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Removal of Methylene Blue Dye Using Low Cost Adsorbent

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Adsorption is an impotent method for colour removal from wastewater. Batch experiments were conducted to assess the potential for removal of methylene blue from aqueous solution by adsorption on to Jack fruit carbon. The equilibrium isotherm was determined and plotted to obtain the Langmuir constants, the Freundlich constants and Peterson constants. It was observed that very short contact time upto 30 min was required for the system to attain equilibrium. The maximum adsorption capacity of Jack fruit carbon was found to be 0.1047 mg of dye/g of Jack fruit carbon.

Key Words: Methylene blue, Removal, Jack fruit carbon, Adsorbent.

INTRODUCTION

Removal of colour from the effluent of dye industry remains a challenging task. Even the presence of very low concentration of dyes (less than 1 mg/L) in the effluent is highly visible and is considered undesirable. The coloured wastewater from industries is harmful to the aquatic life in rivers and lakes due to reduced light penetration and the presence of highly toxic metal complex dyes. Dyes can cause allergic dermatitis, skin irritation, cancer, mutation, *etc*. Reactive dyes are highly soluble in water and their removal from the effluent is difficult by conventional physicochemical and biological treatment methods[1]. Adsorption of reactive dyes have also been investigated by photocatalytic degradation of reactive dye[2], by ozonation[3], in a bubble-column reactor[4], electrochemical process by manganese mineral[5], coagulation[6], ozone membrane separation[7], anaerobic decolourization[8], advanced oxidation with UV/H_2O_2[9]. The adsorption of impurities from solution onto solid materials currently offers an attractive method of wastewater treatment. The process is superior to many other methods of water treatment by virtue of its low initial cost, low energy requirements, simplicity of design and possibility of reusing the spent carbon *via* regeneration. It is necessary to investigate extensively on the relationship between adsorption efficiency and the parameters affecting it. A number of investigators have studied the feasibility of using inexpensive alternative materials like rice husk[10], barley husk[11], coconut-shell based powdered activated carbon[12], de-oiled soya[13], spent brewery grains[14], bagasse fly ash[15], chitson[16], peanut hull[17], neem leaf powder[18] *etc*., as carbonaceous precursors for the removal of dyes from wastewater.

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EXPERIMENTAL

Jack fruit carbon (JFC) was obtained from adsorbent carbon Ltd., Tuticorin. This was then sieved without any treatment to obtain different size fractions. The size fraction between 0.6-1.18 mm was used for subsequent experiments. The dye was bought from Adam colour Co., Chennai. All the colour measurement made using Systronics UV-visible spectrophotometer. The filter user for measurement was 664 -666 nm as specified in the manuel. The instrument was first calibrated by measuring optical densities for the methylene blue solution of known concentrations. Fig. 1 shows the calibration curve where in a linear relationship for a wide range of concentration was observed. Measured quantities of methylene blue was dissolved in water to prepare stock solution for the experiments. The optical density of the solution was again measured and checked for its concentration from the calibration curve.

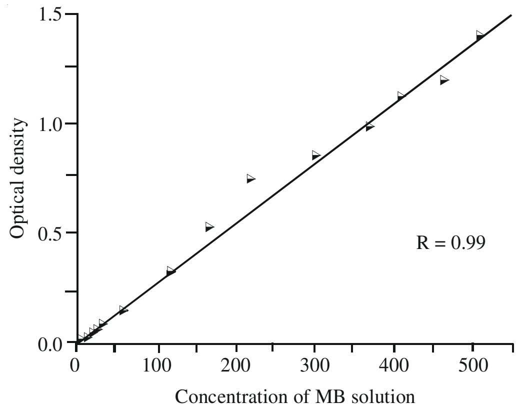

Fig. 1. Calibration curve for Jack fruit carbon

Method: Batch experiments were conducted as per the jar test procedure[19]. The contact time experiments were carried out for 3 different weights of Jack fruit carbon, namely 500, 1500 and 3000 mg. This was added to 500 mL of methylene blue solution of 260 mg/L concentration and agitated in jars at 150 rpm. Samples were collected from the top at regular intervals of 10 min and analyzed for residual methylene blue concentration. For the isotherm studies, 500 mL solution of 260 mg/L of methylene blue was taken in each jar and to that Jack fruit carbon was added in the range of 500-6000 mg in steps of 500 mg. The mixture was agitated at 150 rpm for a contact time of 6 h. After agitation the solution in the flask was allowed to stand for 10 min after which the supernatant was collected for analysis.

