Mesopotamia Environmental Journal ISSN 2410-2598
Mesop. environ. j. 2016, Spicial Issue A.;1-9
(proceding of 6th International conference for Environmental Sciene –University of Babylon).

Acomparative Study for Removal of Dyes from Textile Effluents by Low Cost Adsorbents

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To cite this article:

Dakhil,I.H. Acomparative Study for Removal of Dyes from Textile Effluents by Low Cost Adsorbents. *Mesop. environ. j.*, 2016, Spicial Issue A.:1-9.

Abstract

The aim of this work is a comparison study among three low cost adsorbents [Sawdust "SD", Spend tea leaves "STL", Rice husk "RH"] for removal of Methylene blue (MB) dye which used as a dye in textile factory from wastewater effluents. Batch experiments were conducted to obtain optimum removal conditions of MB dye on three low cost adsorbents.

The effluents of Initial dye concentration (100-1000) mg/l, adsorbent dosage (0.05-1) gm, pH (2-10) and contact time (10-180) min under constant temperature of 30oC on removal of MB dye has been studied by batch adsorption technique. The optimum operating conditions are 100 mg/l initial dye concentration, 0.6 gm adsorbent dose, neutral pH and 120 min contact time. At these conditions, the maximum adsorption capacities were 120 mg/g, 102 mg/g and 86 mg/g for SD, STL and RH, respectively.

The experimental data were analyzed and compared with Langmuir and Freundlich isotherm models. Langmuir model is found very well represent the equilibrium data with correlation factor is close to unity than the Freundlich model.

Keywords: Adsorption, Removal, MB dye, Textile effluents.

Introduction

Textile industries use large amount of dyes for finishing process. These dyes are chemical compounds which become a serious environmental problem if they are discharged as wastewater without any treatment. The adsorption process was efficient way for industrial effluents treatment. However, for successful wastewater treatment, the process must be economic by using available and cheap materials. Recently, enormous researches have been studied the ability use cheap and available adsorbents for treatment of industrial effluents.

Methylene blue (MB) dye is one of the basic dyes which is used for dyeing of leather, paper, plastics, cotton and in manufacturing of printing ink [1]. MB can cause eye burns which may be responsible for permanent injury to the eyes of human and animals. It can cause some harmful effects. Acute exposure to MB will cause increased heart rate, vomiting, shock, Heinz body formation, cyanosis, jaundice and quadriplegia and tissue necrosis in humans [2].

The adsorption process is one of effective way for wastewater treatment which is containing dye effluents. Moreover, this process become economic if the adsorbent material used is available and cheap in cost.

The aim of present work is a comparison study among three low cost adsorbents [Sawdust (SD), Rice husk (RH), Spend tea leaves (STL)] for removal of methylene blue (MB) from wastewater effluents. Batch experiments will conduct to obtain optimum removal conditions of MB dye on three low cost adsorbents. The experimental data will analyze and compare with Langmuir and Freundlish isotherm models to investigate the consistency.

Material and Methods

Materials

The adsorbents (SD, RH, STL) were collected from local sources. Each one of these adsorbents was washed in distillate water several times to remove any color and adhering dirt. After that, it was dried in oven at 70^{o}C for 24 hr. Then, it was sieved to obtain a particle size range of 3-8 mm. Finally, it was stored in glass container for further use.

Chemicals

The MB dye, 99.8 wt% purity, was supplied by (Merk, Germany) which has a chemical formula of $C_{16}H_{18}ClN_3S.3H_2O$. A stock solution of MB dye (1000 mg/l) was prepared by dissolving an accurate weight quantity of dye in double-distillate water. The stock solution was then properly wrapped with aluminum foil and stored in a dark place to prevent direct sunlight, which may cause decolorization.

The residual concentrations of MB dye were measured using UV spectrophotometer equipment (Shimadzu UV/Vis 1601 Spectrophotometer, Japan). The maximum wavelength of this dye is 668 nm. The pH of test solution was adjusted by adding of 0.1 N of sodium hydroxide or 0.1 N of hydrochloric acid.

