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Water purification using different waste fruit cortexes for the removal of heavy metals

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Abstract

The use of different cortex fruit wastes, including banana, kiwi and tangerine peels, for removing toxic and heavy element Cd^{+2}, Cr^{+3} and Zn^{+2} ions from aqueous solutions has been previously investigated. The ground material was powdered in a mortar and passed through a screen to obtain two different particle sizes, 1 and 2 mm, for all of the powders. In preliminary experiments using kiwi cortex, material with a 1-mm particle size showed a higher retention capability (up to 10–16% of Cd^{+2}, Zn^{+2} and Cr^{+3}) than material with 2-mm particles. Considering these results, material with a 1-mm particle size was used in further experiments with the other waste materials. For Cd^{+2}, Zn^{+2} and Cr^{+3} removal, it was determined that kiwi and tangerine cortex showed better biosorption capability when compared with banana cortex (up to 35% more for Cd, 25% more for Zn and 35% more for Cr). The effects of the initial concentration (10–100 mg/l), pH (2–10), adsorbent dosage (0.1–2.0 g) and contact time (5–120 min) were studied at room temperature. A strong dependence of the adsorption capacity on the initial metal concentration was observed. The capacity increased as the initial concentrations decreased. A maximum removal was observed at an adsorbent dosage of 2.0 g and an initial concentration of 10 mg/l. The adsorption isotherms of the different cortex fruit wastes were determined. The equilibrium data were tested using a Langmuir isotherm model, and the kinetics conformed to the pseudo-second equation. The order of the maximum adsorption capacity of these metal ions on banana was $Cr^{+3} < Cd^{+2} < Zn^{+2}$, whereas it was $Cd^{+2} < Cr^{+3} < Zn^{+2}$ for kiwi and tangerine. Complexation is proposed as the adsorption mechanism. The experimental results show that the natural biosorbent was effective for the removal of pollutants from an aqueous solution.

Keywords: Biosorption; Heavy metals; Wastewater; Polluted water

1. Introduction

Heavy metal pollution in aquatic systems has become a serious threat and has a great potential to cause environmental-derived cancer because these metals are non-biodegradable and therefore persistent. Metals are mobilized and carried into the food web as a result of leaching from waste dumps, polluted soils and water. These metals increase in concentration at every level of the food chain and are passed onto the next higher level in

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a phenomenon called biomagnification [1]. The contamination of water with substances that have an adverse effect on human beings, animals and plants is called water pollution. Water pollution is a worldwide problem, and its control has become increasingly important in recent years [2]. Municipal or industrial effluents treated by wastewater treatment plants contain large amounts of organic matter and pollutants, including metals such as Cu, Zn, Cd and Pb. The uptake of metals by sludge flocks is of great significance in pollution control [3]. Lead is a very toxic heavy metal, and its target organs are bones, the brain, blood, kidneys, and the thyroid glands. The presence of lead in discharge and its toxic nature cause other adverse effects on receiving waters in the aquatic system. Even a very low concentration of heavy metals in water can be very toxic to aquatic life. The main source of lead and cadmium in water is the effluents of processing industries, i.e., electroplating, paint, pigment, basic steel work, textile industries, metal finishing and electric accumulators' batteries [4].

Conventional methods for removing metals from aqueous solutions include chemical precipitation, chemical oxidation and reduction, ion exchange filtration, electrochemical treatment, reverse osmosis, membrane technologies and evaporation. The major disadvantage of conventional treatment technologies is the production of toxic chemical sludge, whose disposal/treatment becomes a costly affair and is not eco-friendly. Therefore, removal of toxic heavy metals to an environmentally safe level in a cost-effective and environmentally friendly manner is of great importance [5,6]. In recent years, considerable attention has been devoted to the study of the removal of heavy metal ions from solution by adsorption using agricultural materials. Natural materials that are available in large quantities or certain wastes from agricultural operations may have the potential to be used as low-cost adsorbents, and they represent unused resources, which are widely available and are environmentally friendly. Some investigations on the removal of heavy metal ions with agricultural by-products have been previously reported [7]. Biosorption is defined as the ability of biological materials to accommodate heavy metals from wastewaters through the metabolically mediated physico-chemical pathways of uptake. Algae, fungi, bacteria, parts of some higher plants and yeasts have proven to be potential metal biosorbents. When the heavy metal concentration exceeds the tolerance level, it will show harmful effects on human physiological and other biological systems [8].

Several biosorption studies have been conducted using microbial systems and mainly involve bacteria, microalgae and fungi [9,10]. Nevertheless, the term is now applied to all manners of organic and inorganic pollutants, and the term biosorption can describe any system in which a sorbate (i.e., an atom, molecule, a molecular ion) interacts with a biosorbent (i.e., a solid surface of a biological matrix) and results in an accumulation at the sorbate–biosorbent interface and therefore a reduction of sorbent concentration in the solution [11]. Many different approaches have been studied and developed for the effective removal of heavy metals using biosorbents such as peat [12], fly ash [13,14], microbial biomass and other agricultural by-products such as sugarcane bagasse [15], soya bean hulls [16], walnut hulls [17], cotton seed hulls and corn cobs [18]. It has also been observed that these biosorbents require further modifications to increase the number of active binding sites and make them readily available for sorption. Huang and Huang have stated that pre-treatment of the biomass removes the surface impurities on the biosorbents and exposes the available binding sites for metal sorption [19,20].

The main goal of this work was to demonstrate the use of modified waste materials from banana, kiwi and tangerine cortex as an excellent source of biomass for the chelating of heavy metals such as Cr^{+3}, Cd^{+2} and Zn^{+2}. The effects of the adsorbent dose, pH, contact time and initial metal ion concentration on the adsorption capacity were investigated. The equilibrium of adsorption was modelled using the Langmuir isotherm.

2. Materials and methods

2.1. Reagents

All of the chemicals used in this study were of analytical purity. Stock solutions of single heavy metals were prepared as follows: the stock solutions of cadmium, chromium and zinc (1000 mg/l) were provided from the BDH Company; the working standard solutions of metal ions were prepared by diluting 100 ml of the stock standard solution of the selected ion to 1 l with distilled water (or by diluting 50 ml of the stock standard solution of the selected ion to a half litre with distilled water). A total of 5 ml of this solution was diluted to 50 ml with distilled water to obtain a solution containing 10 mg/l of the selected ion. These concentrations were used throughout the experiments. The pH of the solution was adjusted using 0.1 M HCl or 0.1 M NaOH for fresh dilutions. All of the adsorption experiments were conducted at room temperature.