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Research Article

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Sugarcane bagasse- a low cost adsorbent for removal of methylene blue dye from aqueous Solution

Mahalakshmi Mathivanan and Saranathan E. S.

School of Civil Engineering, SASTRA University, Thanjavur, Tamil Nadu, India

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ABSTRACT

Dyeing effluent is one of the critical environmental problems now a days. The objective of the work was to evaluate a suitable cost conservative adsorbent for methylene blue removal from an aqueous solution. Low cost adsorbents such as sugar cane bagasse, corn corb, paddy straw, rice husk and coconut fibre were taken for color removal. According to efficiency of dye removal, sugar cane bagasse was selected among four low cost materials. Effect of specific adsorption capacity on initial dye solution concentration was studied. Then adsorption equilibrium study was investigated to estimate adsorption parameters using Freundlich and Langmuir's isotherm models with varying dye solution concentration from 100 to 450 ppm. The maximum specific uptake capacity on sugarcane bagasse was found to be 108.67 mg/g.

Keywords: Methylene blue dye, Low cost adsorbent, sugarcane bagasse, Langmuir and Freundlich isotherms

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INTRODUCTION

Dye removal is one of the challenging environmental problems near dyeing industries. In order to provide the color to their end product, industries such as paper & pulp, leather and textile are using various dye solutions. Owing to composition and volume, waste water leaving the dyeing unit and textile industry was treated as a pollutant in Asian countries [1]. According to the toxicity nature of dye to human beings and living organisms, dye effluent from industries might be treated to protect our environment[2]. Disposal of dye effluent with necessary treatment was great task[3]. Heterocyclic aromatic chemical compound in the dye (methylene blue) is widely used in paper& pulp, acrylic, silk and wool industry. Methylene blue dye is an indicator to measure the microbial concentration in milk[4]. Dye effluent was treated by biological process under aerobic or anaerobic condition and chemical method such as oxidation, flocculation, coagulation, sorption, electrochemical method, reverse osmosis, ultra filtration, membrane separation and ion exchange etc [5,6,7,8].

Adsorption is superior to above said chemical methods due to low cost, simplicity, greater pollutant removal, easy to treat dye solution even at high concentration and elimination of sludge formation during the process [9,10]. Activated carbon as an adsorbent was used everywhere for decolonization of dye. However in large scale adsorption, usage of activated carbon leads more operating cost and problem due to regeneration process [8,9]. Several attempts had been made to improve the decolorization treatment using suitable inexpensive adsorbents such as coal, silica gel[9], agriculture wastes such as wheat shell [9], fly ash [11,12], modified rice straw[8], rice husk [13,14,15] and chemically treated & untreated guava leaves[16,14].

In this present work, several trails had been performed to check the decolorization efficiency of methylene blue dye using various low cost materials such as sugarcane bagasse, corn corb, paddy straw, coconut fibre and rice husk. Suitable adsorbent was screened according to the % efficiency of color removal and used for adsorption isotherm studies.

EXPERIMENTAL SECTION

Waste materials such as sugarcane bagasse, corn corb, paddy straw, coconut fibre and rice husk from agro industry were taken as an adsorbents for color removal. Materials were washed with double distilled water and dried at 60ºC for 48 hours in a hot air oven. Dried materials were made in to fine powder, screened through 600µ size mesh and stored.

Methylene blue ($C_{16}H_{18}N_3SCl$; FW: 319.86 g/mole; Maximum wave length: 662 nm, C.I NO: 52015) was selected in our work as adsorbate according to the known adsorption properties. It was procured from Ranbaxy Laboratory Limited, India. Stock dye solution (500 ppm) was prepared by adding the necessary quantity of dye in double distilled water. According to the concentration of dye solution, stock solution was diluted with double distilled water.

Dye solution composition was estimated by UV-Vis spectrophotometer (Elico SL-164) using 662nm as a maximum wavelength [14]. Before carryout an experiment, calibration chart was constructed with different composition of dye solution and slope was determined. When absorbance of estimated dye sample was more than 0.9, sample was diluted and dilution factor was included during calculation. Concentration of dye solution was expressed by mg of dye per liter of solution.

