Journal of Colloid and Interface Science 360 (2011) 760–767

Contents lists available at ScienceDirect

Journal of Colloid and Interface Science

www.elsevier.com/locate/jcis

Kinetics and thermodynamic study of aniline adsorption by multi-walled carbon nanotubes from aqueous solution

Hind Al-Johani [a,b], Mohamed Abdel Salam [a,*]

[a] Chemistry Department, Faculty of Science, King Abdulaziz University, P.O. Box 80203, Jeddah 21589, Saudi Arabia
[b] Center of Excellence in Environmental Studies, King Abdulaziz University, P.O. Box 80216, Jeddah 21589, Saudi Arabia

ARTICLE INFO

Article history:
Received 12 March 2011
Accepted 26 April 2011
Available online 4 May 2011

Keywords:
Carbon nanotubes
Aniline
Adsorption
Kinetics
Thermodynamics

ABSTRACT

Multi-walled carbon nanotubes (MWCNTs) were used in the adsorptive removal of aniline, an organic pollutant, from an aqueous solution. It was found that carbon nanotubes with a higher specific surface area adsorbed and removed more aniline from an aqueous solution. The adsorption was dependent on factors, such as MWCNTs dosage, contact time, aniline concentration, solution pH and temperature. The adsorption study was analyzed kinetically, and the results revealed that the adsorption followed pseudo-second order kinetics with good correlation coefficients. In addition, it was found that the adsorption of aniline occurred in two consecutive steps, including the slow intra-particle diffusion of aniline molecules through the nanotubes. Various thermodynamic parameters, including the Gibbs free energy change (ΔG°), enthalpy change (ΔH°) and entropy change (ΔS°), were calculated. The results indicated that the spontaneity of the adsorption, exothermic nature of the adsorption and the decrease in the randomness reported as ΔG°, ΔH° and ΔS°, respectively, were all negative.

1. Introduction

A common problem in most industries is the disposal of large volumes of wastewater containing potentially toxic organic solutes. Considering general safety and the environmental consequences of these solutes, their presence in wastewater requires treatment prior to disposal. Aniline is one of the most common pollutants found in effluents from the pharmaceutical, pesticide, dyestuff, petrochemicals and agrochemical industries. Aniline harmfully affects both public health and environmental quality. Aniline-containing wastewater has created a series of serious environmental problems due to its high toxicity and environmental accumulation. Strict limits on the release of aniline have been established. Traditionally, aniline-containing wastewater is treated with photodecomposition [1–3], electrolysis [4], adsorption [5,6], oxidation [7,8], biodegradation [9] and other processes. Generally, adsorption technology has proved to be one of the most effective techniques in the separation and removal of a wide variety of organic pollutants from wastewater [10,11]. These techniques do not produce harmful byproducts, and the regeneration of both the adsorbent and pollutants is possible. One challenge faced by adsorption technologies is the discovery of new adsorbents that successfully remove organic pollutants, such as aniline, from aqueous solutions.

Carbon nanotubes (CNTs) are a relatively new adsorbent that have been shown to possess great potential for removing many types of pollutants. Examples of the potential of CNTs for the removal of several types of pollutants include the following: ionizable organic compounds from water [12,13]; dichlorodiphenyltrichloroethane and its metabolites at trace levels from water samples [14]; organophosphorus pesticides from wastewater sludge [15]; nicosulfuron, thifensulfuron-methyl and metsulfuron-methyl from water samples [16]; atrazine from aqueous solutions [17–19]; polyhalogenated organic pollutants from environmental water samples [20–24]; tetrabromobisphenol A [25], pharmaceuticals from spiked water samples [26]; drugs from urine samples [27]; viruses from water [28]; polyaromatic hydrocarbons [29]; thiamethoxam, imidacloprid and acetamiprid [30]; polycyclic aromatic hydrocarbons from environmental water [31]; and pesticides [32] and metal ions [33–38] from various environments. The remediation ability of CNTs relative to other adsorbents is due to its strong interactions with the pollutants. This interaction results from the delocalized electrons in hexagonal arrays of carbon atoms on the surface of CNTs.

Although it has been reported that carbon nanotubes have strong adsorption capabilities for various pollutants, the literature detailing the removal of organic compounds, such as aniline, using CNTs is still scarce [11,39,40]. Further investigations on the adsorption/removal of aniline using carbon nanotubes in an aqueous environment are needed. In this study, various carbon nanotubes were used to study the removal/adsorption of aniline from an aqueous solution. The effects of various operating parameters, such

* Corresponding author. Fax: +966 2 6952292.
E-mail address: masalam16@hotmail.com (M.A. Salam).

0021-9797/$ - see front matter © 2011 Elsevier Inc. All rights reserved.
doi:10.1016/j.jcis.2011.04.097