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Removal of Phenol from Water Different Types of Carbon – A Comparative Analysis

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Abstract

Toxic organic substances are considered among the pollutants that have direct effect on humans and animals. Industrial wastewaters containing dissolved phenol can contaminate groundwater resources and thus lead to a serious groundwater pollution problem. In the present research, the adsorption technique for the efficient removal of phenol pollutants at trace level in water was employed. Four type of micro and nanocarbon materials including carbon nanotubes (CNTs) and carbon nanofibers (CNFs) as nano carbon adsorbents, activated carbon (AC) and industrial carbon fly ash (CFA) as micro carbon adsorbents were used to remove phenol from water. Characterization of these adsorbents was performed by Field Emission Scanning Electron Microscopy (FE-SEM), Transmission Electron Microscopy(TEM), Thermogravimetric Analysis (TGA), BET specific surface area while the concentration of phenol in water before and after treatment was analyzed using UV-Spectroscopy. The pH (3-9) of the solution, was varied in order to determine their effect on the removal of phenol from water and hence on the adsorption rate.

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Keywords: Phenol, carbon nanotubes, carbon nanofibers, activated fibers, carbon fly ash, adsorption

1. Introduction

Environmental pollution is currently one of the most important issues facing humanity. It has increased exponentially in the past few years and reached alarming level in terms of its effects on living creatures. Toxic organic substances are considered among the pollutants that have direct effect on human and animals.

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Industrial wastewaters containing dissolved polycyclic aromatic hydrocarbons (PAHs) and phenols can contaminate groundwater resources and thus lead to a serious groundwater pollution problem. Exposure to such chemicals can damage the central nervous system, respiratory system, kidney, and blood system if entered into human body [1]. Agency for Toxic Substances and Disease Registry, USA, has classified phenols as the top 45th priority hazardous substances that need urgent treatment before entering into the environment [2]. Therefore, removing these organics or decreasing their concentrations to the permitted levels before discharging becomes a challenging issue. Several ways have been developed to remove phenol compounds from wastewaters, including electrochemical oxidation [3], chemical coagulation [4], solvent extraction [5],. membrane separation [6], bioremediation [7] and photo catalytic degradation [8]. Several technological processes can be performed to remediate organic compounds from water. Bioremediation of phenols and low molecular weight PAH is a preferred technique because of its ease of implementation but tends to be timely and often incomplete especially at high-molecular weight PAHs (with five or six aromatic rings), which are proven to be more recalcitrant to biological degradation [7]. Among the potential adsorbent materials are carbon-based compounds which are hydrophobic and non-polar, including materials such as activated carbon (AC)[1]-[17], carbon nanotubes (CNTs) [15], carbon nanofibers (CNFs) [16] and industrial fly ash (FA) [17]. Carbonaceous materials such as AC are characterized by a large surface area, well-developed porosity and tunable surface-containing functional groups. It is extensively used for removal of both organic and inorganic compounds from aqueous solution [12]-[20]. In the present work, the effect of four types of micro and nano carbon materials on the removal of phenol from water was investigated.

2. Experimental Procedure and Materials

2.1. Carbon nanotubes and carbon nanofibers , Activated Carbon and Carbon Fly ash

Carbon nanotubes and carbon nanofibers were purchased from Nanostructured & Amorphous Materials, Inc. USA. The Purity of CNTs and CNFs are>95%,their outside diameters are 10-20 nm and 200–500 nm; respectively while their length ranges from 1-10 μm and 10–40 μm respectively. The activated carbon (AC) used in this study was purchased from Calgon, and it was supplied in 10–30 mesh (0.60 –1.0 mm) size. The granular-activated carbon was milled in a hammer-cutter mill to a powder (<0.18 mm in particle diameter).The surface area of AC was measured by nitrogen adsorption at 77 oK using Micromeritics Gemini 2375 surface area analyzer (Micromeritics, Norcross, GA) using a 15-point BET. Fly ash (FA) is one of the residues generated in the combustion process of coal and liquid fuels and represents the fine particles that rise with the flue gases. The fly ash used for this study was produced by burning heavy fuel oils in one of Saudi Aramco company main power plants and the produced ash contains high percentage of unburned carbon and some other metals. Saudi Aramco produces hundreds of thousands of tons of FA per year [20]. FA was analyzed by Energy Dispersive X-ray (EDX) analysis to identify the elemental composition. The EDX analysis indicated that FA contains 67.56% weight carbon beside many other different metals as shown in the EDX spectrum (Table 1).

Table 1. The Energy Dispersive X-ray analysis of FA

Spectrum	C	O	Na	Mg	S	V	Fe	Ni	Cu	Zn	Total
Wt%	67.56	23.73	0.12	2.04	4.98	0.76	0.12	0.25	0.25	0.19	100.0

2.2. Batch mode adsorption experiment

Experiments of batch mode adsorption were conducted at room temperature to study the effect of the initial pH of the solution, the carbon dosage, the contact time and the agitation speed on the adsorption of phenol