1st International & 28th National Conference
on Nuclear Science & Technology 2022 (ICNST22)

Nuclear Science & Technology
Research Institute

Synthesis and characterization of sugarcane bagasse-derived magnetic hybrid nano bio-composite as potential bio-sorbent of trace uranium from wastewater

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Abstract

In this work, the sugarcane bagasse-derived magnetic hybrid nano bio-composite (SB-MHNBC) has been synthesized by the co-precipitation method and examined for the removal of uranium from contaminated water. The effectiveness of magnetite insemination on the sugarcane bagasse (SB) was evaluated by XRD, BET, and SEM-EDX analysis. Uranyl sorption experiments have been performed under the best pH conditions reported in the literature, at ambient temperature. The maximum sorption capacity of bio-sorbent for uranyl ion was 10.2 mg.g^{-1}. The results also indicated that the percentage removal of uranyl ions was 97.92% at a sorbent amount of 5 g L^{-1}.

Keywords: ***Hybrid nano bio-composites; Uranyl ion; Co-precipitation; Sugarcane bagasse.***

Introduction

Uranium is a toxic radioactive heavy metal, found in the environment in the hexavalent form. Alarmingly, large amounts of uranium have been released into the environment through various activities such as mining, combustion, and nuclear industry [1]. Once uranium is released into the environment it could endanger the lives of living beings. Therefore, wastewater treatment is required as a part of eliminating uranium contamination to a sufficient degree to protect water. Sugarcane bagasse (SB), an abundantly produced by-product of the sugar and alcohol industry, presents interesting characteristics to be successfully employed as bio-sorbents for the removal of heavy metals from wastewaters and enhance the bioeconomy [2]. The three main polymeric components of sugarcane bagasse (cellulose, hemicelluloses, and lignin), provide functional groups with the potential to bind large amounts of water-soluble contaminants [3]. In this work, the sugarcane bagasse-derived magnetic hybrid nano bio-composite (SB-MHNBC) as a magnetically responsive potential bio-sorbent for water purification was synthesized, characterized, and effectively used to remove uranyl ions from water and wastewater.

Experimental

Reagents and apparatus

All the reagents (sourced from Merck) used in this study were analytical reagent (AR) grade. Magnetite nanoparticles (MNP) and the sugarcane bagasse-based magnetic hybrid nano bio-composite (SB-MHNBC) were prepared via the co-precipitation method [4], by adding sugarecane bagasse (SB), to the mixture of iron chloride in HCl medium and precipitation with NaOH solution.

Batch biosorption procedure

The studies were performed for assessing the sorption efficiency of the uranyl ions from aqueous solution using the above- synthesized SB-HMNBC through batch-wise experiments at room temperature (25 ± 1.0 ºC) with 5.0 g L^{-1} bio-sorbent dropped in 20 mL of a 50 mg L^{-1} uranyl ion solution at pH 3.0 in a 100 mL Erlenmeyer flasks under constant stirring at 180 r min^{-1} for 120 min. After equilibrium was reached, the bio-sorbent was separated from the solution and the final solution was immediately analyzed for residual uranyl ions concentration using LSC spectrometry. The sorption capacity (mg g^{-1}) and the percentage removal were calculated by using Eqs. (1) and (2), respectively:

$$q_e = \frac{C_0 - C_e}{m} V \qquad (1)$$

$$\text{Percentage removal} = \frac{C_0 - C_e}{C_0} \times 100 \qquad (2)$$

where C_o (mg L^{-1}) and C_e (mg L^{-1}) are sorbate solution concentrations before and after sorption, respectively; V (L) is the metal ion solution volume in contact with the sorbent, and m (g) is the sorbent mass.

Results and discussion

Characterization of the bio-sorbents

Figure 1 presents the XRD spectra of the investigated materials (MNP, SB-MHNBC). The XRD pattern of MNP indicated that the main reflection peaks of this material were also present in prepared SB-MHNBC. In the diffractograms of MNP and SB-MHNBC the characteristic peaks in 2θ (30.29, 35.48, 43.30, 56.96, 57.10, and 62.56) are present, indicating the efficiency of nanoparticle impregnation on the SB biomass.