Two grams of different adsorbents such as sugar bagasse, corn corb, paddy straw, coconut fibre and rice husk were taken and carefully packed in a burette which was considered as a batch recirculation system. Dye solution was introduced through batch column with constant flow rate under isothermal condition. Samples were obtained from the batch recirculation setup at regular time interval and dye concentration was estimated by UV-Vis. spectrophotometer. Experiments were investigated in triplicates and average value was taken for analysis. Dye adsorption capacity was calculated using the following material balance after equilibrium has been established by the system.

Equilibrium uptake of dye

$$Q_e = \frac{C_0 - C_e}{M} \text{V.} \quad (1)$$

Adsorption efficiency was calculated by the following

$$\% \text{ R} = \frac{Co - C}{Co} \text{ x } 100 \quad (2)$$

Accurate adsorption isotherms, called as equilibrium data are essential for design of adsorption system. To explain equilibrium data in an adsorption system, generally Freundlich and Langmuir isotherms were used.

Freundlich isotherm is applicable when liquid adsorbed on heterogeneous solid surface and is given by

$$Qe = \text{K } Ce^{1/n} \quad (3)$$

Rearranging eq. (3)

$$\ln Qe = \ln K + (1/n) \ln Ce \quad (4)$$

Where, K and n are used to measure the capacity and intensity of adsorption. For favorable adsorption, n should be in the range between 1 and 10. Parameters K and n were obtained from an eq (4).

Langmuir adsorption isotherm widely used for homogeneous adsorption system, is given by

$$Qe = \frac{QmKCe}{1+KCe} \quad (5)$$

Taking the reciprocal of eq. (5) for making linearity

$$\frac{1}{Qe} = \frac{1}{QmKCe} + \frac{1}{Qm} \quad (6)$$

Adsorption design parameters were obtained by plotting a graph between (1/Qe) and (1/Ce).

An important parameter (R_L) was used to measure the feasibility and nature of the adsorption and is calculated by the following [17,18,3,9].

$$R_L = \frac{1}{1+KCo} \quad (7)$$

Where, R_L ($0 < R_L < 1$), adsorption is favorable and reversible.

Table1: Parameters of Freundlich and Langmuir Isotherms

Parameters	Values
K_F(mg/g)(ml/mg)$^{1/n}$	26.63
1/n	0.5458
n	1.83
K (dm^3/mg)	0.2045
q_m (mg/g)	108.69
Separation parameter R_L	0.01-0.0466

Table2: Comparison of various adsorption capacities of various low cost adsorbents for Methylene Blue Dye solution

Adsorbents	Maximum specific dye uptake (mg/g)
Teak wood bark	915[10]
Activated carbon	435[22]
Rice husk	312.26[10]
Spent tea leaves	300.052[23]
Untreated Guava leaves	295[13]
Ground nut shell powder	242[24]
Jack Fruit peel	285.713[23]
Cotton waste	278[10]
Modified Rice straw	208.33[8]
Sunflower stalk	205.317[25]
Chemically treated guava leaves	133.33[16]
Teak leaf powder	145.21[14]
Sugarcane bagasse	108.69
Plant leaf carbon	61.22[26]
Neem leaf powder	8.76-19.61[27]
Rice husk	40.59[15]
PET carbon	33.4[28]
Banana peel	20.8[29]
Orange peel	18.6[29]
Wheat shell	16.52-21.50[9]
Fly ash	13.42[12]

RESULTS AND DISCUSSION

Figure 1 shows screening of low cost adsorbent such as sugar cane bagasse, corn corb, paddy straw, coconut fibre and rice husk according to maximum % removal dye from dye solution. Among the five adsorbents, sugarcane bagasse was selected as a best adsorbent owing to the highest % removal of dye from the solution and used for further studied. Similarly, sugar cane bagasse[19], chemically treated sugarcane bagasse[20] and sugarcane bagasse ash[21] were taken as a adsorbent material for decolorization of dye solute from aqueous solution.

