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Sorption Studies of Methylene Blue on Silica Gel

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***Abstract*—The removal of methylene blue (a basic dye) from its aqueous solution by adsorption on silica gel has been carried out. It has been noted that low adsorbate concentration, low temperature and basic medium favor the removal of the dye. A 95.2% removal of the methylene blue was achieved at 25 mg/liter dose, 35^{O}C & at pH 10.The kinetics studies were made using the model suggested by Langergren. The rate constants were found to be 1.22/min for 30^{O}C and 6.58/min for 35^{O}C. The equilibrium data fits well in the Langmuir and Freundlich model of adsorption. Effect of temperature was studied. Fixed bed studies were made in a glass column. It was found that at 1.6cm of adsorbent bed height, 97.6% removal was possible. The adsorption capacity of silica gel has been estimated as 195 mg/liter in fixed bed study.**

***Index Terms*—basic dye, textile wastewater, adsorption, silica gel, capacity.**

I. Introduction

The removal of colour from textile wastewater is one of the major environmental problems because of the treatment of such water by conventional methods. Colored waters are also objectionable on aesthetic ground for drinking and other municipal as well as agriculture purpose[1],[2],[3].Many colored effluents are composed of non-biologically oxidisable organic components because of the molecular size and structure of the dyestuffs. The increasingly tighter legislation of effluent discharges in most countries will bring new developments, resulting in considerably smaller amount of effluents [4]. Adsorption is a physico-chemical process which offers great potential for treating effluents containing undesirable components and render them safe and reusable.[5],[6],[7]**,[**8].The feasibility of using silica gel for adsorption of a methylyne blue has been tested in this study. The major advantage of an adsorption system for water pollution control, are low investment in terms of both initial and land cost, simple design easy operation and no effect by toxic harmful substance [9]. Adsorption offers an attractive method of treatment for producing high quality colorless effluents. It is important to study the dependence of initial and final concentration of the adsobate on the contact time with the adsorbent under several operating conditions. Various low cost material such as, bagasse pith [10], Fullers earth [11], Activated carbon [12], Ash cinder [13], Coconut husk [14], Aquatic Plants [15] have been investigated with varying degrees of success.

The present investigation reports on the use of silica gel to adsorb the dye-methylene blue from aqueous solution in a batch and column study.

II. Materials and Methods

Stock solution of dye was prepared by dissolving 200mg of dye/liter of double distillated water was taken in a 250 ml beaker and a known quantity of adsorbent i.e. Silica gel was added to it .The pH of the solution was adjusted to a desired value using HCL & NaoH. After pH adjustment the temperature of the solution was also adjusted at the end of reaction time. The solution was filtered through the whatman filter paper No.42 and the filtrate was taken to analyses the dye present in the solution by UV spectrophotometer (systronics-118) at 665 nm. In order to have a clear picture of the effect of different parameters on the adsorption of dye, the experiments were carried out at different initial concentrations, dosages, pH, and different temperatures. During the uptakes of dye from the solution by adsorption process, two factors namely; concentration of dye in the solution and time of contact between adsorbate and adsorbent phases, play an important role. A rapid transport of adsorbate cuts through the equilibrium period. The time taken to attain the equilibrium is important to predict the efficiency and the feasibility of the adsorbent. The experiments were conducted at two different initial concentrations of dye i.e. 25mg/liter & 12.5 mg/liter of solution. The amount of adsorbent is kept fixed at 500 mg & at room temperature i.e.20^{O}C with a pH 8.

Adsorption at Different Adsorbent Doses: -The experiment was carried out to observe the effect of different amount of adsorbent on the adsorption of dye on silica gel. Moreover the experiment was conducted for two concentration of dye solution i.e. 25mg/liter & 12.5 mg/liter to observe comparative study of the two. The experimental procedure was same as described earlier and the total time of experiment was 10 min. The temperature was fixed at 20^{O}C ($\pm$ 5^{O}C) & pH 8.

Adsorption at Different pH Values: -The aim of the experiment was to find out a suitable pH range for the maximum efficiency of the removal process. The experiment was carried out for two different concentration of the dye i.e. 25 mg/liter and 12 .5 mg/liter of solution for each concentration of solution, the temperature was maintained at 20^{O}C ($\pm$ 5^{O}C) . The pH was adjusted by adding 1N HCL or NaoH as desired.