The BET equation was used to determine the specific surface area of the SB-MHNBC samples. The high values of BET surface areas (102.3 m^2 g^{-1}) suggested that the investigated bio-sorbent has high porosity. High bio-adsorption capacity requires high surface porous materials with very high specific surface areas. However, large surface area bio-adsorbents, sometimes give poor sorption capacity [5]. Because it is not only the pore size alone that determines the surface area but also the pore diameter distribution present also matters a lot.

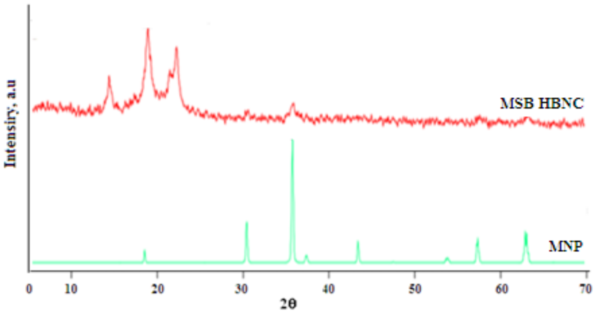

Fig. 1. Diffractograms of the MNP and SB-MHNBC.

The investigated materials were also characterized by EDX spectrometry and SEM. The micrographs and analytical results of EDX micro-analysis of bio-sorbent (SB-MHNBC) and uranium loaded bio-sorbent (SB-MHNBC-U^{VI}) are shown in Fig. 2, and Table 1, respectively.

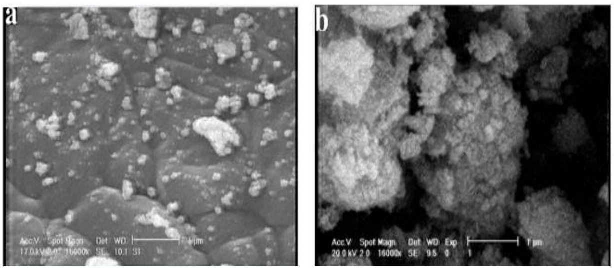

Fig. 2. Scanning electron microscopy images (SEM) at 1000X magnification, of SB-MHNBC (a) before and (b) after biosorption of uranyl ion.

Table 1. Physicochemical properties of SB-MHNBC before and after uranyl ion sorption

Analyte (%)	SB-MHNBC (EDX analysis)	
	Before sorption	After sorption
Carbon	43.05	40.38
Oxygen	19.31	18.65
Fe	30.65	21.26
Uranium	-	19.63

The SEM image of SB-MHNBC before uranyl ion sorption (Fig. 2a) showed a rugged surface in micrometer-length-scale and irregular structure, which could be in favor of the sorption of uranyl ion. Figure 2b illustrates the appearance of the chemical distribution in the bio-sorbent, after the sorption of uranyl ion. In the lighted areas, the greater back scattering of electrons indicates the presence of higher atomic weight elements, like iron contained in the magnetite. This contrast illustrates the disparity distribution of the organic and inorganic proportion of the sorbent.

Uranium sorption ability

Performing the uranyl ions biosorption tests by using the investigated bio-sorbent, under the above-mentioned conditions showed that the sorption capacity of SB-MHNBC and the percentage removal of uranyl ion were 10.2 $mg.g^{-1}$ and 97.92% respectively. Optimization of the sorption conditions and modification /functionalization of sorbents may result in obtaining higher uranyl ion sorption percentages and sorption capacity.

Conclusions

In this study, the SB-MHNBC has been synthesized via the co-precipitation method. EDX characterization confirmed the magnetite insemination on the sugarcane bagasse due to the presence of Fe, and so on the appearance of uranium in uranium loaded SB-MHNBC approved the sorption of uranyl ion by SB-MHNBC. The XRD patterns indicated the efficiency of nanoparticle impregnation on the SB biomass. The proposed magnetically responsive SB-MHNBC with high values of BET surface areas leads to a potential bio-sorbent for contaminants removal from wastewaters contaminated with toxic metal ions, such as uranium. however, in order to reach maximum removal percentage, the sorption operating conditions could be further optimized.

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