

Comparison of Pb(II) uptake by coir and dye loaded coir fibres in a fixed bed column

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Abstract

The possibility of adsorbing Pb(II) from solution using coir, a cheap lignocellulosic fibre, was assessed in a fixed bed column. The coir fibres were also chemically modified by covalent loading of a reactive dye, C.I. Reactive Orange 13, and used as adsorbent. Column adsorption studies were carried out at different initial Pb(II) concentrations and it was observed that the breakthrough time decreased with increase in the initial Pb(II) concentration. The column packed with dye loaded coir fibres was operated for longer duration than the one packed with unmodified coir fibres. The total Pb(II) adsorbed was also higher in a column packed with dye loaded coir fibres. The desorption level in the fixed bed column packed with coir fibres was of the order of 85%, whereas the one packed with dye loaded coir fibres was more than 90%. Both the columns were regenerated and used upto five cycles.

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1. Introduction

Lead, a heavy metal, finds extensive applications in day-to-day commodities like batteries, paints, ceramics, soldering, etc. It is an essential component for the production of many other highly technical products. As the use of lead increases, the waste generated is also tremendous due to the inappropriate waste disposal practices. The dumping of these wastes without monitoring the permissible limits into sewers and drainage causes hazardous effects on life, both aquatic and land. Lead is a very toxic element even at low concentrations. It affects central nervous system, kidneys, gastrointestinal system, etc. [1]. The removal of such a heavy metal from the effluent in an effective and economic manner is a must for a healthy living.

Generally, heavy metals are removed from wastewaters by chemical precipitation [2], ion exchange [3], floatation

[4], membrane systems [5], and adsorption [6]. However, these techniques have their advantages and inherent limitations, like high cost, sludge formation, etc. Hence, other unconventional methods like use of activated carbon from cheap throwaway agricultural/biological wastes [7], biosorption [8], adsorption on to minerals [9,10], etc., have been sought after. Natural bio polymeric materials also are effective in removal of heavy metal ions [11,12].

The application of dye loaded polymeric materials for heavy metal removal is being explored widely. It has been reported that dye loaded synthetic polymeric materials were quite promising in removal of heavy metals from aqueous solutions [13,14]. The reactive dye loaded cheap cellulosic and lignocellulosic materials were quite efficient for heavy metal removal from their aqueous solutions [15–20]. The use of fibrous lignocellulosic materials for removal of heavy metals has been explored recently by a number of researchers [21,22]. Coir and jute fibres loaded with a reactive dye were found efficient in removing heavy metals like Pb(II), Cu(II), Ni(II) and Zn(II) from their aqueous solution in a batch wise manner [23,24]. Very little literature is available where in

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the use of unconventional materials, of agricultural and biological origin, for removal of heavy metals has been studied in a continuous manner in a fixed bed column. Shukla and Sakhardande [25] used dye loaded jute fibres packed in a fixed bed column for removal of different heavy metal ions. Black gram husk, fungal biomass and modified rice husk has also been used in a fixed bed column for removal of different heavy metal ions [26–28].

The present work explores the use of a lignocellulosic fibre, coir, for removal of Pb(II) from lead nitrate solution in a fixed bed column. The efficiency of coir fibre, after loading with a specific reactive dye, CI Reactive Orange 13, for Pb(II) removal in a fixed bed column is also assessed. The desorption and regenerative capacity of dye loaded coir column is also reported.

2. Materials and experimental methods

2.1. Adsorbents

Coir fibre waste was collected from a local industry in Kerala and cut into approximately 1 cm long pieces. It was cleaned thoroughly by washing with water. The cleaned coir fibres as well as the dye loaded coir fibres were used as adsorbents.

2.2. Chemicals

Lead nitrate was of Analytical Reagent grade, supplied by Merck (India) Ltd. A stock solution of 4.8 mmol/L Pb(II) was prepared by dissolving 1.6 g of anhydrous lead nitrate in 1 L of demineralised water. The experimental solutions ranging from 2.13 to 4.16 mmol/L Pb(II) were prepared by approximately diluting the stock solution. The other chemicals used, sodium hydroxide, sodium carbonate, nitric acid were also of Analytical Reagent grade, supplied by Merck (India) Ltd. Glauber's salt was supplied by S.D. Fine Chemicals, Mumbai, and the non-ionic detergent, Auxipon NP was supplied by Auxichem Ltd., Mumbai.

Demineralised water was used for all experiments.

2.3. Dye

A commercially available monochlorotriazine-type reactive dye, C.I. Reactive Orange 13, procured from Atul (I) Ltd. was used for covalent loading of coir. The structure and the covalent reaction of this dye with cellulose have been given in Fig. 1.

2.4. Methods

2.4.1. Dyeing of coir fibres

The technique used for dye loading was that of dyeing a monochlorotriazine type reactive dye on cellulosic materials like cotton [29]. Cleaned and uniformly cut coir fibres,

100 g were added to 4 L of the diluted dye solution containing 0.5 g predissolved dye powder. The dyeing reaction was started at 40 °C and the temperature was slowly raised to 85 °C for uniform dye loading. After about 10 min, 65 g/L of sodium sulphate deca hydrate (Glauber's salt) was added for further improving the dye exhaustion onto coir. After another 20 min, for covalent fixation of the dye onto the material, 15 g/L of sodium carbonate was added to the same bath and the treatment continued at 85 °C for further 30 min. In the end, the material was filtered, washed thoroughly with hot water and then with cold water to remove the loosely held dye on coir. This was followed by boiling the dye loaded coir fibre with 1 g/L solution of a non-ionic detergent, Auxipon NP, for 20 min and thorough washing with water to remove completely the unfixed dye and the by product of the reaction, the hydrolysed dye. The material was then dried in an oven at 50 °C overnight and used as an adsorbent.

2.4.2. Estimation of dye loading on the materials

The estimation of the amount of dye loaded on to the coir fibres was carried out by measuring the absorbance values of the dye solution used for the dye loading reaction using Tech-comp UV–vis spectrophotometer, (Model 8500 Hong Kong). Each dyestuff gives the colour absorption value at a particular λ_{\max} specific to it. A calibration plot was developed by plotting known quantities of dye concentrations (mmol/L) against their absorbance (%) values at the particular λ_{\max} , which is linear at lower concentrations. The absorbance of initial dye liquor used for dye loading was measured at λ_{\max} of 495 nm (A). After completion of the dyeing process, the coir fibres were carefully removed from the bath without spilling any drop of spent liquor. Water after washing, the soap liquor as well as final washings were carefully collected together, added to the exhausted dye bath and its absorbance was measured (B). This absorbance equals the amount of dye not loaded on the adsorbent. Thus, (A–B) is related to the dye loaded onto the material. By making use of the calibration curve, the amount of dye loaded on to coir was determined. The dye loading observed for coir fibres was 2.16 $\mu\text{mol/g}$.

2.4.3. Column adsorption studies

2.4.3.1. Adsorption cycle. The coir fibres and dye loaded coir fibres, were used for adsorption of Pb(II) in a fixed bed column. 100 g of coir was filled in a glass column of 4.8 cm inner diameter to yield a bed length of 43 cm. Glass beads were used as support at bottom and top. The feed containing known concentration of Pb(II) ion was given from bottom using a peristaltic pump (Electrolab, Mumbai). A constant flow rate of 40 mL/min was used for the entire study. The liquor coming out from the top of the column was collected at regular intervals and the amount of Pb(II) adsorbed was estimated. The estimation of Pb(II) was carried out using flame type atomic absorption spectrophotometer (Model GBC 932 Plus, Australia). Three different Pb(II)

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