Effect of Process Parameters on Adsorption of Methylene Blue from Synthetic Effluent Using Jack Fruit Seed Powder

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Abstract- Batch sorption experiments were carried out using jackfruit seed powder (JSP), for the removal of Methylene Blue (MB) from dyeing synthetic effluent waste water. Effects of process parameters pH, adsorbent mass, adsorbate concentration, contact time and temperature were studied. The adsorption process attains equilibrium within 60 minutes. The amount of MB adsorbed per unit mass of the adsorbent increased with increase in adsorbate concentration and contact time, while decreased with increase in adsorbent mass and temperature. The results obtains suggest that JSP can be successfully used as an adsorbent for treating aqueous solution containing MB with low contact times (less than 20 minutes contact) of adsorbent/dye concentration. JSP is an inexpensive and easily available material, can be an alternative for more costly adsorbent used for dye removal in wastewater treatment processes.

Keywords – Adsorption, Jackfruit seed powder, Methylene blue, Adsorbate, Adsorbent, Contact time, Equilibrium,

I. INTRODUCTION

Methylene Blue (MB) or tetramethylthionine chloride is a cationic dye, which is most commonly used for colouring among all other dyes of its category. Though MB is not hazardous compared to other dyes, acute exposure to MB will cause increased heart rate, vomiting, harmful effects on inhalation and shock [1,2]. Hence, the necessity for the dye containing water to undergo treatment before disposal to the environment [1]. Among different treatment processes, adsorption has been found to be an efficient and economic technology to remove dyes, pigments and other colorants because of low initial costs, simplicity of design, ease of operation and insensitivity to toxic substances [3]. In this regard, Jackfruit seed powder (JSP) is a cheap and easily available agricultural biomass which could be an alternative for more costly adsorbents such as activated carbon used in wastewater treatment [4-6]. The aim of this work was to evaluate the adsorption potentiality of JSP for the removal of MB dye from aqueous solutions so as to facilitate the use of this adsorbent in developing countries like India. In fact, the advantage of the use of waste materials as adsorbents is their low cost, versatility and easy operations [7]. The effects of changing different parameters were studied along with kinetic mechanism of the adsorption process.

II. MATERIALS AND METHODS

A. Adsorbent –

Jackfruit seed powder (JSP) used in this study was prepared from the jackfruit seeds (Figure 1) obtained from the vegetable market in Nedumangad, Kerala, India. The seeds were washed with distilled water to remove all dirt and dried at 60º C for 24 hours. The dried seeds were coarsely powdered using domestic mixei. The powder was sieved with 200 mesh size and particle size less than 0.075mm was used as adsorbent for the present study.

(a) (b)

Figure 1. (a) Raw Jackfruit seed (b) Jackfruit seed powder (JSP)

B. Adsorbate –

Methylene blue (MB) supplied by Fine Chemical Division (Indian Drugs and Pharmaceuticals Ltd.) was used as an adsorbate. The chemical formula of the dye is $C_{16}H_{18}N_3SCl.3H_2O$ and the structural formula is given in Figure 2. The aromatic moiety of MB is planar and it contains N and S atoms. Dimethylamino groups are attached to the aromatic units. The stock solutions of MB (1000 mg/L) were prepared by dissolving 1 g of methylene blue in 1 L of distilled water. All working solutions were prepared by diluting the stock solution with distilled water to the desired concentration. Analytical grade HCL and NaOH was used for adjusting the variation of pH.

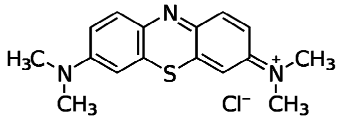

Figure 2. Structure of Methylene Blue

C. Batch Adsorption studies –

Adsorption studies of MB using JSP were carried out using batch adsorption method. Batch adsorption experiments were conducted by placing known amount of adsorbent into separate 250 ml conical flask. 100 ml aqueous solutions containing MB (synthetic effluent) of desired concentrations was added to the flask. The flask was then placed on an oscillatory shaker. The samples were agitated at 150 rpm for contact time of 10, 20, 30, 40 and 60 minutes at constant temperature. The tests were run in triplicates. After each contact time, the samples were filtered for residual MB concentration measurements. The concentration was determined using a UV-VIS spectrophotometer (UV100 Series double beam Spectrophotometer) at a maximum adsorption of 650 nm wave length [8]. Batch mode adsorption experiments are carried out by varying initial dye concentration, temperature and pH.

