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Dynamic adsorption behavior and mechanism of Cefotaxime, Cefradine and Cefazolin antibiotics on CdS-MWCNT nanocomposites

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ABSTRACT

Normative batch adsorption studies of Cefotaxime, Cefradine and Cefazolin onto the developed CdS-MWCNT nanocomposites were well elucidated and investigated. The whole experimentation was carried out as a function of several influential parameters such as adsorbent dose, pH, contact time, and temperature. The developed adsorbent i.e. CdS-MWCNT nanocomposites were found to have high specific surface area and prodigious adsorption capacity. Several adsorption isotherm models such as Freundlich, Langmuir, Temkin and Scatchard were applied for the examination of equilibrium data, but Langmuir isotherm was found to be well fitted and in good agreement with the equilibrium data. One of the key finding is that the adsorption capacity increases on increasing pH and decreasing temperature. Thermodynamic parameters such as Gibbs free energy, enthalpy and entropy were calculated, the analysis showed negative values of ΔG, which reveals the spontaneous nature, negative values of ΔH reveals the exothermic nature as well as physical nature of adsorption, additionally negative values of ΔS reveals the decreased disturbance interface of Cefotaxime, Cefradine and Cefazolin removal using CdS-MWCNT nanocomposites.

1. Introduction

The presence of noxious pharmaceuticals chemicals in the lentic surroundings as well as in swig water has enhanced a germinating interest lately [1–6], because they cause severe detrimental and carcinogenic effects on the human health. The noxious substance concentration has been reported to be between ng L^{-1} to μg L^{-1} [7,8]. Novel pharmaceutical compounds included petty molecules of organic compound that are gently soluble in water as well as they are lipophilic in nature. The presence of antibiotics in pharmaceuticals companies' effluents, their arrival into surface or underground water has posed two influential hazards. First, incidence of these materials in the environment itself is a fulmination and finally their arrival into environment follows the risk of microorganism resistor [9]. Cefotaxime, Cefradine and Cefazolin is a third-, first- and first-generation cephalosporin antibiotic. These blends are a class of β-lactam antibiotics and from fungus *Acremonium*. The chemical and physical specification of Cefotaxime, Cefradine and Cefazolin are presented in Table 1. The therapy of organic blends in industrial wastewater enhanced several problems since organic blends are generally non-biodegradable and non-photodegradable. Among all the water treatment techniques, adsorption is the most beloved physicochemical treatment for the removal of dissolved organics from waters. Nanomaterials, such as nanorods, nanoribbons, nanowires and nanoparticles, have been of major concern in materials science and their basic attributes and feasible usage in multiplex region [10–17].

The ill effect of Cefotaxime includes pain and inflammation at the site of injection/infusion (4.3%), rash, pruritus, or fever (2.4%), colitis, diarrhea, nausea, vomiting (1.4%).

The ill effect of Cephradine includes diarrhea that is watery or bloody, fever, chills, body aches, flu symptoms, tightness in your chest, unusual bleeding and increased thirst, loss of appetite, swelling, weight gain, feeling short of breath, urinating less than usual or not at all.

The ill effects of cephazolin drug include hypersensitivity side effects which may be anaphylaxis, eosinophilia, urticaria, itching, drug fever, skin rash, Stevens-Johnson syndrome, and allergic cross-sensitivity. Cephalosporin-class side effects have included allergic reactions, urticaria, serum sickness-like reaction, erythema multiforme, and toxic epidermal necrolysis.

There are several adsorbents such as bagasse fly ash [18,19], bottom ash [20,21], CNTs and MWCNTs [22–25], fix bed adsorbers [26], resins

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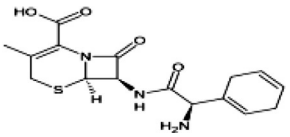
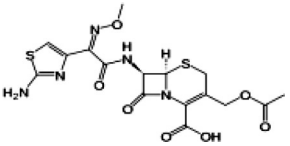
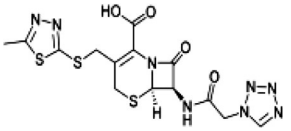
Table 1
Physicochemical attributes of Cefotaxime, Cefradine and Cefazolin.

	Molecular weight (g mol^{-1})	Melting point (°C)	Chemical structure
Cefradine	349.40	140–142	
Cefotaxime	477.45	162–163	
Cefazolin	454.51	198–200	

[27], nanoparticles [28–33], rubber tire [34,35], sensors and electrochemical devices [36–40] and these all the previously developed have various applications in many scientific and industrial fields, including wastewater purification, catalysis and antibacterial activity.