Results and Discussion

Effect of Contact Time

The influence of contact time on removal efficiency of MB dye was studies. The experiments were carried out for different contact time (10-180) min by adding a fixed adsorbent dose 0.5 gm in test dye solution of 100 ml at initial concentration of 500 mg/l and neutral solution at pH = 7. The results which are obtained at these conditions are shown in Fig.(1), it was observed that the removal efficiency increased with the contact time increased and the amount of MB dye adsorb rapidly in the first 30 min for all initial concentrations. The contact time was reach to saturation within 120 min for all three adsorbents that mean the saturation time was independent of adsorbent nature. After that, the removal efficiency curves are smooth and continuous indicating the formation of monolayer coverage of the adsorbate on the outer surface of the adsorbent [3]. A similar observation of an equilibrium contact time of 135 min was reported for removal of MB dye onto wheat shell [4] and 150 min for the removal of MB dye on fallen phoenix tree's leaves [5].

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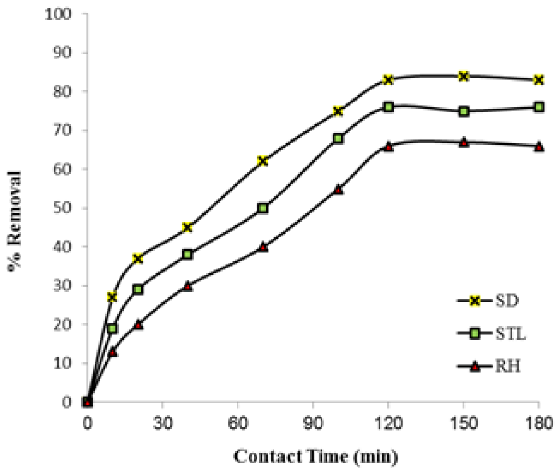

Fig.(1) Effect of contact time on removal efficiency at constant initial dye concentration of 500 mg/l, adsorbent dose of 0.5 g and neutral pH

Effect of Initial Dye Concentration

Fig.(2) shows the effect of initial MB dye concentration on removal efficiency at constant adsorbent dose 0.5 gm, neutral pH and optimum contact time at 120 min. It was also found that the removal efficiency of MB dye decreased from (94% - 60%), (85% - 51%) and (77% - 43%) as the initial MB dye concentration increased from (100 -1000) mg/l for SD, STL and RH, respectively. This finding is due to increasing of initial dye concentration which resulting high mass transfer driving force, so the MB dye adsorption becoming higher. The initial dye concentration provides an important driving force to overcome all mass transfer resistances of the MB dye between the aqueous solution of MB dye and solid phase of the adsorbents. A similar finding was observed for the adsorption of MB dye onto banana stalk waste [6] and adsorption of MB dye onto marble powder [7].

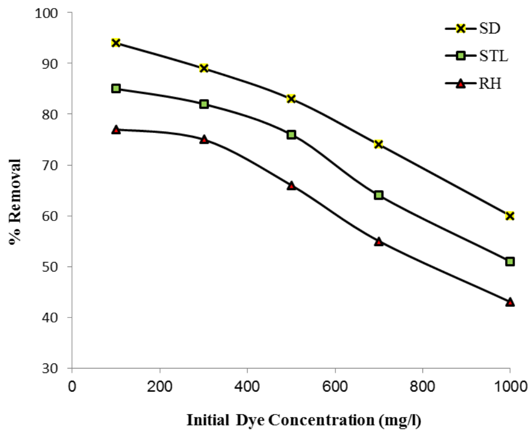

Fig.(2) Effect of initial dye concentration on removal efficiency at constant adsorbent dose of 0.5 g, neutral pH and contact time of 120 min

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Fig.(3) shows that the equilibrium adsorption increases from (18-120), (17-102) and (15-86) mg/g with increasing of initial MB dye concentration from (100-1000) mg/l for SD, STL and RH, respectively.

