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Cadmium removal from aqueous solution by green synthesis zero valent silver nanoparticles with *Benjamina* leaves extract

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A B S T R A C T

Cadmium (II) is an important element used in various industries, however, it is a poisonous element that affects the health of plants, animals and humans alike. It's very important to remove this element from contaminated waters. This study aims at synthesizing zero valent silver nanoparticles by environmentally ecofriendly method without using hazardous compounds (via green approach). In this work, silver nanoparticles were prepared using hot water for the *Ficus tree (Ficus Benjamina*) leaf extract (FBLE). The size of crystalline for AgNPs was measured by UV–vis spectroscopy and flourier transform infrared (FTIR). The properties of nano-silver particles (AgNPs) have been studied using scanning electron microscope (SEM). The capability of nanoparticles to remove Cd^{2+} from contaminated solution was then studied. Parameter like adsorbent dose, heavy metal concentration, pH, agitation speed and contact time were studied. Cadmium removal increased when the dosage of biosorbent increases, pH increased from 1 to 6, contact time from 5 to 40 and initial concentration of Cd decrease. Isotherm adsorption was also described by the Freundleich model with a constant correlation (R^2) higher than 0.973.

Introduction

One of the most popular applications for the development and research in technical disciplines is nanotechnology. In the last decade, nanotechnology is one of the most important advances in technology and science. When preparing the nanoparticles, new and unique properties appear to have many benefits such as magnetization. Nanotechnology-derived products can also help reduce concentrations of toxic compounds at sub-levels to meet water quality standards and health reports (Savage and Mamadou, 2005). Nanoparticles are a good solution to address some pollution problems and clean up the contaminated environment. As the size of the material approaches the nanometer, its properties change and the proportion of atoms on the surface of the material becomes larger. According to (Zhang, 2003), nano scale iron particles have high surface reactivity and large surface areas (Zhang, 2003). Many researches have shown that the nanoparticles for iron are effective for the detoxification and transformation of a vast diversity of environmental pollutants, such as organo chlorine pesticides, harmful organic solvents and others contaminates. The characteristics of nanoparticle are characterized by X-ray Diffraction (XRD) and Scanning Electron Microscope (SEM). The average diameter of iron particles ranged from 10 to 30 nm (Ponder et al., 2000) while their size of is known to range from 10 to 100 nm (Sun et al., 2007).

The extraction of cadmium ions from polluted water is important benefit from both economic and environmental due to its high toxicity to animals, plants and humans. Different adsorbents have been used such as peels and wastes of different plants, activated carbons, biopolymers, clay and others. Long term Pollution of drinking water with Lead and Cadmium ions may cause many health problems as convulsions, nausea, coma, cancer, renal failure, and subtle effects on metabolism and intelligence (Deng et al., 2010). Several extraction methods have been tested for the extraction of heavy metal from solution, such as: coagulation, precipitation, ultrafiltration, adsorption, membrane separation and reverse osmosis (Sun et al., 2014; Yang et al., 2009). Recently, adsorption technique has been known as an effective and economic method for heavy metals extraction (Zhang et al., 2013; Cheng et al., 2015; Wang et al., 2011).

Last decade, the development of nanotechnology and Nano science has shown marked ability to address environmental pollution (Lee et al., 2010). Nanomaterials have shown high faster rates and efficiency in water treatment than traditional old materials. Nanoparticles commonly used include zero metals to uptake heavy metal ions from contaminated water (Xu et al., 2010;

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Wang et al., 2010; Xiong et al., 2007; Liu et al., 2010; Liu and Zhang, 2010; Lin et al., 2005).

The objective of this study is to evaluate the capacity of zero valent silver (Ag^0) nanoparticles (AgNPs) synthesized by Fresh *Ficus Benjamina* leaves to remove Cd (II) from aqueous solutions. Batch adsorption process has been used to evaluate the maximum adsorption capacity of zero valent silver (Ag^0) nanoparticles (AgNPs) synthesized by Fresh *Ficus Benjamina* leaves. The main parameters considered are pH, contact time, initial metal ions concentration, agitation speed and adsorbent dose.