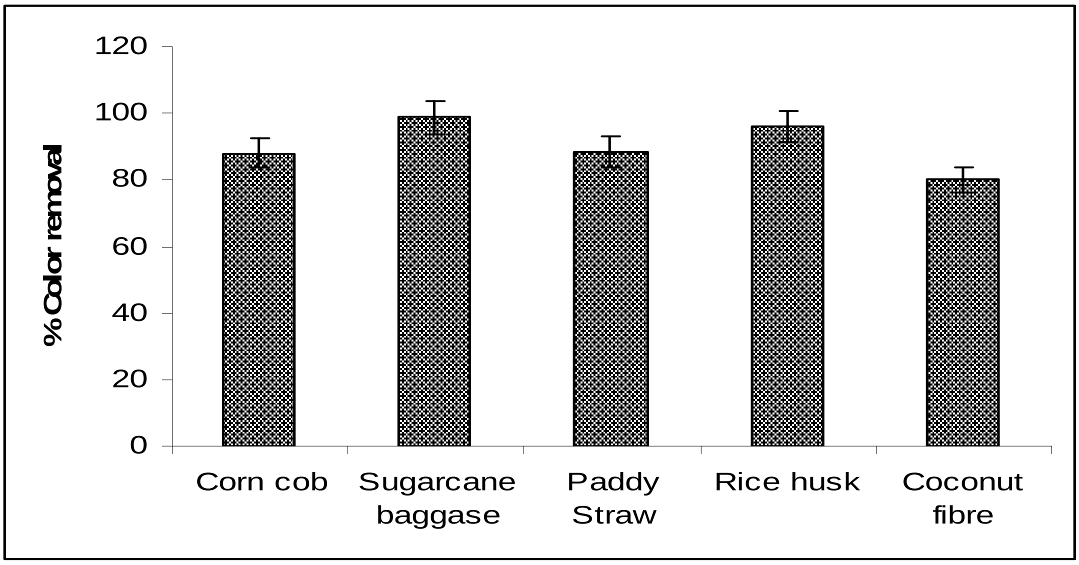

Fig.1.Screening of various adsorbent (T= 303K, dosage= 2 g per 300ml; Initial dye solution concentration= 50ppm; Particle size= 600µm) (± 5% Error bar)

Figure 2 explains the effect of specific adsorption capacity on initial dye solution concentration. It is shown that specific adsorption capacity was linearly increased when initial dye solution concentration was increased from 100 to 450ppm. It is clear that specific adsorption capacity was so high at high dye solution concentration because of the development of highest concentration gradient for mass transfer of dye solute from aqueous solution to adsorbent[3].