RESULTS AND DISCUSSION

Effect of contact time: Fig. 2 shows the effect of variation in the amount of adsorbent on the contact time for a constant initial concentration. It was observed that maximum removal of methylene blue took place within the first few minutes, while equilibrium was attained in *ca.* 2 h. The removal of dye significantly increased when more Jack fruit carbon was added because of more active sits were made available for adsorption. It's important to note that short contact times indicate that the predominant mechanism of adsorption is chemisorptions and hence the process is irreversible[20]. This implies that regeneration of Jack fruit carbon would be very difficult, but, nevertheless due to negligible cost and abundance of adsorbent, it is possible the use of Jack fruit carbon as an alternative for removal of colour.

Adsorption isotherm: The equilibrium adsorption isotherm is a significant criteria for the design of adsorption system. It essentially express the relation between the concentration of the solute in solution at equilibrium with the concentration of the solute adsorbed onto the adsorbent, at constant temperature.

Langmuir isotherm: The basic assumption in the Langmuir isotherm is that sorption takes place at specific sites on the adsorbent and once a site is occupied no further adsorption can take place at that site. This implies that at saturation the adsorbent is covered uniformly by a layer of molecules. This monolayer saturation is represented by the following equation[21].

$$q_e = Q_oaC_e/1 + aC_e$$

where, 'Q_o' and 'a' are isotherm constants for a particular adsorbate/adsorbent combination. A linear form of this expression is:

$$C_e/q_e = 1/Q_oC_e + 1/Q_oa$$

Fig. 3 shows the linear plot of the Langmuir isotherm. The figure exhibits derivation from linearity indicating that the monolayer theory may not be applicable to this system.

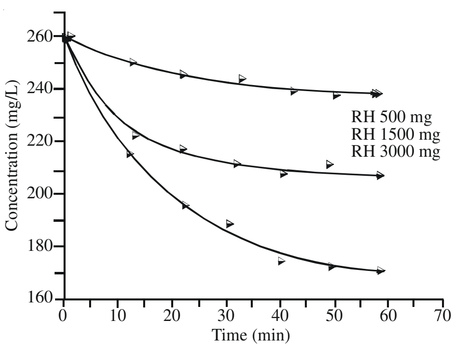

Fig. 2. Effect of dosage on contact time

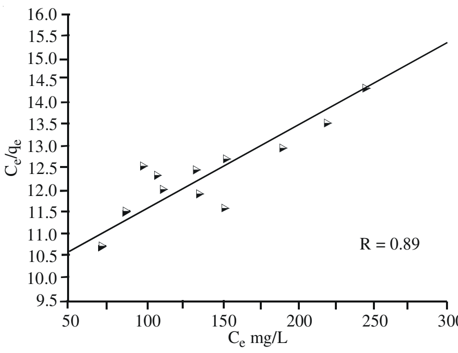

Fig. 3. Langmuir isotherm

The maximum adsorption capacity of Jack fruit carbon as an suitable adsorbent for an colour removal, compared to the other adsorbents is shown in Table-1.

Freundlich isotherm: According to Freundlich isotherm, if the concentration of solute at equilibrium C_e, is rised to the power n and the amount of solute adsorbed

TABLE-1
MAXIMUM SORPTION CAPACITY OF METHYLENE BLUE ON TO OTHER SORBENTS

Sorbent	Q_e mg/g; maximum adsorption capacity	Reference
Magnetic charcoal	20.2000	23
Coal	120.3000	26
Cotton waste	875.2000	26
Neem saw dust	4.4000	28
Jute fiber carbon	28.0000	29
Jack fruit carbon (JFC)	0.1047	Present study

being q_e, then C_e^n/K is a constant at given temperature. This is written in the empirical form as following[22]:

$$q_e = KC_e^n$$

The linear form of this expression is:

$$\ln (q_e) = \ln (K) + n[\ln (C_e)]$$

As can be seen from the Fig. 4, the Freundlich log plot is linear. This can be explain by the fact that according to Freundlich equation the concentration of the dye on the adsorbent increase as the dye concentration in liquid increases. The experimental observation too suggest that the isotherm plateau is not reached event at very high concentration of the adsorbent as seen in Fig. 5. Favourable adsorption process also indicated by the fact that value[23] of n is less than 1.

