Shodhshauryam, International Scientific Refereed Research Journal
© 2018 SISRRJ | Volume 1 | Issue 4 | ISSN : 2581- 6306

Adsorption of Reactive Dye by Natural Material

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ABSTRACT

Lemon peels was used to remove reactive red dye from synthetic wastewater by means of adsorption, using a continuous fixed bed column reactor system. The optimum pH level for this purpose was found to be within the range of 6. The effect of different flow rates (27, 45, and 60 ml/min), on the removal of reactive red dye was studied. The final removal efficiency was 94, 89, and 78 % respectively, which indicates that the removal efficiency increases with the decrease of the influent flow rate. Four initial concentrations of reactive red dye were investigated (10, 15, 20, and 25 ppm). The corresponding removal efficiencies were 94, 92, 88, and 83 % respectively. This reveals that the removal efficiency increases with the decrease of initial dye concentration. The results of this study can be represented well by both Langmuir and Freundlich equations, but with Freundlich having a higher correlation coefficient, 0.9968; it is considered more accurate to represent this case of study.

Keywords : Adsorption, Langmuir, Freundlich, Lemon Peel, Reactive Dye.

I. INTRODUCTION

Environmental pollution is one of the major and most urgent problems of the modern world. Also, increasing in the world's population, placed pressure for the industries to reclaim and reuse some of its wastewater or face the prospect of being shutdown. The textile industry is one that demands large quantities of water, and produce large amounts of wastewater. Dyes are applied to various substrates (textiles, leather, paper, hair, etc) from a liquid in which they are completely or at least partly, soluble. Dye compounds are synthetic organic compounds with complex molecular structures and large molecular weights. These properties augment treatment difficulties of dye wastewater (Ling, 2009).

Common technologies applied for treating textile wastewater include various combinations of physical, chemical and biological processes (Dehvari, et al., 2015) Adsorption has become one of the alternative treatments, in recent years; the search for low-cost adsorbents has intensified (Leung et al., 2000) .The adsorbents may be of mineral, organic or biological origin, zeolites, industrial by products, agricultural wastes, biomass, and polymeric materials (Kurniawan et al., 2005). In this regard, agricultural waste materials like sugarcane bagasse ,peanut hulls , peanut husk ,bottom ash and de oiled soya and corn stalk have been tried successfully (Wasti and Awan, 2014).

The present study was carried out to monitor the decolorization rate of reactive red dye (Cibacron Red FN-R) by using lemon peel as an adsorbent media in continuous operation mode. The effect of important parameters such as pH, initial dye concentration, and flow rate were examined with respect to the decolorization rate of reactive dye.

II. Experimental Set-Up and Materials Used

Materials

Reactive red dye (Cibacron FN-R) had been supplied from al-Kut textile factory south of Baghdad. A stock solution of 1000ppm of reactive red dye was prepared to be used as a synthetic textile wastewater. The chemical formula for this dye is $C_{29}H_{15}O_{13}S_4ClFN_7Na_4$ and the color index number is CI Reactive Red 238 [18-21]., H_2SO_4, HCL and NaOH were used as such without further purification.

Lemon peels used as adsorbent were collected, dried, grinded and sieved to different sizes. Then these peels were submerged in hydrochloric acid for a period of one day, then rinsed with distilled water several times and dried at 50 °C for 24h.

Experimental Set-Up

The experimental setup used in this study was constructed manually. It consist of an 8L upper steady head tank, used to contain the raw wastewater and provide continues discharge into the system. This tank is connected to a cylindrical filter having a diameter of 3cm and a height of 11cm. The flow into and out from the filter is controlled by means of valves. The experimental setup is shown in Figure 1.

The influent and effluent discharges were measured using the conventional stopwatch-volume method. All conditions, but one, were fixed during the individual experiment.

Effluents have been sampled regularly every (30) min for (3) hour. Seven samples have been collected for each trial, in which the first sample represents the initial influent wastewater and the other six samples represent effluent concentrations at different times.

