Adsorption of Direct Blue 53 dye from aqueous solution by multiwalled carbon nanotubes

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Abstract

Multi-walled carbon nanotubes (MWCNT) was used as adsorbent for adsorption of Direct Blue 53 dye (DB-53) from aqueous solutions. The effects of initial pH, contact time and temperature on adsorption capacity of the adsorbent were investigated. At pH 2 was optimum adsorption of the dye. Equilibrium contact times of 3 and 4 hours were achieved by MWCNT. The general order kinetic model provided the best fit of the experimental data compared to pseudo-first order and pseudo-second order kinetic adsorption models. For DB-53 dye, the equilibrium data (298 K) was best fitted to the Sips isotherm model.

Keywords: carbon nanotubes; adsorption; nonlinear isotherm fitting; direct blue 53

Introduction

Many industries such as textile, feedstuffs, paper, cosmetics, among others use dyes for colouring their final products [1,2], and consequently produce large amounts of dye-containing effluents. One of the unitary operations mostly used for the removal of synthetic dyes from industrial effluents is the adsorption [2] due to its simplicity and high efficiency as well as the availability of a wide range of adsorbents [3]. (CNTs) happen to be among the adsorbents that have been employed for the successful removal of dyes from aqueous effluents [4]. Carbon nanotubes CNTs are attractive alternative adsorbents for the removal of dye contaminants from aqueous effluents because they possess large specific surface area, small size as well as hollow and layered structures, giving rise to adsorbents with much higher sorption capacity when compared with ordinary adsorbents[5].

Experimental Procedure

Adsorbents

MWCNTs with purity of 95% were prepared by catalytic chemical vapour deposition (CCVD). This method of synthesis has been described previously [5]

Adsorption studies
For these experiments, 30.0 mg of adsorbent containing 20.0 ml of dye solution (80.00 to 1000.0 mg L^{-1}), which were agitated for an appropriate time (0.0833 to 24.00h at temperature 298K). The amount of dye adsorbed and the percentage of the dye removed by the adsorbents were calculated by applying Eqs. 1 and 2, respectively Fig.1. In which \( q \) is the amount of dye adsorbed by the adsorbent (mg g^{-1}), \( C_0 \) is the initial dye concentration placed in contact with the adsorbent (mg L^{-1}), \( C_f \) is the dye concentration (mg L^{-1}) after the batch adsorption procedure, \( m \) is the mass of adsorbent (g) and \( V \) is the volume of dye solution (L).

**kinetic and isotherm parameters**

The kinetic and equilibrium models were fitted by employing a nonlinear method. The models were evaluated by using a determination coefficient \( (R^2) \), an adjusted determination coefficient \( (R^2 \text{ adj}) \), as well as by an error function \( (\text{Ferror}) \), which measured the differences in the amount of dye taken up by the adsorbent as predicted by the models and the actual \( q \) measured experimentally. \( R^2, R^2 \text{ adj} \) and \( \text{Ferror} \) are given below, in Eqs 3, 4 and 5, respectively, Fig.2. Where \( q_i, \text{model} \) represents each value of \( q \) predicted by the fitted model, \( q_i, \text{exp} \) represents each value of \( q \) measured experimentally, \( \text{exp} q \) is the average of \( q \) experimentally measured, \( np \) is the number of experiments performed, and \( p \) is the number of parameters of the fitted model [6]. The kinetic equations used in this work are: Pseudo-first order (Eq. 6); Pseudo second-order (Eq. 7); General order kinetic model (Eq. 8), Fig 3. Langmuir (Eq. 10), Freundlich (Eq. 11) and Sips (Eq. 13) are the equilibrium equations used in this work.

**Results and Discussion**

The effects of initial pH on the percentage removal of DB-53 dye using MWCNT adsorbent was evaluated within the pH range of 2.0 and 9.0. The percentage of dye removal slightly decreased from pH 2.0 up to 9.0. Adsorption kinetic studies are important in the treatment of aqueous effluents because they provide valuable information on the mechanism of the adsorption process [2,6]. It is important to point out that the initial DB-53 concentration employed during the kinetic studies was 300.0 mg L^{-1}. It was verified that the \( q_e \) values found in the general order kinetic model were closer to the experimental \( q_e \) values when compared with all other kinetic models and explain the adsorption process of DB-53 dye using MWCNT, Fig. 5.

Adsorption isotherm describes the relationship between the amount of adsorbate adsorbed by the adsorbent (\( q_e \)) and the adsorbate concentration remaining in the solution after the system has attained the equilibrium state (\( C_e \)) at constant temperature. In this work, the Langmuir (Langmuir, 1918), the Freundlich (Freundlich, 1906) and the Sips (Sips, 1948) isotherm models were tested at 298K with DB-53 dye on the adsorbent using the best experimental conditions previously described. Sips equilibrium model has the least \( \text{error} \) values this implies that the \( q \) fit by the Sips isotherm model was close to the \( q \) measured experimentally, Fig 6.

**Conclusion**

The general order kinetic model best described the kinetic of adsorption. The equilibrium isotherms of the DB-53 dye were best fit with the Sips isotherm model.
References


