

Adsorption kinetics for the removal of chromium (VI) from aqueous solutions on the activated carbons prepared from agricultural wastes

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Abstract

The batch removal of Cr(VI) from aqueous solution using low-cost adsorbents such as cornelian cherry, apricot stone and almond shell under different experimental conditions was investigated in this study. The influences of initial Cr(VI) ion concentration (20 to 300 mg·L⁻¹), pH (1 to 4) and particle size (0.63 to 1.60 mm) have been reported. Adsorption of Cr(VI) is highly pH-dependent and the results indicate that the optimum pH for the removal was found to be 1 for all types of carbon. A comparison of kinetic models applied to the adsorption of Cr(VI) ions on the adsorbents was evaluated for the pseudo first-order, the pseudo second-order, Elovich and intraparticle diffusion kinetic models, respectively. Results show that the pseudo second-order kinetic model was found to correlate the experimental data well.

Keywords: adsorption; Cr(VI); adsorption kinetics; low-cost adsorbents; aqueous solution

Introduction

Hexavalent chromium is present in the effluents produced during the electroplating, leather tanning, cement, mining, dyeing and fertilizer and photography industries and causes severe environmental and public health problems. Hexavalent chromium has been reported to be toxic to animals and humans and it is known to be carcinogenic (Raji and Anirudhan, 1998). Its concentrations in industrial wastewaters range from 0.5 to 270.000 mg·L⁻¹ (Patterson, 1985). The tolerance limit for Cr(VI) for discharge into inland surface waters is 0.1 mg·L⁻¹ and in potable water is 0.05 mg·L⁻¹ (EPA, 1990). In order to comply with this limit, it is essential that industries treat their effluents to reduce the Cr(VI) to acceptable levels.

A number of treatment methods for the removal of metal ions from aqueous solutions have been reported, mainly reduction, ion exchange, electro dialysis, electrochemical precipitation, evaporation, solvent extraction, reverse osmosis, chemical precipitation and adsorption (Patterson, 1985). Most of these methods suffer from drawbacks such as high capital and operational costs or the disposal of the residual metal sludge.

Many reports have appeared on the development of low-cost activated carbon adsorbents developed from cheaper and readily available materials (Babel et al., 2003; Bailey et al., 1999; Pollard et al., 1992). Activated carbons with their large surface area, microporous character and chemical nature of their surface have made them potential adsorbents for the removal of heavy metals from industrial wastewater.

The adsorption of Cr(VI) by a number of materials such as leaf mould (Sharma and Forster, 1994a), activated groundnut husk carbon (Srinivasan et al., 1991; Periasamy et al., 1991), coconut husk and palm pressed fibres (Tan et al., 1993), coconut shell activated

carbon (Alaerts et al., 1989), coconut shell, wood and dust coal activated carbons (Selomulya et al., 1999), coconut jute carbon (Chand et al., 1994), coconut tree sawdust carbon (Selvi et al., 2001), sawdust and used tyres carbon (Hamadi et al., 2001), phosphate treated sawdust (Ajmal et al., 1996), cactus, olive stone/cake, wool, charcoal and pine needles (Dakiky et al., 2002), rice husk carbon (Low et al., 1999; Srinivasan et al., 1988), moss (Lee et al., 1995), sphagnum moss peat (Sharma and Forster, 1993), coconut fibre compost, maize cob, sugar beet pulp and cane bagasse (Sharma and Forster, 1994b), hazelnut shell carbon (Kobya, 2004), almond shell carbon (Candela et al., 1995), corncob (Bosinco et al., 1996), quaternized wood (Low et al., 2001), cow dung carbon (Das et al., 2000), waste slurry (Srivastava et al., 1989) and carbon slurry (Singh and Tiwari, 1997) have been reported in the literature.

In this study, three activated carbons prepared from agricultural wastes are used to remove Cr(VI) from aqueous solution. A kinetic study was carried out using pH, concentration and particle size as parameters.

Material and methods

Adsorbent

Cornelian cherry (CC), apricot stone (AS) and almond shells (ASC) were obtained from various regions of Turkey. These materials are low-value agricultural waste products. Each material was ground in a micro-hammer cutter mill (Glen Mills) and sieved to a 2.0 mm x 0.5 mm particle size prior to activation. Chemical activation using H₂SO₄ at moderate temperatures produces a high surface area and high degree of micro-porosity (Demirbas et al., 2002). The materials were mixed in a 1:1 wt ratio with concentrated H₂SO₄ and allowed to soak for 24 h at room temperature. The samples were placed in an oven and heated to 200°C where they were held for 24 h. After this, the samples were allowed to cool back to room temperature. Then, the samples were washed with distilled water and soaked in

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