The target of the present work was to survey the use and application of developed adsorbent i.e. CdS-MWCNT nanocomposites for the rapid removal of Cefotaxime, Cefradine and Cefazolin from aqueous matrices. The Freundlich, Langmuir, Temkin and Scatchard isotherm equations were applied to elucidate the equilibrium data. The adsorption mechanisms of Cefotaxime, Cefradine and Cefazolin from aqueous solutions onto CdS-MWCNT nanocomposites were also appraised in states of kinetics and thermodynamic parameters.

2. Materials and methods

2.1. Raw material

Multi-walled carbon nanotube synthesized by catalytic chemical vapor deposition (CVD, purity >95%) with, tube length of 0.5–200 nm and inner diameter (i.d.) of 5–10 nm and outer diameter (o.d.) of 10–20 nm was obtained from Nanostructured & Amorphous Materials (Houston, TX, USA). Cefotaxime, Cefradine and Cefazolin (99%) were obtained from Hangzhou Dayangchem Co. (Hangzhou, China) and used as received without any further purification. All the other chemicals were obtained from Sigma-Aldrich Ltd., USA. All the chemicals used for the study were of analytical grade.

2.2. Purveyance of CdS-MWCNT nanocomposites

The pristine MWCNTs were first undergo ultrasonic treatment in concentrated H_2SO_4/HNO_3 mixtures (3:1 *v*/*v*) for 8 h at 10 °C, and then washed repeatedly with distilled water. The product obtained was dried and denoted as acidic-MWCNTs. 100 mg of the acidic-MWCNTs powder is dispersed in 250 mL of H_2O by an ultrasonic device. Suspension of acidic-MWCNTs and the 0.5 M Na_2S solution was added drop wise to the 0.5 M Cadmium acetate dehydrate solution and simultaneously 2 mL of 0.1 M PVP was added under continuous stirring until the solution pH reached 8. Then the mixture solution was stirred at 80 °C for 6 h and then dried at 80 °C for 10 h.

A field emission scanning electron microscopy (FESEM-Hitachi SU8000 and X-ray diffractometer (XRD) Philips X'Pert were used to distinguish the adsorbent morphological information. The particle size of the CdS-MWCNT nanocomposites was measured using Transmission Electron Microscope (TEM) (Zeiss EM-900). The Brunauer–Emmett–Teller (BET) of the CdS-MWCNT nanocomposites was analyzed by nitrogen adsorption instrument in an ASAP2020 surface area.

2.3. Adsorption experiment methods

The removal of antibiotics using CdS-MWCNT nanocomposites was surveyed by batch methods. For this test 1000 mg/L solution of supply was confected by adding 1 g of antibiotics in 1000 mL water. Various temperatures 20 to 40 °C of solutions were confected. The between range for dosage of adsorbent 0.05–1.05 gL^{-1} was added after pH regulation made in between 1 and 10. The equilibrium removal capacity was calculated by

$$q_e = \frac{(C0 - Ce)V}{W} \quad (1)$$

where, q_e (mg/g) is the equilibrium adsorption capacity, C_e is the antibiotic concentration at equilibrium (mg/L), V is the volume of solution (L) and w is the mass of adsorbent (g). The antibiotics concentration was distinguished with the aid of a two dimensional Gas Chromatogharphy (GC*GC) (Kimia Shangarf Pars Research Co., Iran). The analysis of data was performed using analysis of relevance employing least-square model and the residuals sum of square is computed by Eq. (2) [41]:

$$RSS = \sum \left[q_{e,exp} - q_{e,cal}\right]^2. \quad (2)$$

3. Results and discussions

3.1. Characterizations of CdS-MWCNT nanocomposites

From Fig. 1A (B), the (111), (220), and (331) planes of CdS are observed at $2\theta = 26.5, 42.4$ and 54° respectively. It can be seen that the diffraction peaks at $2\theta \approx 26, 43$ and 53° are assigned to (002), (110), and (004) planes of MWCNTs in Fig. 1A (A). These three diffraction peaks are attributed to the graphitic structure of MWCNTs. The graphitic structure of MWCNTs isn't destroyed after MWCNTs were coated with CdS nanoparticles as we can observe that the characteristic peaks of MWCNTs still exist in Fig. 1A (B). However, the main peak of MWNTs assigned to (002) plane and also other peaks are overlapped by that of CdS.

Fig. 1B depicts the FE-SEM images of the CdS/MWCNT nanocatalyst. The CdS nanoparticles that were produced in situ exhibit a mean particle size of approximately 10 nm. The images illustrate that the CdS nanoparticles were well attached to the MWCNTs. This result was further confirmed by TEM micrographs of the CdS/MWCNTs nanocatalyst (Fig. 1C). The CdS nanoparticles existed in the size of approximately 10 nm which was in good agreement with the calculated crystallite