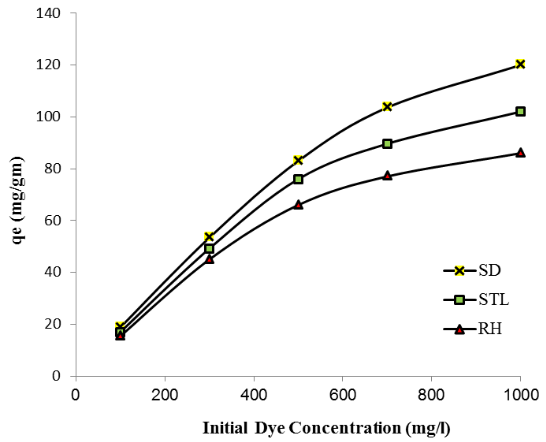

Fig.(3) Effect of initial dye concentration on amount of dye adsorbed at constant adsorbent dose of 0.5 g, neutral pH and contact time of 120 min

Effect of Adsorbent Dosage

The effect of adsorption dosage has been studies by varying adsorbent dosage over a range of (0.05-1) gm at fixed initial MB dye concentration of 100 mg/l, neutral pH and optimum contact time of 120 min and the obtained data are shown in Fig.4. It can be observed that the percentage removal increased from (52%-97%), (48%-88%) and (44%-80%) with increase in adsorbent dose from 0.05 to 1 gm for SD, STL and RH, respectively. The maximum percentage removal reached at dosage of 0.6 gm per 100 ml of MB dye solution, after that, the percentage removal of MB dye curves was smooth and continues leading to saturation. This can be attributed to increased adsorbent surface area and availability of more adsorption sites resulting from the increase dosage of the adsorbent. A similar observation was reported for removal of MB dye by OH-Fe modified bentonite [8] and for removal of an acid dye on granular activated carbon [9].

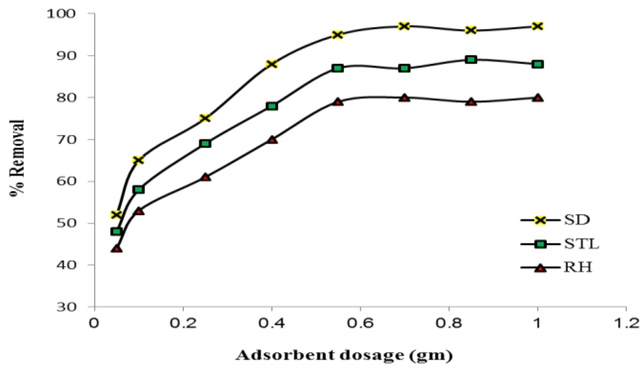

Fig.(4) Effect of adsorbent dosage on percentage removal of dye at constant initial dye concentration of 100 mg/l, neutral pH and contact time of 120 min

Effect of pH

The effect of pH on MB dye removal has been studies by varying the pH over a range of (2-10) at constant initial dye concentration of 100 mg/l. optimum adsorbent dose of 0.6 gm and contact time of 120 min, the results are shown in Fig. (5). It can be seen that the removal efficiency over pH range 2 to 7 was increased from (69%-96%), (53%-87%) and

(48%-80%) for SD, STL and RH, respectively. MB is a cationic dye which exists in the form of positively charged ions in aqueous solution. The low percentage removal of MB dye at acidic pH can be attributed to the presence of excess H+ ions that complete with the MB dye cation for adsorption site, the number of positively charged sites decreases while the number of the negatively charged sites increases that favor the adsorption of MB dye due to electrostatic attraction. As the pH increased over a range of 7-10, the percentage removal of the MB dyes is decreased again from (96%-75%), (87%-68%) and (80%-60%) for SD, STL and RH, respectively. This can be attributed due to the formation of soluble hydroxyl complex between the adsorbent and the MB dye. A similar result was reported for the adsorption of MB onto wood shavings [10] and onto sunflower seed hull [6].

