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ORIGINAL PAPER

Removal of hexavalent chromium from aqueous solution using activated carbon prepared from walnut shell biomass through alkali impregnation processes

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Abstract Walnut (*Juglans regia*) is a commonly used nutrient industrial crop but the shell of the walnut has no economic value. Hence to revamp the waste walnut shell biomass to useful product, activated carbon (AC) was prepared from *J. regia* shells by impregnating with NaOH. Different ACs were prepared by varying the impregnation ratio of char:NaOH as 1:1 (AC1), 1:3 (AC2), and 1:5 (AC3). The effect of impregnation ratios on the adsorptive properties of ACs for the adsorption of hexavalent chromium [Cr(VI)] was studied. The ACs were characterized by SEM, surface functionality, and zero point charge. Langmuir, Freundlich, Temkin, and Dubinin–Radushkevitch isotherm were used to interpret the batch equilibrium data. The adsorption of Cr(VI) onto ACs followed Langmuir isotherm model. Kinetic data followed pseudo second-order rate equation. Intraparticle diffusion model and Boyd plot were used to study the mechanism of the adsorption reaction. The adsorption was both by film diffusion and intraparticle diffusion. The rate-controlling step was predicted as external mass transfer. Thermodynamic parameters were also estimated. Overall, AC with higher impregnation ratio (AC3) possessed better adsorption properties compared to AC2 and AC1.

Keywords NaOH activation · Hexavalent chromium · Impregnation ratio · Adsorption isotherm · Adsorption kinetics · Thermodynamics

Introduction

Walnuts are high density nutrient rich in protein and essential fatty acids. Due to its high nutritional value and antioxidant property, the worldwide production of walnut has been increasing rapidly in recent years particularly in Asian countries (Arranz et al. 2008). In India, walnut is abundantly grown in states like Jammu and Kashmir, Uttaranchal, Himachal Pradesh, and Arunachal Pradesh. Total area under walnut production is estimated to be 36,500 ha with the annual production over 31,000 metric tonnes. The annual growth rate of walnut production in India was about 2.9 % (Dewan and Bahadur 2005). Unfortunately, the shells of walnuts make no economic value and considered as waste which generate the disposal problems (Martinez et al. 2006). Like most other agricultural by-products, walnut shells too can be carbonized and used as adsorbents for treating polluted water. Water is termed as polluted when it contains the contaminants which affect the biological and chemical equilibria of the water system. A number of water treatment processes mostly chemical processes ranging from precipitation/flocculation to photo oxidation were available (Visa et al. 2011). Out of these methods, adsorption has proved to be the most efficient and economical method for the wastewater treatment (Merrikhpour and Jalali 2012). The efficiency of the adsorption process lies in the preparation of the adsorbent. Activated carbons (AC) with high porosity and surface functional groups had better properties as adsorbents than crude biomasses (Rivera-Utrilla and

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