Figure 1: Sketch of the experimental set-up

III. RESULTS AND DISCUSSION

1- Effect of solution pH

The removal of reactive dye from aqueous solution by adsorption is related to the pH of the solution. Therefore, the first sets of tests examine the effect of pH on the effluent concentration; the initial concentration of dye was fixed to 25 ppm, while the pH ranged from 2 to 12. Figure 2 illustrates the relation between pH levels with the percentage removal of reactive red dye.

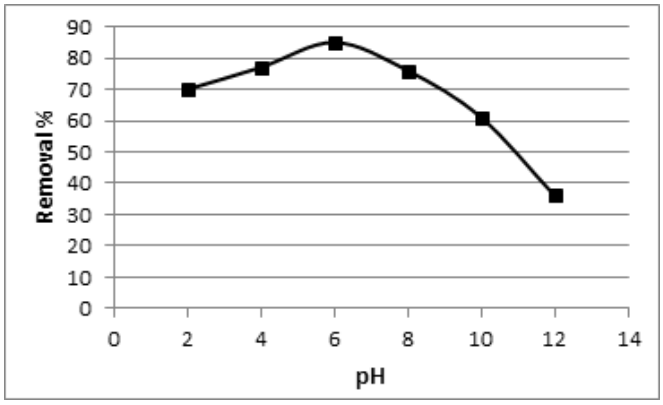

Figure 2 : pH and percentage removal efficiency of reactive red dye

This figure shows that the optimum pH that gives the best removal efficiency of reactive red dye was 6. For that the pH level was kept within this range in the further experiments.

2-Effect of flow rate

The effect of flow rate on the removal efficiency of reactive red dye is tested for three different conditions of flow rates which are: (27, 45 and 60) ml/min, respectively while the other conditions were fixed (bed height=8cm, pH=6, and influent concentration=10ppm).

Figure 3 illustrates the relation between different flow rates and the percentage removal with time. From this figure, it can be seen that the lowest flow rate gives the highest removal efficiency. This can be attributed to the fact that lower flow rate means longer contact time between the adsorbent and the adsorbate, and by that larger amounts of dye are adsorbed on the surface of the lemon peels.

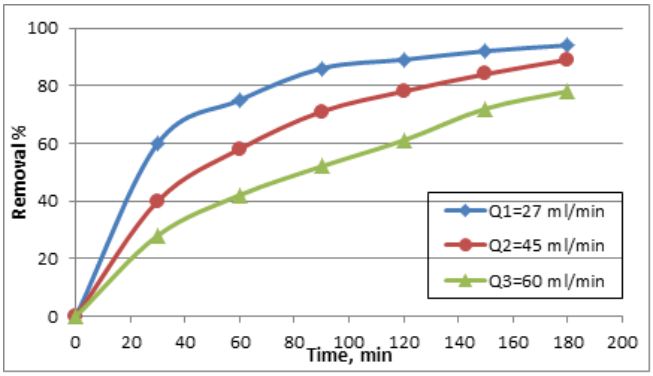

Figure 3: The effect of flow rate on removal efficiency of reactive red dye

3-Effect of initial dye concentration

Four experiments were carried out at different initial concentrations of reactive red dye .These concentrations are: 10, 15, 20, and 25 ppm. The variations of the removal percent of reactive red dye with time, for different initial dye concentrations for the above experiments were plotted in Figure 4.

It becomes clear from this figure that, the removal efficiency of reactive red dye from aqueous solution by using lemon peels decreases with the increase of initial dye concentration. Also, Figure 4 shows that the removal efficiency for each concentration increases with time having the highest removal for the lowest initial dye concentration.

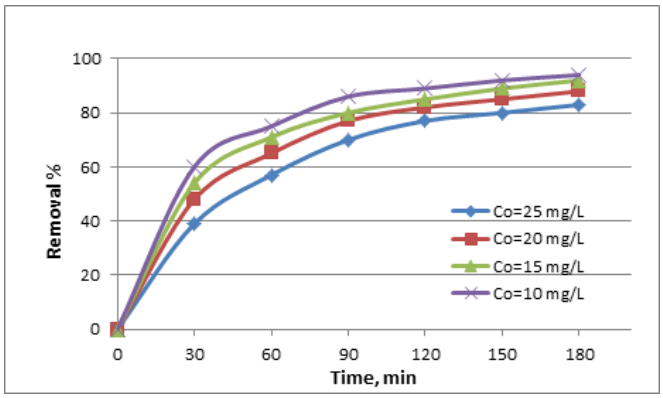

Figure 4 : Effect of initial dye concentration on removal percent of reactive red dye