Adsorption at Different Temperature: -Temperature has significant effect on the process of adsorption. Physical adsorption is always an exothermic process and hence any increases in temperature do not favor the extent of adsorption. Therefore at higher temperature silica gel proved to be good adsorbent. The decrease in adsorption density is attributed to the weakening of adsorptive forces between the adsobate and adsorbent and also between the adjacent sites of adsorbed phase. Time rate adsorption studies were carried out at a particular initial concentration of dye solution at 25mg/liter and 12.5 mg/liter and at a particular pH value of 8 of the solution; with total time of the experiment 10 minutes at different temperatures 35^{o}C, 45^{o}C, 55^{o}C, 60^{o}C & 65^{o}C.

Kinetic Study: - Kinetic studies have been carried out by using Freundlich, Langmuir and Langergren equations.

Langmuir Model: - The equation is

$$\frac{X}{M} = \frac{b\,(x\ /\ m)\,Ce}{1 + bCe} \qquad (1)$$

Where b is an adsorption coefficient.

Freundlich Model: -The linear plot of the Langmuir adsorption model suggested the application of the model for the investigated system.

The equation is

$$X = \frac{KC^{1/n}}{M} \qquad (2)$$

here

X =Amount of solute adsorbed

M = Weight of adsorbent

C = Concentration of solute remaining in solution after adsorption is complete.

K and n = Constant that must be evaluated for each solute and temperature.

Langergren's Model: - Kinetic modeling for the removal of methylyne blue by silica gel has been carried out by lageregen's equation.

$$Log(qe - q) = Logq_e - \frac{Kad}{2.303} * t \qquad (3)$$

Where q_e & q = Amounts of dye adsorbed at equilibrium and at time t respectively.

K_{ad} = Rate constant for the adsorption of dye.

Column Studies: Column studies were conducted using down flow technique. A column of 15-mm diameter was prepared. Initial concentration of 200-mg/liter solution was passed through the column. Glass wool was kept at the bottom of the column to avoid the loss of adsorbent with the flow of dye solution. Methylyne blue solution was fed into the column at 5ml/min. To determine exhaustive capacity, fraction of effluent was collected from the bottom of the column. The process was continued until the amount of dye in the effluent was same as that in the feed.

III. Results and Discussion

Effect of Different Initial Concentration and Fixed Dose on Adsorption of Methylene Blue on Silica Gel:-

Initially the rate of adsorption increases due to different in bulk flow and when equilibrium is established the nature of the graph become a straight line as there is decrease in mass transfer as shown in **figure 1**. The equilibrium time is 4 minutes. The time taken to attain equilibrium is independent of the concentration. It was found that 93% removal for 25 mg/liter of dye solution & 94.6% removal for 12.5 mg/liter of dye solution occur.

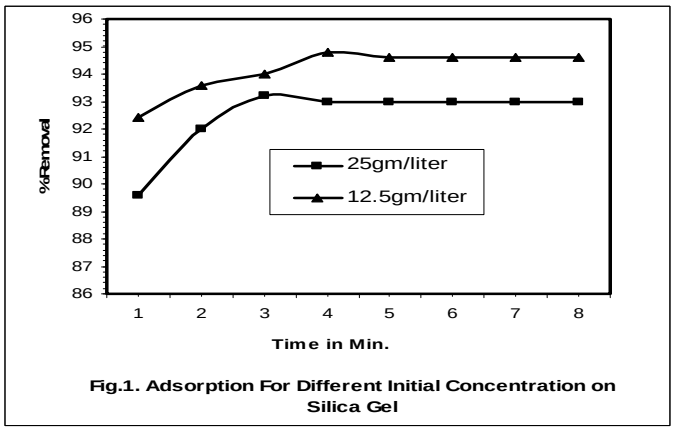

Fig.1. Adsorption For Different Initial Concentration on Silica Gel

Effect of Different Dosages on Adsorption of Methylene Blue on Silica Gel: -

Initially the rate of adsorption increases as dosage increases but after the dose of 600 mg/liter, the rate of adsorption does not increase i.e. it remains constant as shown in **figure 2**.