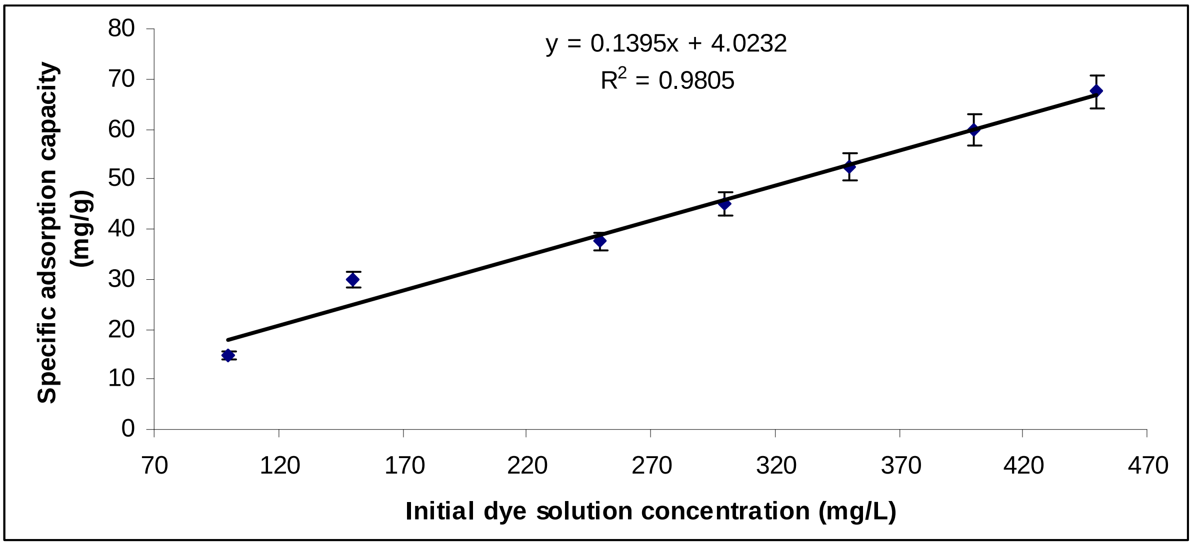

Fig.2. Effect of specific adsorption capacity on initial dye concentration ((T= 303K, dosage= 2 g per 300ml; Dye solution= 50ppm; Particle size= 600µm) (± 5% Error bar)

Color removal experiments were investigated in batch recirculation system using initial dye concentration varying from 100 to 450 mg/dm^3 in order to evaluate the adsorption isotherm parameters at 303K and other parameters were kept constant (Adsorbent dosage= 6.6 g/dm^3, pH=6.9 and particle size = 600micron). Samples were obtained from the batch recirculation system and dye solution concentration was estimated at regular time interval until an equilibrium composition had been attained by the system. Isotherm parameters were determined by both Langmuir and Freundlich models and adsorption parameter values were represented in Table 1. Regression coefficient in these two isotherms (R^2 values) was approximately close to 1.0.

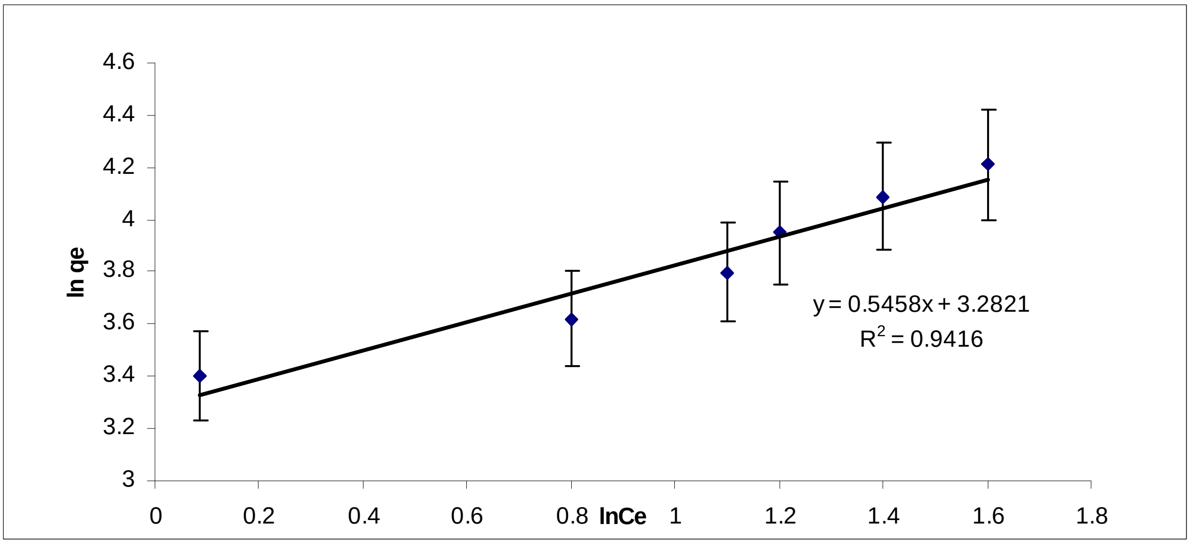

Fig 3 Freundlich Isotherm. (± 5% Error bar)

