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Investigation of Reactive Red Dye 198 removal using multiwall carbon nanotubes in aqueous solution

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ABSTRACT

The present study evaluates the performance of multiwalled carbon nanotubes (MWCNTs) for removing Reactive Red Dye 198 (RR198) from the color wastewater. In this study, the influence of pH, adsorbent dose, initial dye concentration, and contact time on the RR198 adsorption by MWCNTs was investigated. The results showed increasing the dye concentration from 20 to 200 mg/L, removal efficiency decreased from 99.62% to 66.99%. Moreover, by increasing the pH from 3 to 10, the efficiency of dye removal decreased from 76.34% to 54.98%. Freundlich isotherm and pseudo-second-order kinetic model were the best models for describing the adsorption reactions.

1. Introduction

Synthetic dyes are widely used in textile, leather, paper, cosmetics and other similar industries. Discharging colored wastewater cause serious environmental problems due to its high toxicity and accumulation in the environment [1,2]. Dyes are categorized into reactive, azo, acid, basic, direct, and dispersing dyes based on their chemical structure and the applied methods [3]. Almost 1–20% of the overall dyes of the world are wasted during the dyeing processes, and are directly entered into the wastewater [4]. It is estimated that 20–40% of reactive dyes are lost in the effluent. Thus, textile wastewater is a major source of environmental pollution [5]. In order to minimize the pollution risks and harmful effects of this type of material, dye effluents are carefully treated with an appropriate method before discharging the wastewater to the environment [6]. So far, numerous techniques have been proposed by various researchers for the treatment of dye effluents [7]. Such as ion-exchange, chemical precipitation, chemical oxidation, electrodialysis, chemical degradation, and ozone have been used for removal of color from waste water [1,8]. But these methods have limitation, such as low removal efficiency, high investment costs, and complex operation [9]. Among all existing techniques, adsorption is considered the one of the efficient methods to remove dye from wastewater [10]. Today, many researchers use the various natural adsorbents such as chitosan, activated carbon, zeolites, bentonite, fly ash, peach kernel, olive, charcoal, barley, wheat straw, and sawdust for dye removal [11,12]. However, since Long and Young first reported that carbon nanotubes were more effective than activated carbon for removing dioxins, these materials as new adsorbents attracted the attention of many researchers [13]. Carbon nanotubes are classified into two categories of singlewalled carbon nanotubes and multiwalled carbon nanotubes, high surface area, small size and cylindrical hollow structure, electrical conductivity of carbon nanotubes have caused these materials to be used for removing organic and inorganic pollutants [14,15]. Therefore, the present study aims to evaluate the performance of multiwalled carbon nanotubes as an adsorbent for removing Reactive Red 198 from textile wastewater.

2. Experimental

2.1. Adsorbent

Multiwalled carbon nanotubes (MWCNTs) used in this study were purchased from Iran's Research Institute of Petroleum Industry and utilized without any modifications in the lab scale. It should be mentioned that the nanotubes with over 95% purity were used in this study. Characteristics of (MWCNTs) are

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Table 1
Characteristics of nanotubes used in this study.

Parameter	Size
Length	10 μm
Nano-sized particles	20 nm
Specific surface area	<270 m^2/g
Purity	<95%
Diagonal	10–30 nm
electrical conductivity	1500 S/m

presented in Table 1. Also, Fig. 1 shows SEM and TEM images of this material provided by the Research Institute of Petroleum Industry.

2.2. Chemicals

RR198 used in this study was purchased from Alvan Sabet Company, Hamadan, Iran and utilized without further purification. The dye information is presented in Table 2.

Dye stock solution of 500 mg/L was prepared by dissolving (RR198) in the deionized water and different dye concentrations were prepared by dilution of the stock solution in suitable conditions. The maximum of adsorption wavelength was determined in the wavelength range of 300–800 nm and initial dye concentration 100 mg/L by spectrophotometer UV/Vis (Hatch – DR5000). In this experiment, it was observed that the maximum of adsorption spectrum was in the visible area (518 nm). Finally, the residual dye concentration was determined by spectrophotometer UV/Vis (Hatch – DR5000, Germany) at the wavelength of 518 nm according to the standard method [16]. Other chemicals used in this study had Merck's Laboratory purity.

2.3. Adsorption studies and analytical techniques

The current study was an applied-fundamental research conducted on the synthetic wastewater in a laboratory scale. The experiments were performed in 250 mL glass containers. HCL and NaOH 1N was used in order to adjust the pH. To study the effect of parameters such as contact time, pH, adsorbent dosage, temperature, and initial dye concentration for the removal of RR198, batch experiments was done using a shaker (models rotator R430) at a constant speed of 150 rpm. At the end of equilibrium, in order to separate the MWCNTs from the dye solution, the samples were centrifuged at 4000 rpm for 10 min and passed from 0.2 μ filter paper [10]. Dye analysis was carried out by spectrophotometer UV/Vis (Hatch – DR5000, Germany) at the wavelength of 518 nm. In this study, using one factor method at time, each parameter was separately optimized and then sample size was determined. Sample size in this study was 120.

The percentage of dye removal, and the amount of RR198 adsorbed by the adsorbent (adsorption capacity) at time t (q_t, mg/g), was calculated using Eqs. (1) and (2), respectively.

$$R_e(\%) = \frac{C_0 - C_t}{C_0} \times 100 \quad (1)$$

$$q_t = \frac{(C_0 - C_t)V}{m} \quad (2)$$

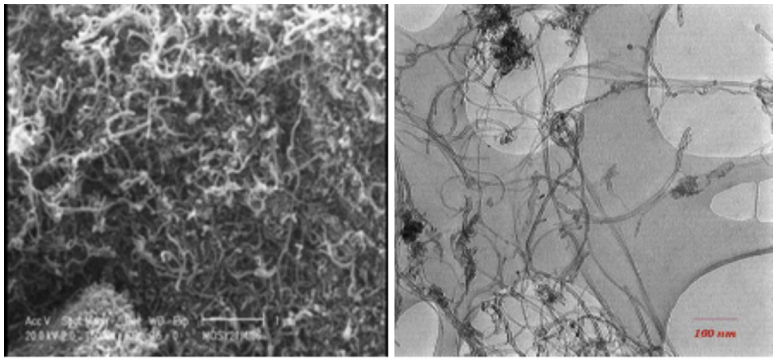

Fig. 1. (a) SEM and (b) TEM of a (MWCNTs).

Table 2
Profile of dye used in the study.

Parameter	Characteristic
Type color	Anionic
Symbol	RR198
Chemical formula	$C_{27}H_{18}ClN_7Na_4O_{15}S_5$
Molecular weight (g/mol)	968/21
Wavelength of maximum absorption (nm)	518
Chemical structure of color