A hybrid adsorbent for the decolourization of dyes: Equilibrium investigation and Kinetic modeling

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1. Introduction

Dye pollutants from the textile industry are an important source of environmental contamination. It is estimated that 1 to 15% of the dyes are lost during dyeing processes and are discharged as wastewaters. The release of these coloured wastewaters in the ecosystem is a dramatic source of aesthetic pollution, eutrophication and perturbations in aquatic life. So, the removal of dyes from effluents in an economic fashion remains a major problem for textile industries. Adsorption technique has been proved to be an excellent way to treat effluents, offering advantages over conventional process, especially from the environmental point of view. Weber had identified many advantages of adsorption over several other conventional treatment methods [1]. Activated carbon is being used as potential adsorbents because of its high efficiency. But, the rise in the price of activated carbon results in economic difficulties. In the present syudy, a hybrid adsorbent consisting of 1:1 mizture of carbon and flyash was investigated for its efficiency to remove three classes of dyes namely Acid Blue 125, Basic Blue 69 and Reactive Red 3GL from aqueous solution. The eqilibrium and kinetic analysis which are very important for better understanding and designing of adsorption processes were performed and experimental studies were carried out and results were clearly analyzed.

2. Experimental

2.1 Preparation of Hybrid adsorbent and batch studies

Flyash, obtained from Ennore Thermal Power Plant, India, was washed with distilled water, dried under sunlight and subsequently in hot air oven at 60℃. Hybrid adsorbent was prepared by mixing carbon (supplied by SD Fine chemicals) with flyash at 1:1 ratio by pyrolysing in an isothermal reactor powered by an electric furnace. High purity nitrogen was used as the puring gas. The isothermal reactoe was heated to the desired temperature of 650℃ at a heating rate of 15℃/min, and a holding time of 3 h. After pyrolysis, the product was activated at the same temperature for 3 h using CO2 as oxidizing agent and subsequently used as adsorbent. The Scanning Electron Micrograph (SEM) image. Using the adsorbent, Equilibrium as well as Kinetic batch adsorption was carried out and the amount of dyes adsorbed per gram of adsorbent were computed as follows,

$$q_e = \left[\frac{C_0 - C_e}{W}\right]V$$

where, C_o (mg/l) represents the initial concentration of dye solution, C_e (mg/l) represents the equilibrium concentration of dye solution, V (ml) represents the volume of the solution and W (g) represents the weight of the adsorbent. The dye concentration of the solution was analyzed by an UV-VIS Spectrophotometer.

3. Results and Discussion

Langmuir Equilibrium Model [2]

$$q_e = \frac{b\,q_m\,C_e}{1 + b\,C_e}$$

The values of Langmuir constant, q_m mono layer capacity of the adsorbent are 344.82 mg/g, 357.14 mg/g and 333.33 mg/g for AB 25, BB69 and RR 3GL respectively. The results show the promising efficiency of the hybrid adsorbent.

Separation factor

$$r = \frac{1}{1 + bC_{emax}}$$

The separation factor 'r' wascaculated for all the dyes using the above equation and the results were found to be very encouragable. The values for all the dyes were in between 0 to 1 I.e., 0.555787, 0.565786 and 0.543699 for AB 25, BB69 and RR 3GL respectively that show the good adsorption property of the adsorbent and the favourable condition of the process.

Freudnlich Isotherm Model [3]

$$q_e = kCe^{1/n}$$

The magnitude of the exponent 1/n is an indication of the favourability of adsorption. The values in the range $0<1/n<1$ represents favourable adsorption conditions according to Treybal. The 1/n was found to be 0.7799, 0.7819 and 0.7664 for AB 25, BB 69 and RR 3GL respectively and the results were showing benefical adsorption of the hybrid adsorption. Langmuir and Freundlich fit is given in Fig. 1 & 2 respectively

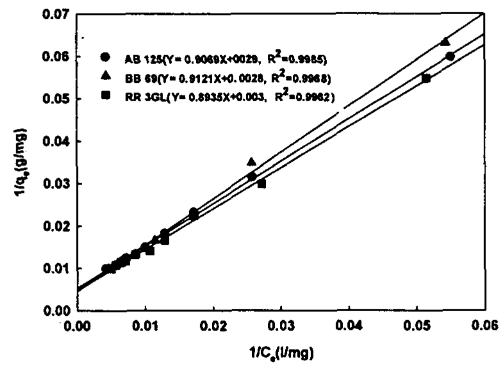

Fig. 1. Langmuir fit

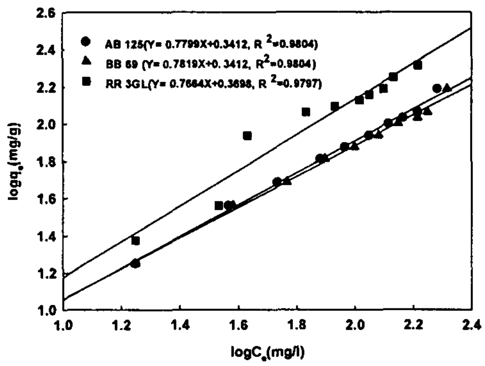

Fig. 2. Freundlich fit

Pseudo First Order Model

$$\log(q_e - q_t) = \log q_e - \frac{k_1 t}{2.303}$$

Pseudo Second Order Model

$$\frac{t}{q_t} = \frac{t}{q_e} - \frac{1}{k_2 q_e^2}$$

The second order fit is given Figure. 3. The correlation coefficients for the first order kinetic model obtained at various optimum conditions are lower than the case of the second-order model for all the three dyes. Also the calculated q_e values found from the first-order kinetic model did not give reasonable values for the dyes. The correlation coefficients for the second-order kinetic model were 0.9909, 0.9886 and 0.8588 for AB 125, BB 69 and RR 3GL respectively at all the optimum conditions studied for each dye. The calculated q_e values also agreed very well with the experimental q_e values in the case of second-order kinetics. These suggest that each of the dye sorption system is not first-order reaction but that the second-order model.

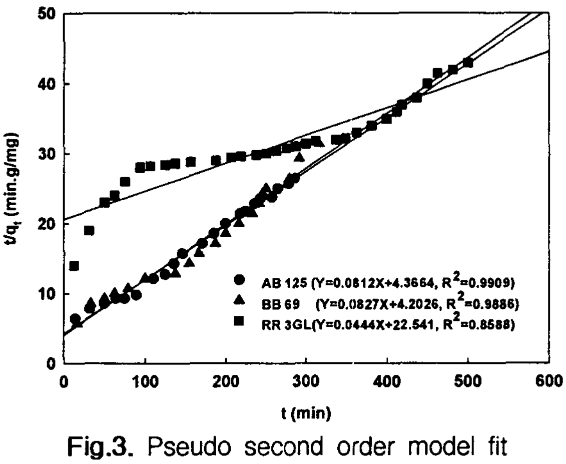

Fig.3. Pseudo second order model fit

4. Conclusion

The obtained results showed that adsorbent have a high sorption capacity to remove the dyes. Adsorption equilibrium data fitted very well to both Langmuir and Fruendich Model. It was observed that the sorption kinetics of the dyes to hybrid adsorbent obeyed the second order kinetics. It may be concluded that hybrid adsorbent can be used as a low-cost, natural and abundant source for the removal of reactive dyes as an alternative to more costly materials such as activated carbon.

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