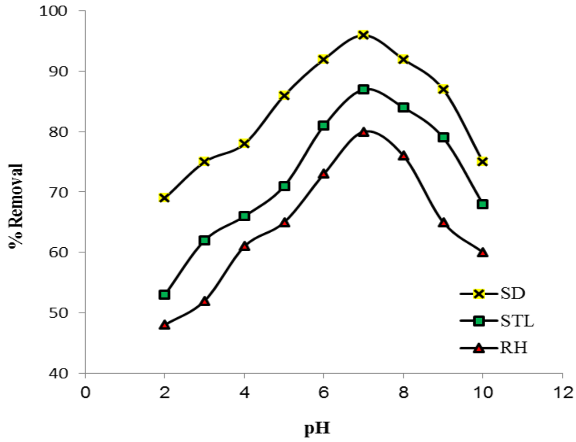

Fig.(5) Effect of pH on percentage removal of dye at constant initial dye concentration of 100 mg/l, optimum dosage of 0.6 gm and contact time of 120 min

Adsorption Isotherm

The adsorption isotherms show how the adsorption molecules distribute between the liquid and solid phases at equilibrium state in adsorption process. The most common models used to represent the experimental data of adsorption process are Langmuir and Freundlich isotherms.

The batch experiments were conducted at different initial dye concentrations (100-1000) mg/l and optimum of other parameter examined for adsorption isotherms analysis. The optimum conditions were 0.6 gm of adsorbent dose, pH 7 and 120 min of contact time.

Langmuir isotherms assume monolayer adsorption into a homogenous surface. It can be represented by the following equation (11):

$$\frac{1}{q_e} = \frac{1}{q_o} + \frac{1}{q_o K_l} \cdot \frac{1}{C_e} \quad \ldots (1)$$

where q_e is the amount of amount dye adsorbed at equilibrium (mg/g), C_e is the equilibrium concentration of the adsorbate (mg/l), and q_o (mg/g) and K_l are the Langmuir constants which can be determined from the intercept and the slope of the linear plots of experimental data of $1/q_e$ versus $1/C_e$ as shown in Fig. (6) and tabulated in Table 1. The highest value of adsorption capacity q_o (maximum uptake) at optimum conditions were (120 mg/g), (102 mg/g) and (86 mg/g) for SD, STL and RH, respectively.

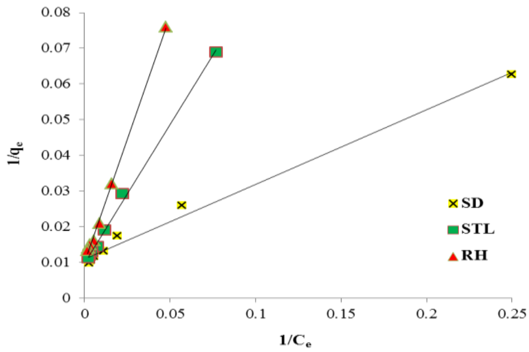

Fig. 6: Langmuir isotherm for MB dye adsorption

The essential characteristics of the Langmuir isotherm may be expressed in terms of a dimensionless constant separation factor or equilibrium parameter which is computed to confirm the favorability of the adsorption process, [12], R_L, which is defined as:

$$R_L = \frac{1}{1 + K_l\, C_o} \qquad \ldots (2)$$

where C_o is the initial concentration (mg/l) and K_L is the Langmuir constant related to the energy of adsorption (l/mg). The value of R_L indicates the shape of the isotherms to be either unfavorable ($R_L > 1$), linear ($R_L = 1$), favorable ($0 < R_L < 1$) or irreversible ($R_L = 0$) [13]. The values of R_L at different initial dye concentration which is found in the range of (0.01875-0.1604), (0.07314-0.44108) and (0.12324-0.58432) ($0 < R_L < 1$) for SD, STL and RH, respectively, which confirms the favorable adsorption process for MB dye adsorption. The calculated R_L values are shown in Fig.(7).