Effect of pH –

The amount of dye removal and effect of pH was analyzed over the pH range of 2 to 12. The pH was adjusted by using 0.1N NaOH and 0.1N HCl solutions. 100 ml of MB solution having a concentration of 100 mg/L was agitated with 0.2 g of JSP in mechanical shaker at 150 rpm and 303 K for different intervals of time to know the effect of pH. The absorbance of filtrate was measured and optimum pH was selected for further studies.

Effect of adsorbent mass –

A series of experiments were performed to know the effect of adsorbent by varying the amount of adsorbent dosage from 0.05 g to 0.4 g. The measurement was carried out by agitating 100 ml of MB solutions of initial concentration of 100 mg/L for about 60 minutes. Residual dye concentration was analysed for every 10 minutes using UV-spectrophotometer.

Effect of initial dye concentration –

The effect of initial dye concentration was estimated for every 10 minutes by contacting 0.2 g of JSP with 100 ml of MB solutions at different initial concentrations ranging from 20 to 100 mg/L for 60 minutes. Experiments were performed at optimum pH and temperature of 303 K.

D. Sorption equilibrium and Sorption kinetics –

Sorption equilibrium was studied at three different solution temperatures of 303, 313 and 323 K. Equilibrium experiments were performed by contacting 0.2 g of JSP with 100 ml of dye solution of different initial dye concentration 100, 80, 60, 40, 20 mg/L. The kinetics of adsorption was determined by analysing adsorptive uptake of MB from the aqueous solution at different time intervals. The adsorption density (Q_t) defined as the amount of MB adsorbed per unit weight of adsorbent (JSP) at time *t* [9]. The Q_t (mg of MB/g of JSP), was calculated based on equation (1):

$$Q_t = ((C_o - C_t)V) / M \qquad (1)$$

where C_o and C_t (mg/L) are the concentration of MB at initial time and any given time *t*, respectively. *V* is the volume of solution (L), and *M* is the mass of adsorbent used (g). For adsorption isotherms, 100 ml of MB solutions of different initial concentrations (100, 80, 60, 40, 20 mg/L) were agitated with 0.2 g adsorbent till the equilibrium was attained. The adsorption density at equilibrium (Q_e) (mg/g), was calculated by equation (1) where C_t was replaced by C_e, the concentration of MB at equilibrium.

III. EXPERIMENT AND RESULTS

Effect of pH

The effect of pH on adsorption studies corresponding to varying Q_e (mg/g) values is showed in Figure 3. Here Q_e was obtained by the mass balance equation $Q_e = [((C_o - C_e)V) / M]$. From Figure 3, it was observed that the solution pH (2 to 12) affects the amount of dye adsorbed in the synthetic effluent medium. The dye sorption behaviour of the JSP bio-sorbent relative to solution pH can be described by several reasons. There are large numbers of active sites on the surface of JSP to which the solute uptake can be related. The chemistry of solute in the effluent solution plays an important role in describing the behaviour of its ions. As the pH of the system increases, the number of positively charged sites increases. Subsequently, the negatively charged sites favour the adsorption of dye cations due to electrostatic attraction. It is also possible that at lower pH the protonation of COO^- species present in JSP occurs, precluding the electrostatic attraction with the MB decreasing the adsorbate uptake. At lower pH, the surface charge may get positively charged, thus making H^+ ions compete effectively with the dye cations causing a decrease in the amount of dye adsorbed (mg/g).

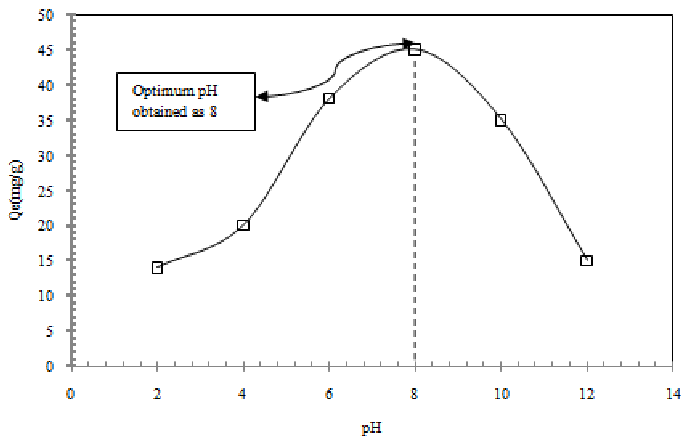

Figure 3. Effect of pH on amount of MB adsorbed at initial dye concentration of 100 mg/L, adsorbent dose 0.2 g/100 mL, equilibrium time 1h, temperature 303 K and agitation speed 150 rpm

