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Comparison of 4-chloro-2-nitrophenol adsorption on single-walled and multi-walled carbon nanotubes

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Abstract

The adsorption characteristics of 4-chloro-2-nitrophenol (4C2NP) onto single-walled and multi-walled carbon nanotubes (SWCNTs and MWCNTs) from aqueous solution were investigated with respect to the changes in the contact time, pH of solution, carbon nanotubes dosage and initial 4C2NP concentration. Experimental results showed that the adsorption efficiency of 4C2NP by carbon nanotubes (both of SWCNTs and MWCNTs) increased with increasing the initial 4C2NP concentration. The maximum adsorption took place in the pH range of 2–6. The linear correlation coefficients of different isotherm models were obtained. Results revealed that the Langmuir isotherm fitted the experimental data better than the others and based on the Langmuir model equation, maximum adsorption capacity of 4C2NP onto SWCNTs and MWCNTs were 1.44 and 4.42 mg/g, respectively. The observed changes in the standard Gibbs free energy, standard enthalpy and standard entropy showed that the adsorption of 4C2NP onto SWCNTs and MWCNTs is spontaneous and exothermic in the temperature range of 298–328 K.

Keywords: Carbon nanotube, 4-Chloro-2-nitrophenol, Adsorption, Isotherm model, Thermodynamic

Introduction

Phenolic derivatives, such as a number of chloro- and nitrophenols are toxic and carcinogenic [1]. Chronic toxic effects due to phenols reported in humans include vomiting, difficulty in swallowing, anorexia, liver and kidney damage, headache, fainting and mental disturbances [2]. 4-Chloro-2-nitrophenol (4C2NP), which was chosen as the model compound in the present study, is recalcitrant and persistent towards biodegradation and is constituent intermediate of many industrial effluents [3]. While the World Health Organization (WHO) has recommended the permissible phenolic concentration of 0.001 mg/L in potable waters, the European Union (EU) has set a maximum concentration level of 0.5 μg/L of total phenols in drinking water [2,4]. Hence, removal of the phenolic compounds from wastewater before its discharge is necessary in order to reduce their side effects on the environment and human health.

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Many methods such as biodegradation [5], photocatalytic degradation [6], ultrasonic degradation [7], solvent extraction [8], ozonation [9,10] and decomposition by Fenton reagents [11] may be used to remove phenolic materials from aqueous solution. However, by far, the most frequently used technology is adsorption by a solid phase.

Several different adsorbents such as activated carbon [12], silica [13], polymeric resins [14] and zeolites [15] have all been proposed to remove phenolic pollutants from wastewater. In most cases, the adsorbents have diameters in the range of submicron to micron and have large internal porosities to ensure adequate surface area for adsorption. However, the diffusion limitation within the particles leads to decreases in the adsorption rate and available capacity. Therefore, it is important and interesting to develop a novel adsorbent with a large surface area for adsorption, a small diffusion resistance and a high capacity.

The relative large specific surface area of carbon nanotubes (CNTs) enables them to become candidate for adsorption of phenolic compounds [16,17]. CNTs provide