Studies on adsorption behaviour of Cr(VI) onto synthetic hydrous stannic oxide

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Abstract

Hydrous stannic oxide (HSO) was synthesized in the laboratory and its systematic Cr (VI) adsorption behaviour was studied by means of batch experiments. The particle size of HSO used was in the range of 140 to 290µm. The variable parameters viz. the effects of pH, concentration of Cr (VI) and time of contact etc. are here reported. The optimum pH and time of contact required for maximum adsorption was found to be 2.0 and nearly 90 min, respectively. The experimental equilibrium adsorption data are tested for the Langmuir, Freundlich, Temkin and Redlich-Peterson equations. Results indicate the following order to fit the isotherms equations: Redlich- Peterson > Temkin > Freundlich > Langmuir. Different kinetic models have been applied to fit the experimental kinetic data. The results are compared, and indicated that the best fit is obtained with the Lagergren or pseudo first-order and the power-function models. A discussion on the adsorption mechanism with respect to the thermodynamic parameters leads to two possible interpretations: One is the exothermic nature of the adsorption process and the other is the ion-ion type electrostatic interaction between the adsorbent and adsorbate ion.

Keywords: Cr (VI), adsorption mechanism, hydrous stannic oxide(HSO), isotherm, kinetics, thermodynamic parameters

Introduction

Chromium, an element of 6th group in the latest IUPAC periodic table, exists in the aqueous environment mainly in +III and +VI states. Cr (III) is non-toxic, and an essential species to mammals that helps the body to control blood-sugar levels in trace concentrations, but toxic to fish when present in water above 5.0 mg/ℓ (Alloway and Ayres, 1997). Cr (VI) is a powerful epithelial irritant, and a confirmed human carcinogen (Porter et al., 1999). Additionally, Cr (VI) is toxic to many plants, aquatic animals and bacteria (Mearns, 1974). Water containing Cr (VI) above 0.05 mg/ℓ is toxic to both mammals and aquatic organisms (Strreth, 1978). Most industries like paint and pigment manufacturing, leather tanning, chrome plating, textile, match, etc. in under-developed countries like India discharge wastewater into the surface water containing Cr (VI) after reduction to the trivalent state. The major drawback of this conventional treatment method is the high cost of chemicals used for the reduction purposes and incomplete reduction of Cr (VI), which may produce toxic sludge due to surface adsorption of Cr (VI) onto the Cr (III) hydroxide precipitate. It is therefore necessary to explore viable technologies for controlling the concentration of Cr (VI) in aqueous discharges/effluents.

Surface adsorption is found to be an important basis for the treatment of toxic element-contaminated water. Numerous adsorbents such as goethite (Mesuere and Fish, 1992), clay (Lazaridis et al., 2001), layered double hydroxides (Goswamee et al., 1998), used tyres and sawdust (Hamadi et al., 2001), activated carbon (Lalvani et al., 1998; Han et al., 2001), zeolite (Tahir et al., 1998; Haggerty and Bowman, 1994), feldspar (Singh et al., 1992), hydrotalcite (Lazaridis and Asouhidou, 2003), hydrated zirconium oxide (Ghosh et al., 2001), hydrous titanium oxide (Ghosh et al., 2003), polyacrylamide grafted sawdust (Raji and Anirudhan, 1998), ion-exchange resin (Rengaraj et al., 2001), etc. have been reported in the literature showing Cr(VI) sorptive behaviour and removal from the aqueous solution. A few of them are found to be important for contaminated water treatment but cost-ineffective for 3rd World countries like India. Hydrated stannic oxide (HSO) is a cheap, non-toxic and an insoluble compound showing anion-exchange properties (Amphlett, 1964). Sen et al. (1979) used its anion-exchange property to separate and estimate Cr in some ores and alloys. As the mechanism for the Cr(VI) adsorption onto hydrous metal oxide is not reported earlier, hence hydrous stannic oxide (HSO) is used to investigate the same here.

This study reports the pH effect, contact time and kinetic study on Cr (VI) adsorption. The adsorption data are tested for a number of kinetic and isotherm equations. An evaluation of thermodynamic parameters on Cr (VI) adsorption onto hydrated stannic oxide (HSO) is made. This study will contribute to an understanding of the Cr (VI) adsorption mechanism using hydrous stannic oxide as the adsorbent.

Materials and methods

Reagents

Potassium dichromate (A.R, Glaxo Laboratories India Ltd) was used for the preparation of 1 ℓ of stock Cr (VI) solution (1 000 mg/ℓ) in distilled water. For pH adjustment throughout the experiment, hydrochloric acid (AR, BDH) and / or sodium hydroxide (Reagent grade, BDH) solutions were used as necessary. A standard (0.25%) diphenyl carbazide (G.R, E.Merck) solution was used for estimation of Cr (VI) spectrophotometrically. Sodium stannate (0.1M) solution was used for the adsorbent synthesis.

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