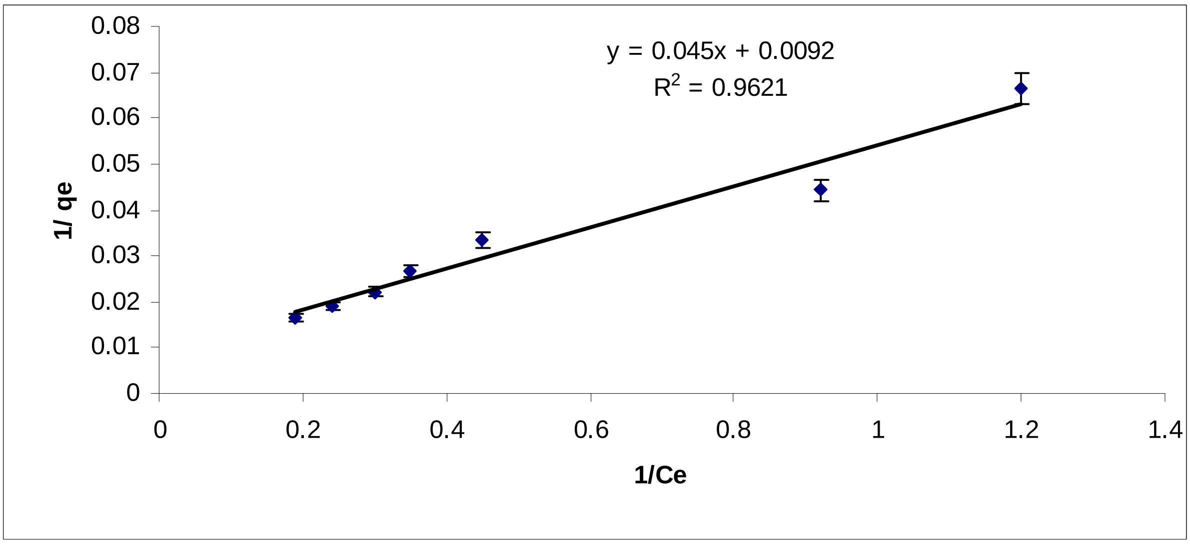

Fig.4. Langmuir isotherm (± 5% Error bar)

Using Langmuir model, $R_{L,}$ separation parameter was obtained in the range between 0 and 1 and indicated that favorable adsorption carried out on sugarcane bagasse[18]. R_L signify an importance of nature of adsorption[9]. Freundlich constant was found to be 1.83 which in turn explains favorable adsorption on low cost adsorbent. One of the most important parameters called maximum specific dye adsorption capacity (Q_m) which was needed to design the adsorption system was estimated to be 108.69 mg/g using Langmuir adsorption isotherm (pH 7; dosage = 6.6 g/dm3, pH 7.5, size = 600 micron; temperature = 303 K). Previously various cost conservative adsorbents were tried to decolorize the dye from aqueous methylene blue solution. Comparison of specific adsorption capacity of low cost adsorbent was explained in Table 2. According to this, specific adsorption capacity of sugarcane bagasse was so high for methylene blue dye solution since it may contain same capacities of dye with same ionic load and molecular weight.

CONCLUSION

Low cost adsorbents such as sugar cane bagasse, corn corb, paddy straw, coconut fibre and rice husk were taken for color removal. Sugarcane bagasse was screened according to efficacy of dye removal. Effect of specific adsorption capacity on initial dye concentration was studied. Adsorption equilibrium study was carried out with varying dye concentration to evaluate adsorption parameters using Freundlich and Langmuir isotherm. The maximum dye uptake capacity for sugarcane bagasse was obtained to be 108.67 mg/g. K and n values were found to be 0.2045 and 1.83 respectively. According to parameter (K), adsorption of dye on sugarcane bagasse was favorable and reversible.

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