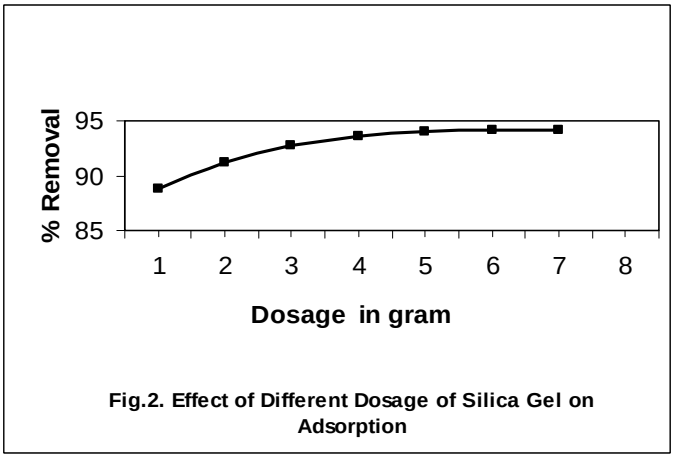

Fig.2. Effect of Different Dosage of Silica Gel on Adsorption

Effect of pH on Adsorption of Methylyne Blue on Silica Gel: -

As the pH increases, the removal of dye also increases. For the good rate of adsorption higher pH is favorable. **Figure 3** has shown the change in the rate of adsorptions due to change in pH. In the range of pH 8 to 10, maximum removal is possible.

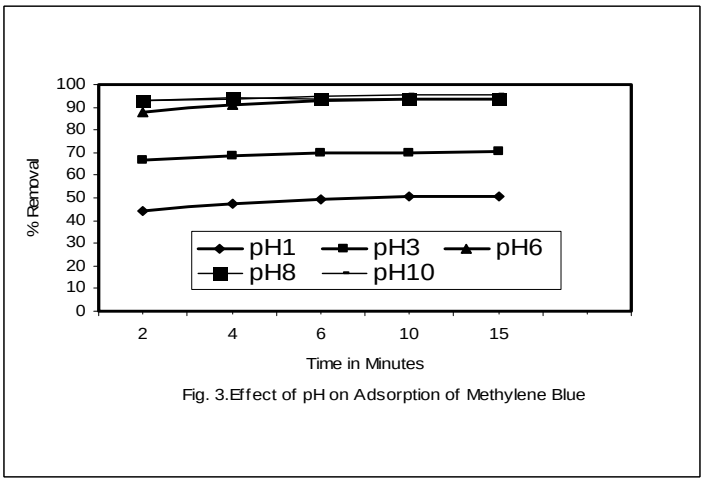

Fig. 3.Effect of pH on Adsorption of Methylene Blue

Effect of Temperature on Adsorption of Methylene Blue on Silica Gel:-

As temperature increases the removal decreases, since it is

an exothermic phenomenon. **Figure 4** shows the rate of adsorption with the change in temperature. The optimum temperature for maximum removal was found to be 35^0C for the finest removal of dye.

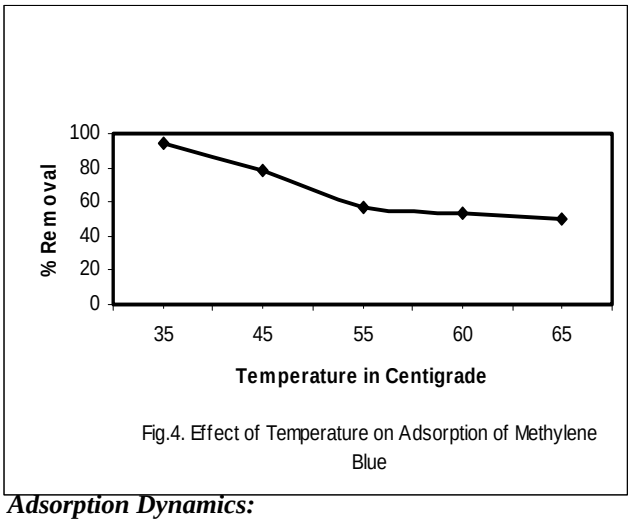

Fig.4. Effect of Temperature on Adsorption of Methylene Blue

Adsorption Dynamics:

Freundlich Model: -The sorption data also follows the linear path as shown in **figure 5.** Thus the applicability of the Freundlich model is justified.

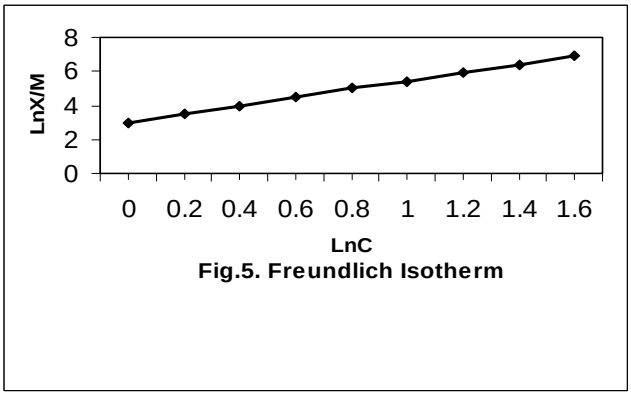

Fig.5. Freundlich Isotherm

Langmuir Model: The linear plot of the Langmuir adsorption model suggested the application of the model for the investigated system shown in **figure 6**.