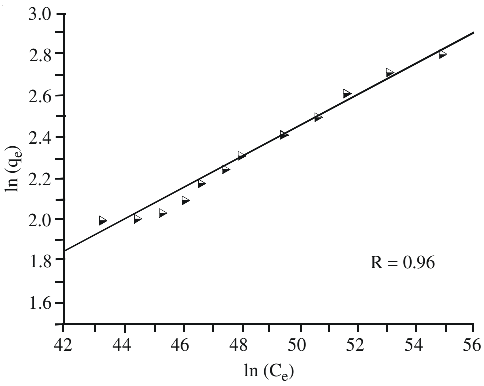

Fig. 4. Freundlich isotherm

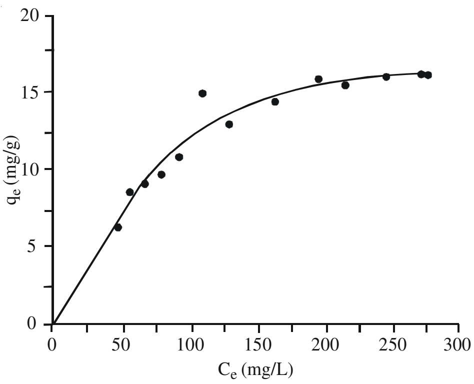

Fig. 5. Equilibrium adsorption isotherm

Redlich-Peterson isotherm: The features of Langmuir and Frundlich isotherm are incorporated in the Redlich-Peterson isotherm and this is represented by the following equation[24].

$$Q_e = KC_e/1 + a_rC_e^b$$

where K, a_r and b are isotherm constants. The linear form of the equation is represented by the following equation:

$$\ln (KC_e/q_e - 1) = \ln (a_r) + b[\ln (C_e)]$$

The isotherm constants are obtained from a linear plot of the above equation as shown in Fig. 6.

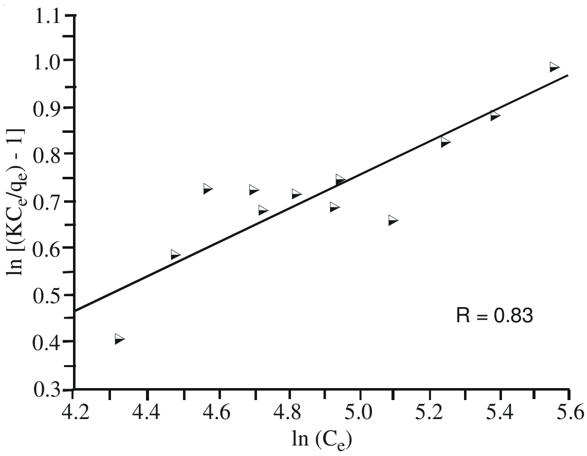

Fig. 6. Redlich-Peterson isotherm

The value of the constants for the different isotherms calculated by linear regression is presented in the Table-2.

TABLE-2
ISOTHERM CONSTANTS FOR ADSORPTION OF METHYLENE BLUE ON TO JFC

Isotherm	Isotherm constants	Coefficient of correlation
Langmuir	Q_o = 0.1047 mg/g, a = 0.0024 mg^{-1}	0.82
Ferundlich	K = 0.2455 mg/g, N = 0.7728	0.98
Redlich-Peterson	b = 0.3389, a_r = 0.3867	0.80

Conclusion

The preliminary investigation indicated that Jack fruit carbon is a suitable adsorbent for removal of methylene blue and that very short contact time is required for the process to attain equilibrium. Langmuir isotherm exhibits some deviation from linearity while Freundlich isotherm found to well explain the experimental observations. Though the maximum adsorption capacity of Jack fruit carbon is very less compared to the other adsorbents, it should be noted that it requires very less contact time. Moreover, the use of Jack fruit carbon, unlike some of the other adsorbents does not require any per - treatment and with the ease of incineration of Jack fruit carbon, disposal of used Jack fruit carbon does not pose a problem. In the Indian context, where, Jack fruit carbon is abundant and is presently of the no mark value, it could be one of the cheapest adsorbent available for colour removal. The use of Jack fruit carbon may provide significant economic advantage over others.

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