Effect of adsorbent mass

Figure 4 show the plot between the amounts of dye adsorbed *Qe* (mg/g) against adsorbent mass (g). From the figure it was observed that, the amount of dye adsorbed is varied with varying sorbent mass in the synthetic effluent medium and it decreases with increase in adsorbent mass. The possible reason may be all the active sites are completely exposed and utilized at lower JSP dosage in the medium. Moreover, we speculate that only part of the active sites were exposed and occupied by MB at higher JSP dosage. Hence, the present adsorption studies describe a falling *Qe* values with respect to the adsorbent mass as depicted in Figure 4.

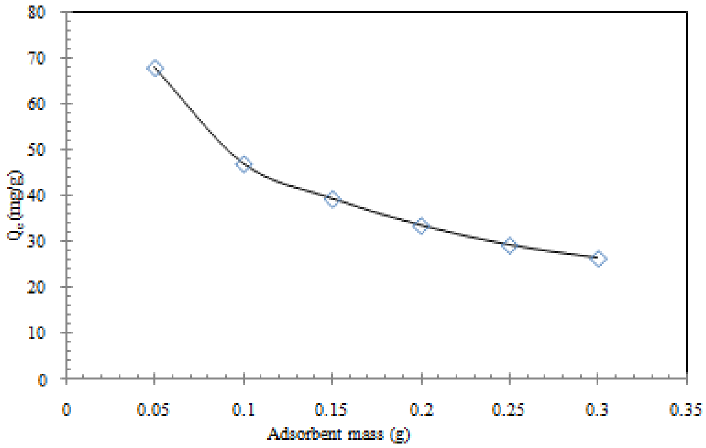

Figure 4. Effect of adsorbent mass on adsorption at initial dye concentration of 100 mg/l, equilibrium time 1h, pH 8, temperature 303K and agitation speed 150 rpm

Effect of initial dye concentration

Figure 5 show the plot between amounts of dye adsorbed Q_t (mg/g) versus time (min) for initial dye concentration of 20, 40, 60, 80 and 100 mg/L. It was observed that the amount of dye adsorbed Q_t (mg/g) increased with respect to an increase in initial dye concentration from 20 to 100 mg/L. During the adsorption process, initially the dye molecules reach to the boundary layer and then they diffuse into the porous structure of the adsorbent. This phenomenon takes a relatively longer contact time [10]. Figure reveals that the curves are single, smooth, and continuous, leading to saturation, suggesting the possible monolayer coverage of MB on the JSP surface. The amount of dye adsorbed (mg/g) increased with increase in time and then reaches to equilibrium (Figure 5).

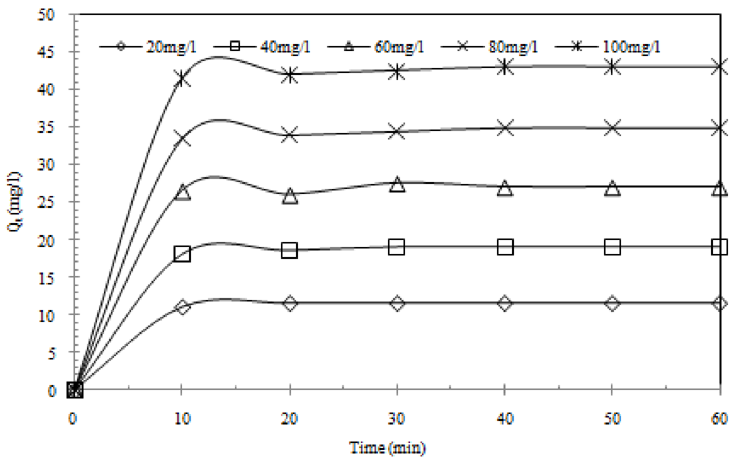

Figure 5. Effect of initial dye concentration with respect to amount of dye adsorbed at equilibrium time 1h, 303K , adsorbent dose of 0.2 g/100 ml, pH 8, and agitation speed 150 rpm

Figure 6 depicts the plot between amounts of dye adsorbed Q_e (mg/g) versus initial dye concentration (mg/L). The amount of dye removed at equilibrium increased with an increase in initial dye concentration from 20 to 100 mg/L. The initial dye concentration provides the necessary driving force to overcome the resistances to mass transfer of MB between the aqueous and solid phase.

