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Adsorption of Cr(III) ions by Turkish brown coals

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Abstract

The equilibrium and kinetic properties of Cr(III) ion adsorption by two brown coals from Anatolia, Turkey, have been investigated in batch stirred-tank experiments. The effects of adsorbent dose, initial sorbate concentration and contact time on the adsorption of Cr(III) by Isparta-Yalvaç-Yarikkaya (YK) and Kasikara (KK) brown coals were evaluated. The Cr(III) ions are able to form complex compounds with carboxylic and phenolic groups of brown coals and they were also bounded with phenolic groups even at low pH reaction of the solution (<3). Mechanisms including ion exchange, complexation and adsorption to the surface are possible in the sorption process. Our batch adsorption studies show the equilibrium adsorption data fit the linear Langmuir adsorption isotherm. Adsorption equilibrium was achieved in about 15–20 min for chromium(III). The Langmuir adsorption isotherm was used to describe the observed sorption phenomena. The maximum equilibrium uptake was 0.05 mmol of Cr(III)/g for KK, and 0.26 mmol of Cr(III)/g for YK, respectively, at a pH of 4.5. More than 90% of chromium(III) was removed by KK and YK from an aqueous solution after 60 min. In every experiment, the maximum Cr(III) was sequestered from the solution within 60 min. It is proposed that KK and YK brown coals can be used as potential sorbents for Cr(III) removal from aqueous solutions.

Keywords: Chromium; Batch mode; Adsorption; Natural product; Brown coal

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1. Introduction

Metals are unique among pollutants that cause adverse health effects in that they occur naturally and, in many instances, are ubiquitous in the environment. Regardless of how metals are used in consumer products or industrial processes, some level of human exposure is inevitable. Furthermore, many metals are biologically essential but become toxic with increasing dosage. Removal heavy metal pollution is an important problem especially in industrial effluents [1–4].

Removing metals from water requires development of new sorbents. The main industrial sources of chromium pollution are leather tanning, electroplating, textile, metal processing, wood preservatives, paint and pigments, dyeing and steel fabrication [5,6]. Chromium is an important toxic material because it does not undergo biodegradation. Metals can accumulate in the environment with insufficient wastewater treatment, or if the polluted water is released to a water supply. Removing heavy metals present in wastewaters at relatively low concentrations is difficult. The common methods (conventional ion-exchange, electrolytic or liquid extraction, electrodialysis, precipitation and reverse osmosis) are for chromium either economically unfavorable or technically complicated, and are used only in special cases of wastewater treatment. A wide range of commercial sorbents including chelating resins and activated carbon is available for metal sorption, but they are relatively expensive [7–10]. In recent years, numerous low-cost natural materials have been proposed as potential sources of commercial synthetic sorbents [11]. Natural low cost materials that have been studied include leaf mould, moss peat, green algae, activated carbon fibers, coconut waste, rubber, wood, etc. [6,12–16]. However new economical, easily available and highly effective sorbents are still needed.

Although the adsorption capacities of low-rank coals are lower than synthetic ion exchange materials, the substantially lower cost shows great potential for the use of low-rank coals for removing heavy metal ions from wastewater [17]. Recently, adsorption of metal ions on brown coals has been extensively studied [18–24]. Studies of the kinetics and mechanism of adsorption of metal ions by brown coal [23] demonstrated that the amount of ions adsorbed increased in proportion (i) with increasing concentration of metal ions in solution, (ii) with the coal-to-solution contact time, and (iii) with increasing pH value of the solution. Baruach and Upreti [24] used metal salt solutions and potentiometric titration to examine the sorption capacity of humic acids obtained from coal. Examination of adsorption of metal ions on peat proved that ions having higher valency, higher atomic numbers, and lower ionization potentials, have the highest ion exchange capacities [23,24]. Studies of the adsorption of some metal ions on humic acids of peat [25] showed that, at low concentrations of these ions in a solution, chelates are formed, whereas at higher concentrations, adsorption follows the mechanisms of ion exchange.

Brown coals possess a high oxygen, which is largely fixed in carboxyl and hydroxyl groups. These groups are the active centers of the natural polymer for ion-exchange. The brown coals can also be considered as ion-exchange materials [19–27]. Carboxyl or hydroxyl groups are able to take part in the ion exchange according to Eqs. (1) and (2).

$$\mathrm{R-COOH+Me^{+}\Leftrightarrow R-COOMe+H^{+}} \quad (1)$$

$$\mathrm{R-OH+Me^{+}\Leftrightarrow R-OMe+H^{+}} \quad (2)$$