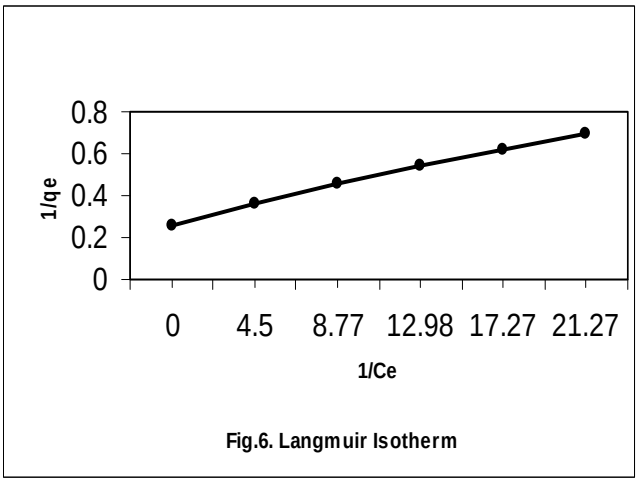

Fig.6. Langmuir Isotherm

Langergren's model: - Kinetic modeling for the removal of methylene blue by silica gel has been carried out by Langergren's equation.

The straight line is shown in **figure 7 and figure 8** indicates the validity of Lageragrens equation and suggests that the removal of methylyene blue follow first order kinetics. The rate constant K for the process is also calculated and found to be 1.22/min for $30\ ^o$C and 6.58 /min for $35\ ^o$C.

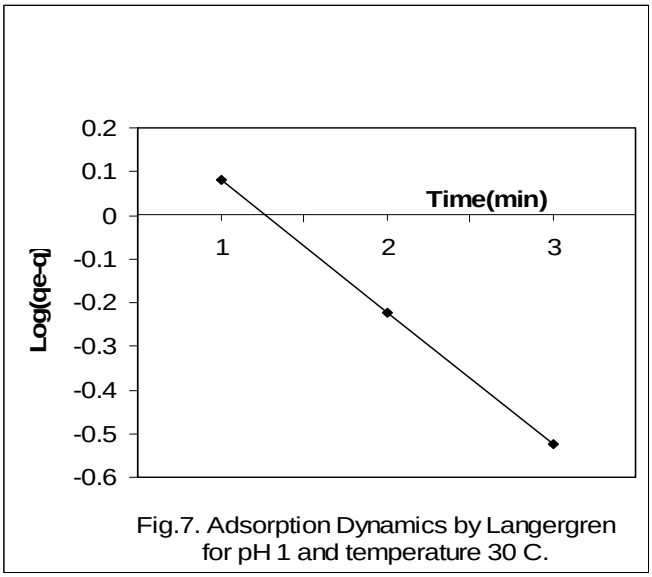

Fig.7. Adsorption Dynamics by Langergren for pH 1 and temperature 30 C.

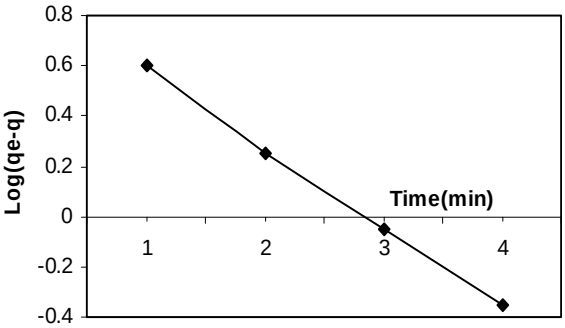

Fig.8. Adsorption dynamics by Langergren for pH 2 and temperature 35 C.

Effect of Bed Heights on Removal of Methylyne Blue:

-Studies on removal of methylene blue at different bed heights are shown in **figure 9**. From the figure, it can be revealed that for 200mg/ltr solution, after 1.6 cm of bed height, removal of dye gets stabilized and are 97.6 %

