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ORIGINAL ARTICLE

Optimization study of adsorption parameters for removal of Cr(VI) using *Magnolia* leaf biomass by response surface methodology

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Abstract
The removal of chromium (Cr) using waste biomass is one of the most important issues throughout the world. In the present study, *Magnolia* leaf, a forest waste, is employed as novel and available adsorbent to abate Cr(VI) from simulated solution through batch study. The effects of operating variables on biosorption were analyzed using a multi-step response surface methodology (RSM). The optimum biosorption conditions were determined at the initial Cr(VI) concentration of 40.0 mg L^{-1}, pH of 2.0, contact time 45.0 min and dose of 0.5 g. At optimum conditions, the biosorption capacity of *Magnolia* leaf for Cr(VI) was found to be 3.96 mg g^{-1} that reflects the removal of 98.8%. The obtained data matched with the pseudo-second-order rate ($R^2 = 0.987$) expression and fitted the Langmuir isotherm ($R^2 = 0.999$) very well. The thermodynamic parameters such as ΔH°, ΔS° and ΔG° for the Cr(VI) biosorption were calculated at six different temperatures. The surface characteristics and the existence of chromium of the biomass, before and after biosorption, were studied through scanning electron micrographs–energy-dispersive X-ray spectroscopy (SEM–EDX) and Fourier transform infrared (FTIR) analysis. The present results indicate that *Magnolia* leaf is a suitable low-cost bio-material to remove Cr(VI) from aqueous solutions.

Keywords *Magnolia* leaf · Biosorption · Cr(VI) removal · Isotherm · Optimization · Response surface methodology

Abbreviations

ANOVA	Analysis of variance
BBD	Box–Behnken design
EDTA	Ethylene diamine tetra acetic acid
FTIR	Fourier transform infrared
MLP	*Magnolia* leaf powder
RSM	Response surface methodology
SEM	Scanning electron micrographs

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Introduction

Heavy metals are considered as a significant public health problem because they are non-biodegradable and have a persistent nature (Sahan and Ozturk 2014). They can be accumulated through the food chain even at low concentrations, leading to a threat to aquatic life as well as to animal and plant life and human health. The presence of heavy metals in drinking water sources and in edible agricultural crops is harmful to human. It is well known that heavy metals are toxic as they damage nerves, liver and bones by blocking functional groups of vital enzymes (Gholami et al. 2006). Chromium (Cr) is one of the most abundant metals present in groundwater contaminants to hazardous level particularly in waste sites. It is widely used in modern industries such as leather tanning, electroplating, cement, steel, paint, dyes and textiles. The two most common and widely available oxidation states of chromium are Cr(III) and Cr(VI). Among the available oxidation states, Cr(VI) is considered to be potentially carcinogenic to humans and is reported to be bioaccumulated into flora and fauna, creating ecological problems (Koyuncu 2012). Compared to its trivalent counterpart, hexavalent chromium forms chromate (CrO_4^{2-}) or hydrogen chromate ($HCrO_4^{-}$) that is more soluble at different

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