Journal of Fiber Bioengineering and Informatics 6:2 (2013) 175–184
doi:10.3993/jfbi06201306

Removal of Mercury from Aqueous Environment by Jute Nanofiber

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Abstract

The biosorption characteristics of mercury ions from aqueous solution using jute nanofibers, a cellulose-based natural fiber, were explored as a function of pH, nanofiber concentration, contact time and temperature. Jute nanofibers were obtained after wet milling the jute fibers and subsequently their morphology was assessed by various spectroscopy and microscopy techniques. The maximum biosorption capacity of the fiber calculated by the Langmuir model was found to be 85.5 mg g^{-1}. The adsorption experiments revealed that ion-exchange and complexation mechanisms were principal role in the biosorption process. The present experimental evidence implies that jute nanofibers could be a potential natural biomaterial for the removal of environmental contaminations from textile and chemical industries.

Keywords: Jute Nanofibers (JNF); Hg^{2+} Biosorption; Adsorption Kinetics

1 Introduction

Jute fiber is composed primarily of the plant materials cellulose, lignin, and pectin. These are agro-based, renewable, biodegradable and low-cost materials. Jute fiber is the second place after cotton in commercial importance. Jute is copiously grown in Indian sub-continent, China and Thailand. The global production of jute, kenaf and allied fibers is presently around 3.3 million tons per year [1]. It is extensively used for the manufacturing of flexible packaging fabrics besides its potential use as carpet backing and decorative fabrics. It has high tensile strength, low extensibility, and ensures better breathability of fabrics [2].

Environmental pollution due to different types of industries is one of the vital global problems presently. Waste generated in textile and chemical industries is essentially based on water- based effluent generated in various processes. Mercury pollution is a worldwide problem due to its wide

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Communicated by editor Dr. Zijian Zheng

application in industries thereby creating effluents and its toxicity effect to all living organisms. The major effects of mercury poisoning are in kidney, brain and lungs [3]. The maximum permissible limit of mercury in drinking water is 0.001 mg/L [4]. It is mandatory to remove mercury and other toxic metals contamination from aqueous and industrial effluents before these toxic effluents are released into the environment.

Biosorption is a process that employs economical biomaterials to impound toxic heavy metals and is predominantly useful for the removal of contaminants from aqueous and industrial effluents [5]. Evaluated with conventional methods of eradicating toxic metals from industrial effluents with various techniques such as precipitation, ion exchange and electrochemical process, the biosorption process recommends the advantages of low working cost, minimization of the volume of chemical and /or biological sludge to be disposed. Different types of biomass have been used for the tidying of industrial wastes such as fly ash, silica gel, zeolites, lignin, wool wastes, agricultural wastes, algae, bacteria, fungi, yeasts, crosslinked chitin, chitosan and plant polysaccharides [6-9]. The use of dead biomass is of particular economic interest, because the biomaterials are used in the same way as synthetic adsorbents or ion exchangers [10]. Diverse metal binding methods are contemplation to be involved in the biosorption process including ion-exchange, surface adsorption, chemisorptions, complexation and adsorption-complexation [11]. However, there is an unrelenting interest in classifying innovative biosorbents that are competent of reducing toxic metal concentrations to environmentally good enough levels at inexpensive cost. One of the approaches to mitigate the environmental pollution is by employing novel bioremediation technologies that are based on the principles of green chemistry.

The endeavour of the present experimental study was to investigate and explore the potential application of Jute Nanofibers (JNF) as a novel biosorbent for removal of the industrially relevant toxic heavy metal such as mercury. This communication describes the ability of JNF to bind toxic heavy metal and its quantitative evaluation and kinetic study. The metal adsorption was assessed based on Langmuir and Freundlich adsorption isotherm model. The interaction of JNF with Hg^{2+} ion was established by Fourier Transform Infrared Spectroscopy (FTIR) and morphological changes due to mercury biosorption was assessed by Scanning Electron Microscopy (SEM) technique.

2 Materials and Methods

2.1 Preparation of Jute Nanofibers (JNF)

Jute fibers were collected from the Gloster Jute Mill, Howrah, India. In order to remove waxy substances from jute fibers, they were sequentially treated with 4% sodium hydroxide (NaOH) at 80 °C for 1 hour and with 7 g/L sodium hypochlorite (NaOCl) at room temperature for 2 hours under pH 10-11. The fibers were subsequently antichlor treated with 0.1% sodium sulphite at 50 °C for 20 min and transferred in ball mill for pulverization in dry and wet conditions. High-energy planetary ball mill of Fritsch pulverisette 7 was used with sintered corundum container of 80 ml capacity and zirconium balls of 10 mm diameter for initial 3 min of dry milling. The bigger balls were replaced by smaller balls of 3 mm diameter for further extended milling in wet condition in distilled water up to one hour. The ball mill was loaded with Ball to Material Ratio (BMR) of 10:1. The rotation speed of the planet carrier was 850 rpm.