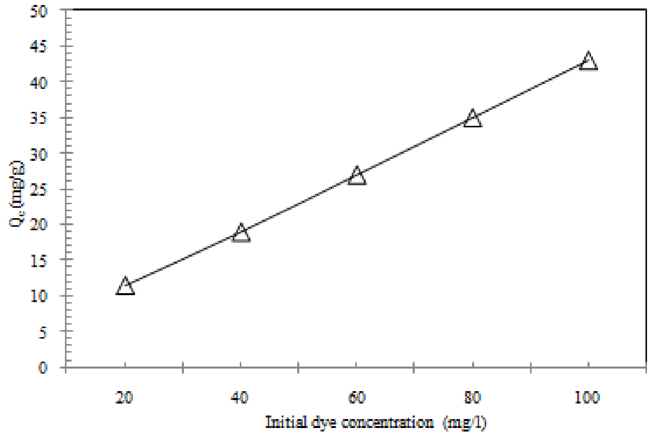

Figure 6. Effect of initial dye concentration corresponding to the amount of dye adsorbed (Q_e) at 303K, adsorbent dose 0.2 g/100 ml, equilibrium time 1h, pH 8 and agitation speed150 rpm

Sorption equilibrium

Figure 7 shows sorption equilibrium studies at three different solution temperatures of 303 (30°C), 313 (40°C) and 323 (50°C) K. The major effect of temperature on the adsorption rate of MB onto JSP is influenced by diffusion rate of adsorbate molecules and internal pores of the adsorbent particles. It is observed that the equilibrium adsorption uptake decreases with increases in temperature at all the concentrations were studied (20, 40, 60, 80, 100 mg/L) as depicted in Figure 7.

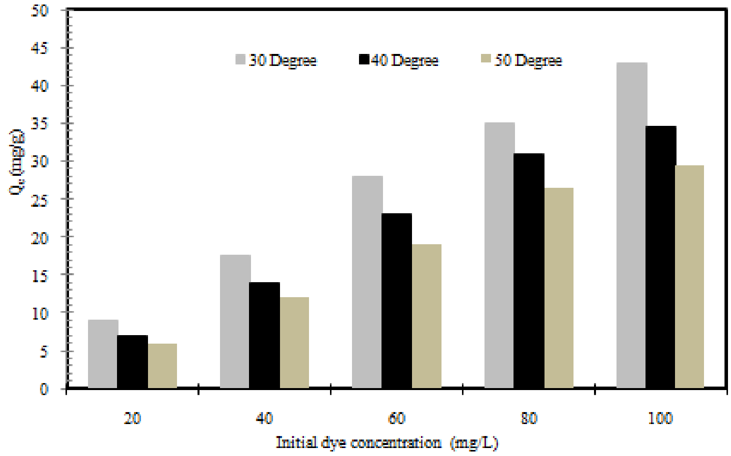

Figure 7. Effect of temperature on dye adsorption at equilibrium against initial dye concentration at different temperatures 30, 40 and 50 °C

IV. CONCLUSION

Jackfruit Seed Powder has been proven to be an effective adsorbent for removal Methylene Blue from dyeing effluent wastewater. Effects of process parameters such as pH, adsorbent mass, adsorbate concentration, contact time and temperature were studied. The adsorption process attains equilibrium within 60 minutes. The amount of MB adsorbed per unit mass of the adsorbent increased with increase in adsorbate concentration and contact time, while decreased with increase in adsorbent mass and temperature. Optimum pH for adsorption was found to be 8 and at temperature 30ºC. The results obtained from this study conclude that JSP can be successfully used as an adsorbent for treating aqueous solution containing MB. In future, JSP can be an alternative for more costly adsorbent used for dye removal in wastewater treatment processes.

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