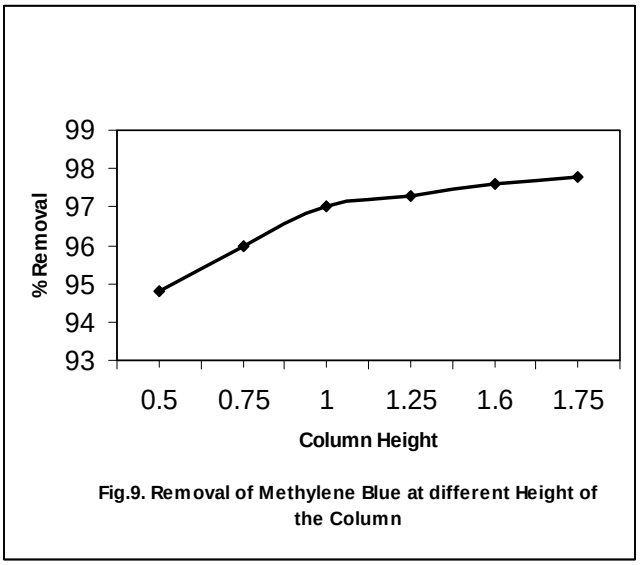

Fig.9. Removal of Methylene Blue at different Height of the Column

Fixed bed Column Study for Adsorption of Dye:

The column study was conducted having initial concentration of 200-mg/lit and pH 8.The parameters of study are given in the table 1.The breakthrough curve obtained is shown in **figure 10.** The breakthrough and exhaustion (ultimate) capacities of the adsorbent were calculated as 170-mg/lit and 195-mg/lit respectively.

IV. Conclusion

Silica gel has good adsorption characteristics towards the methylene blue dye to its desirable limit. Maximum removal of methylyne blue has been obtained in the range of pH 8 to 10 and at a temperature of 35^{O}C. The capacity of adsorption of silica gel is estimated as 195 mg/liter in the batch study. The breakthrough and ultimate adsorption capacities are estimated as 170-mg/lit and 195-mg/liter respectively in the fixed bed study. The parameters studied would be helpful to the engineers in designing the large-scale plants.

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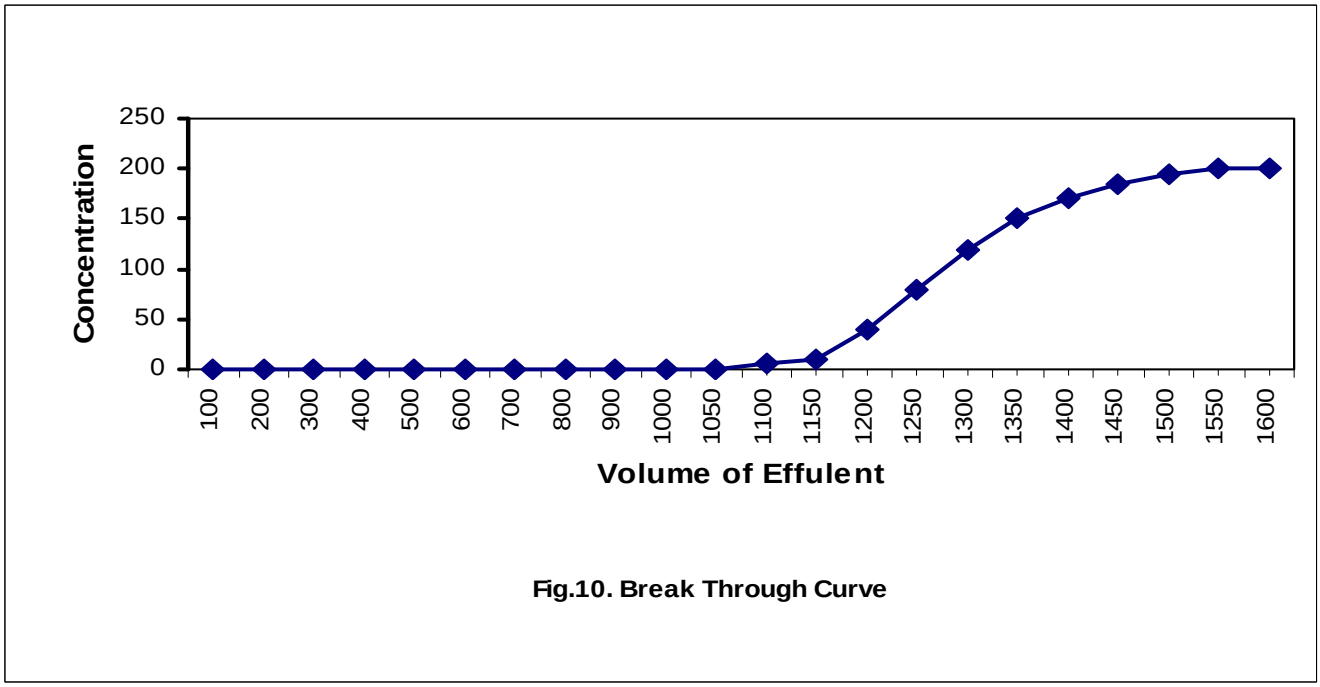

Fig.10. Break Through Curve