Adsorption Isotherm

A plot of C_e/q_e vs. C_e is shown in Figure 5. This figure shows a straight line which means that the equilibrium data is correlated well with Langmuir equations. The constants of Langmuir equation are calculated from the slope and the intercept of the straight line and listed in Table 1.

Plotting Log C_e vs. Log q_e is shown in Figure 6. This figure shows a straight line (Freundlich adsorption isotherm) which means that the equilibrium data is correlated well with Freundlich equation. The constants for Freundlich equation are calculated from the slope and intercept of the straight line, as tabulated in Table 2.

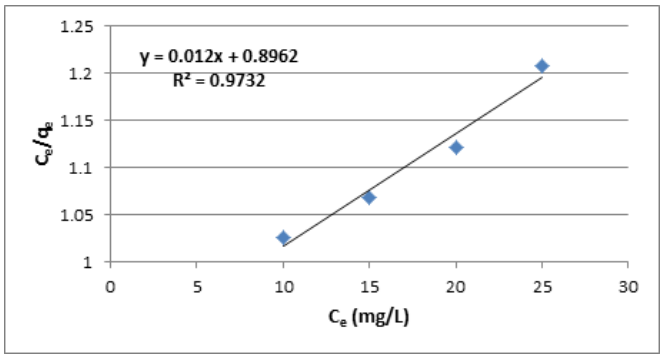

Figure 5: Langmuir equation application

Table 1: The constants of Langmuir equation

1/a	1/ab	R^2	Correlation equation
0.012	0.8962	0.9732	Y=0.012X + 0.8962

The general formula of Langmuir equation was:

$$\frac{C_e}{q_e} = \frac{1}{ba} + \frac{C_e}{a}$$

And for current state it will be :

$$\frac{C_e}{q_e} = 0.8962 + 0.012C_e$$

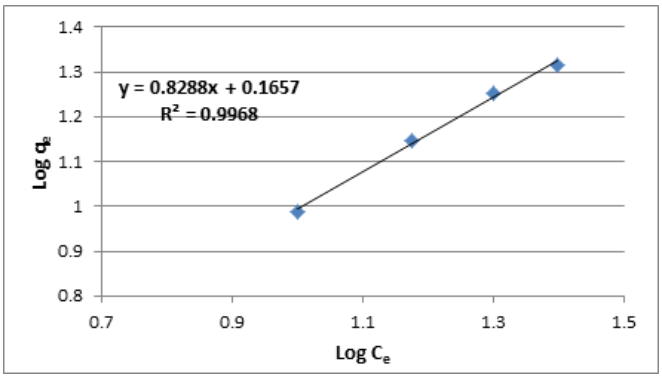

Figure 6 : Freundlich equation application

Table 2: The constants of Freundlich equation

Log K_f	1/n	R^2	Correlation equation
0.1657	0.8288	0.9968	Y=0.8288X + 0.1657

The general formula of Frendulich equation was :

$$\text{Log } q_e = \text{Log } K_f + \frac{1}{n} \text{Log } C_e$$

And for current state it will be :

$$\text{Log } q_e = 0.1657 + 0.8288 \text{ Log } C_e$$

Both Langmuir and Freundlich equations are applied to the data, but with Freundlich having a higher correlation coefficient, 0.9968, it is considered more accurate to this case of study.

IV.CONCLUSION

The main points that arise from the adsorption process of reactive red dye by using lemon peel as adsorbent can be summarized as follow: lemon peels can be considered as effective adsorbent to remove reactive red dye. The optimum conditions for decolorization rate were : pH=6, initial dye concentration =10ppm, and flow rate =27ml/min. The equilibrium isotherm for the above systems is well represented by Langmuir and Freundlich equations, with Freundlich having a higher correlation coefficient.

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