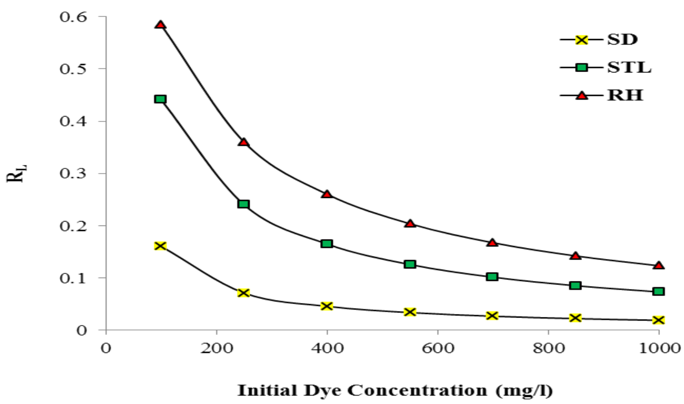

Fig (7): The Separation Factor for dye adsorption

The second an empirical equation employed to describe heterogeneous systems is the Freundlich equation which is characterized by the heterogeneity factor 1/n and is as the following [14]:

$$q_e = K_f \; . \; C_e^{1/n} \qquad \ldots (3)$$

where K_f and n are the Freundlich constants that indicate the adsorption capacity and intensity, respectively. The linear form of Freundlich model can be written as:

$$\ln q_e = \ln K_f + \frac{1}{n} \ln C_e \quad \ldots(4)$$

The values of K_f and $1/n$ are evaluated from both intercept and slope, respectively, of the linear plot of the experimental data of $\ln q_e$ versus $\ln C_e$ as illustrated in Fig. (8).The values of K_f and $1/n$ given in the Table (1).

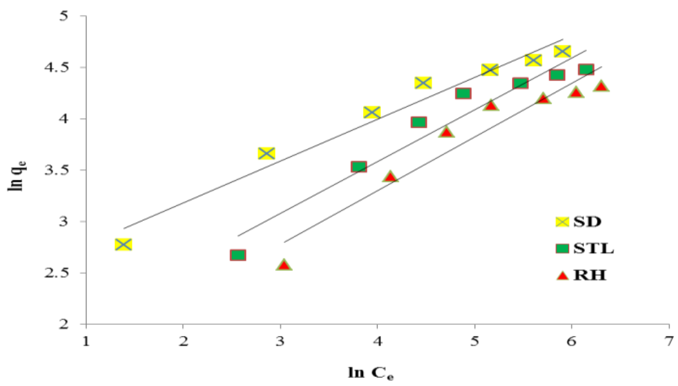

Fig. (8) Freundlich isotherm for dye adsorption

It is important to compare the value of maximum MB dye adsorption capacity obtain from this study with other values of adsorbed for previous studies. The comparison of maximum monolayer adsorption capacity of MB dye onto various adsorbents is presented in Table (2).

Table (1): Parameters of Langmuir and Freundlich isotherm models

Adsorbent	Langmuir Constants			Freundlich Constants		
	q_o(mg/g)	K_l (l/mg)	R^2	K_f	$1/n$	R^2
SD	91.3019	0.05234	-	1.50079	0.42151	-
STL	101.804	0.01267	0.9986	1.65343	0.6371	0.9694
RH	101.701	0.00711	0.9988	1.68528	0.82754	0.959

Table (2): Comparison of maximum uptake of MB dye

Adsorbents	q_{max} *(mg/g)*	**Reference**
Sawdust	120	This study
Spend tea leaves	102	This study
Rice husk	86	This study
Peanut hull treated with sulfuric acid	124	Ozer *et al.* (2007)
Date pits	80.3	Banat and Al-Makhadmeh (2003)
Cherry sawdust	39.8	Ferrero (2007)
Walnut sawdust	59.2	Ferrero (2007)
Orange peel	18.6	Annadurai *et al.* (2002)

Conclusion

The ability of three low cost adsorbents to adsorb MB dye has been investigated. This study has shown that SD, STL and RH have a high adsorption capacity for MB dye. The optimum operating condition were 100 mg/l initial dye concentration, 0.6 gm adsorbent dosage, pH 7 and 120 min contact time. Equilibrium data have been analyzed using the Langmuir and Freundlich isotherms models, The adsorption equilibrium was fitted very well with Langmuir isotherm model for all three adsorbents with maximum monolayer adsorption capacities found to be 120, 102, 86 mg/g for SD, STL and RH, respectively.

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