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The use of new modified poly(acrylamide) chelating resin with pendent benzothiazole groups containing donor atoms in the removal of heavy metal ions from aqueous solutions

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ABSTRACT

The adsorption studies of poly(6-(ethoxybenzothiazole acrylamide) (PEBTA), for Cu(II) and Zn(II) metal ions removal from an aqueous solution have been investigated, as a function of solution pH, adsorbent dose, contact time, initial metal ion concentration and temperature. The chemical and structural characteristics of the adsorbent were determined by the FT-IR, ^{1}H-NMR, TGA, SEM, and EDAX analysis. The maximum adsorption capacities of the adsorbent for Cu(II) and Zn(II) ions, as calculated from the Langmuir isotherm model, were 273.5 and 216.4 mg/g, respectively. The adsorption kinetic studies show that the adsorption of Cu(II) and Zn(II) ions onto PEBTA follows the pseudo second order kinetic model. Thermodynamic parameters such as ΔG°, ΔH° and ΔS° were also evaluated, and it has been found that the adsorption process is feasible, spontaneous and exothermic in nature. Desorption studies were carried out using 0.3 N HCl, and it revealed that the adsorbed Cu(II) and Zn(II) ions can be easily removed. The adsorption–desorption process is reversible, and

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this indicates that PEBTA is an effective adsorbent for the removal of heavy metal ions from an aqueous medium.

1. Introduction

Environmental pollution by toxic metals occurs globally, through waste disposal from agricultural processes, metallurgical, mining and electroplating industries. Among the environmental pollutants, heavy metals have gained relatively more significance, in view of their persistence and immense toxicity [1]. Heavy metals are non-biodegradable, can cause mental retardation, cancer and nervous system damage and, therefore, must be removed from water [2,3]. There are a number of methods in order to remove the heavy metal ions [4–8], including complexation, ion exchange, precipitation, reverse osmosis, extraction and adsorption. Adsorption is one of the most effective and easiest available methods for the removal of toxic heavy metals from aqueous systems. In the recent past polymeric adsorbents having emerging as potential alternative to activated carbon from various sources both agriculture and commercial. Polymeric adsorbents are superior to other solid adsorbents due to their vast surface area, adjustable surface chemistry, and feasible regeneration under mild conditions [9]. For the purpose of separation of metal ions either for purification or enrichment, various kinds of organic chelating resins have been developed. In general such chelating resins are co-ordinating co-polymers possesses covalently bonded side chains which contain single or multiple donor atoms. The donor atom containing active sites acts as Lewis base, which effectively forms co-ordinating bonds with Lewis acids such as the most toxic metal ions. Functional groups such as carboxylic [10,11], amide and amine [12], when present in the polymer structure, provide the binding sites for the removal of metal ions from aqueous solutions. Polymers with specific functionalities can be obtained, by either synthesizing new monomers bearing the functional groups capable of interacting with the target metal ions, followed by polymerization, or by converting the groups on the existing polymers or co-polymers with suitable chemical reactions into the desired functional groups [13,14]. Imidazo and amidoxime functional groups have been incorporated in the polymer back bone to adsorb various metal ions from aqueous solutions [15,16]. Polymers with methacryloyamido-glutamic acid and methacrylamide as the metal complexing ligand were synthesized and used for heavy metal ion removal [17,18]. New generation resins such as the one with bis-picolyamine functional groups were reported for selected metal ion adsorption from acidic solutions [19]. The aim of this study is to synthesize a new vinyl monomer bearing ethoxybenzothiozole pendant groups (which contains donor atoms N, O, and S), the preparation of its polymer, and finally to evaluate the new polymeric resin towards heavy metal ion adsorption. The efficiency of such chelating resins mainly depends on the types of resin functional groups and to a smaller extent on the resin bead size and physiochemical properties. For the first time we have attempted in the preparation and use of resins with pendent ethoxybenzothiozole complexing ligands. Batch adsorption studies were performed by varying parameters, such as solution pH, adsorbent dosage, contact time, initial metal ion concentration and temperature. Adsorption isotherms and kinetic models were used to predict the adsorption mechanism of Cu(II) and Zn(II) ions onto poly(6-(ethoxybenzothiazole acrylamide) PEBTA.

2. Materials and methods

2.1. Chemicals and reagents

Acrylic acid (Fluka) was used as received. Benzoyl chloride (E.Merck) was distilled rapidly before use. 2-Amino-6-(ethoxybenzothiozole) (Aldrich), benzoyl peroxide (Aldrich) were used without