} (mg g^{-1} min$^{-0.5}$)	$q_{e(Cal.)}$ (mg g^{-1})	SSE	R^2	
JC$_{HNO3}$	BB 54	9.640	8.388	9.5484	0.00009	0.9920	
Pore diffusion							
Adsorbent	Adsorbate	$q_{e(expt.)}$ (mg g^{-1})	k_0 (ml(g l^{-1})$^{-1}$)	$q_{e(Cal.)}$ (mg g^{-1})	SSE	R^2	A
JC$_{HNO3}$	BB 54	9.640	5.6519	9.1000	0.00314	0.9351	0.152
Elovich equation							
Adsorbent	Adsorbate	$q_{e(expt.)}$ (mg g^{-1})	β	$q_{e(Cal.)}$ (mg g^{-1})	SSE	R^2	A
JC$_{HNO3}$	BB 54	9.640	0.8034	9.3516	0.00090	0.9351	2.1714

Results and discussion

The BET surface area of JC$_{HNO3}$ was found to be 987m^{2}g^{-1}. The study of effect of adsorbent dose found that the optimum amount of JC$_{HNO3}$ for removal of dye was fixed for further analysis. At 0.5g the percentage removal of dye was found to be 97.20%. From *Figure 2* it is clear that the rate of removal of dye was found to be increased rapidly with increase of carbon doses and slowed down later. When the dose increased from 0.5-1g.This could be attributed to increasing adsorbent surface area, augmenting the number of adsorption sites available [13].

From *Figure 3* it is evident that, as contact time was increased, initially the percentage removals also increase. But after 30min, it gradually approach constant value, denoting attainment of equilibrium, so 30min was fixed as optimum contact time for further. The changes in the rate of removal of dye with time might be due to the fact that initially all adsorbent sites were vacant and the solution concentration gradient was high. Later the dye uptake rate by adsorbent was decreased significantly due to the decrease in available active adsorbent sites. Decreased removal rate, particularly, towards the end of experiment indicates that the possible monolayer adsorption on surface of adsorbent. In *Figure 4* it was observed that as dye concentration increase the percentage removal of dye was decreased from 99.80 to 73%. It could be explained by the fact that, at low adsorbate concentration, the ratio of surface active sites to total dye is high. Hence dye molecules have more number of available active sites at low concentration. But with the increase in adsorbate concentration, the number of active sites was not enough to adsorb dye molecule dye ions. However at 50mgl^{-1} the percentage removal of dye was 96.40% and it was fixed as optimum concentration of dye solution. In *Figure 5* it was depicted that the percent removal of dye increased from 20-50% after that it was going on increasing and reached 99.8% at alkaline P^H 12, at neutral P^H also the percent removal was 96.4% and it was taken as optimum P^H. From *Table .1* the high R^2value (0.9975) and low SSE value (0.00423) indicates the sorption process can be well described by pseudo -second order model confirming to other well established models. It predicts the behaviour over the whole range of studies and it is in agreement with the chemisorptions mechanism being the rate controlling step [14].

Conclusion

The prepared JC$_{HNO3}$ successfully removed Basic Blue 54 dye from its 50 mg l^{-1} aqueous solution. The adsorption process reached equilibrium time within 30 min and the required adsorbent dose is 0.5g. The kinetics of the process was best described by pseudo second order pattern. It indicates that dye was chemisorbed. However, pore diffusion is one of the rate controlling steps during sorption process.

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