Materials and methods

Preparation of AgNPs

Reagents were prepared using chemically pure grade (AnalaR). The fresh plant material was *Ficus tree (Ficus Benjamina)*. This plant is from the *Moraceae* family and is one of the most abundant flowering plants in Australia and Asia Fig. 1. The species can also be found in the States of Florida and Arizona in the United States and in the West Indies. *Ficus benjamina* is a tree that in normal conditions can reach 30 meters.

A biomass of *Ficus Benjamina* was used as a biosorbent of Cd (II). Samples of the biomass were collected from the polluted area around second industrial area, Riyadh City, Saudi Arabia. The leaves were washed first with tap water, de-ionized water drying in oven at 50 °C then cut onto small pieces. To prepare the extract of *Ficus Benjamina* leaves, take 20 g of leaves in Erlenmeyer flask (250 mL) then add 100 mL of sterile distilled water, boil the previous solution for 5 min (60 °C). After boiling for 5 min the mixture was filtered and the filtrate will be stored at 4 °C until used as a reducing and stabilizer agent for the preparation of nanoparticles synthesis process.

For synthesis Ag^0 nanoparticles process, take 2 ml of *Ficus Benjamina* leaves extract (FBLE) and add to 25 mL of $AgNO_3$ (1 Mm). The solution changes its color to brown. Finally, the solution stirred for 40 min to form the silver nanoparticles. This experiment was conducted at room temperature (25 °C). The appearance of brown color shows the formation of Ag nanoparticles. Color changes to brown within 20 min shows that the AgNPs is formed. The characterizations of the formed Ag nanoparticles were studied.

The samples were taken at different times and analyzed by UV–Vis spectrophotometer on UV- 1800 (200–700 nm): JASCO V-530 Japan, measuring lead: Varian ICP – AES. FT-IR studies were performed to observe the evolution of nanoparticles of Ag^o. FT-IR spectra have been taken for dried nanoparticles, done by a Fourier-transform infrared spectrophotometer (JASCO FT/IR-410, Japan) from 400 to 4000 cm^{-1} by grinding the samples powder with potassium bromide for FTIR spectra tests. Scanning electron microscopy (SEM): A thin film of nanoparticles was formed on a copper slide covered with carbon, use blotting paper to remove the extraction solution and then dry the film under the mercury lamp for 5 min. Then the film was placed in the vessel and introduced into the microscope.

Preparation of Cd(II) stock solution

Doubly distilled water was throughout employed. Initial solutions with different concentration of Cd (II) were prepared using standard solution of cadmium 1000 mg L^{-1} (Merck, Ltd., UK). The pH adjustment of the solutions was made with aliquots of 1.0 mol l^{-1} of HNO_3 utilizing a pH/mV hand-held meter (Crison pH meter, PH 25).

Removal experiments

The biosorption experiments were carried out by mixing 0.05 g AgNPs in 30 mL solution of Cd (II) with different concentrations (30, 50, 70, 100, 120 and 150 mg/L). The solutions were well shacked onto bath shaker at different agitation speed (from 100 to 700 rpm). The effect of time on the adsorption process was carried out. Samples of 1 ml were collected from flasks at required time intervals 5–70 min and centrifuged for 5 min. The effect of pH on Cd (II) adsorption was carried out at 25 °C for 3 h equilibrium time. The initial pH values were adjusted in range of 1–8 with 0.1 M HCl or 0.1 M NaOH. The concentration of Cd(II) was estimated by Atomic Absorption Spectrophotometer (model: AAS 240 FS). The percentage of the removal of Cd (II) from polluted water was estimated using the formula:

$$\%\ \text{removal} = \frac{Co - Ce}{Co} \times 100 \qquad (1)$$

whereas, C_e: the final concentration of Cd(II) mg L^{-1} and C_o: the initial concentration of Cd(II) mg L^{-1}.

Assessment of adsorption performance

Adsorption isotherm is very important to understand and explain how the solutes are interacting with the adsorbent. Two models were used to explain the removal process. Freundlich (Eq. (2)), Langmuir (Eq. (3)) isotherm were organizing by using straight-line equation and all its parameter for cadmium (II) ion was calculated from their particular graphs. The straight-line

Fig. 1. Ficus tree (*Ficus benjamina*).

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