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BIOSORPTION OF URANIUM IN A CONTINUOUS FLOW PACKED BED COLUMN USING *CYSTOSEIRA INDICA* BIOMASS

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ABSTRACT

Uranium(II) biosorption from aqueous solution by *Cystoseira indica* biomass was studied in a packed bed column. The uptake capacity of uranium was investigated by natural and different pretreated biomasses. Results showed 0.1 M $CaCl_2$ solution at pH=4, used as pretreatment, increased the uptake capacity more than 30% (371.39 mg/g). Cations concentration measurement in the effluent solution, Fourier transform infrared spectroscopy and X-ray fluorescence analyses on biosorbents proved that ion exchange is the main biosorption mechanism. The elution efficiency for uranium desorption was determined for various chemical agents in a batch system. Among these eluants, 0.1 M HCl exhibited elution efficiency greater than 78%. Also, biomass regeneration by 0.1 M HCl was studied in a continuous system. The obtained results confirmed that reusability of this biomass is conceivable. Thus, *Cystoseira indica* can be used in the packed bed column as a potential biosorbent for treatment of uranium polluted aqueous solutions.

Key words: Biosorption; Uranium; Packed bed column; *Cystoseira indica*; Ion exchange

INTRODUCTION

Human industrial activities (such as mining, metallurgy, electroplating, etc.) lead to releasing heavy metals into the environment. Heavy metals are toxic pollutants. Therefore, this is a worldwide environmental problem (Hawari and Mulligan, 2006; Naddafi *et al*., 2007; Dabbagh *et al*., 2008; Khani *et al*., 2008;) .

Heavy metal removal from wastewater can be achieved via several chemical (neutralization/ precipitation) or physical (evaporation, ion exchange, membrane technology) treatment techniques. These common technologies require not only high capital investment and running costs, but are also are ineffective in low strength wastewaters. Hence, environmental engineers and scientists make an effort to find easy, effective, economical, and eco-friendly techniques for removal of heavy metals from wastewater (Vijayaraghavan *et al*., 2006; Borba *et al*., 2006; Lodeiro *et al*., 2006; Ahluwalia and Goyal, 2007; Naddafi *et al*., 2007; Apiratikul and Pavasant, 2008; Shokoohi *et al*., 2009; Sen and Ghosh Dastidar, 2010).

The search for an economical and eco-friendly option has led to the utilization of biological materials (microbial and plant origin) as adsorbents. These biomaterials interact effectively with heavy metals. Biosorption is a term that describes the removal of heavy metals by dead biomass from an aqueous solution which is attributed mainly to the ligands present in their cell wall biomolecules. Various dead biomasses, such as, marine algae, bacteria, fungi, industrial wastes and several other materials have been

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successfully used to adsorb heavy metal ions from aqueous solution. Among these, the brown algal biomass has been shown to be highly effective, reliable, and predictable in the removal of heavy metals from aqueous solutions (Davis *et al*., 2003; Ahluwalia and Goyal, 2007; Dabbagh *et al*., 2008; Vilar *et al*., 2008; Gaur and Dhankhar, 2009; Nagda and Ghole, 2009; Shokoohi *et al*., 2009; Sen and Ghosh Dastidar, 2010).

The selection of a suitable biosorbent for a given separation is a complex problem. The main scientific basis for biosorbent selection is the equilibrium isotherm. Diffusion rate is generally secondary in importance. From the viewpoint of practical application, availability and economy is a major factor to be considered for selecting the biomass for clean-up purposes. Equilibrium batch tests and dynamic continuous flow studies are two types of investigations that could help to examine a solid-liquid biosorption system. The evaluation of equilibrium biosorption performance needs to be supplemented by process-oriented studies of its kinetics and eventually by dynamic continuous flow tests. The sorption rate of the metal uptake, together with the hydrodynamic parameters, determines the size of the contact equipment. These key process parameters could be used for comparison, for process design, and for scale-up purposes (Wang and Chen, 2009).

Continuous flow columns have been used mainly in sorption of heavy metal ions from aqueous solution. Also, in biosorption technique, a packed bed sorption column is an effective process device for removal of heavy metals from aqueous solutions continuously due to efficient utilization of biosorbent capacity (Borba *et al*., 2006; Naddafi *et al*., 2007; Diniz *et al*., 2008; Vilar *et al*., 2008).

Previous study, in a batch system, indicated that the biomass of the *Cystoseira indica* brown algae could be used as an efficient biosorbent material for biosorption of uranium ions from aqueous solutions. The effect of the basic parameters such as pH, contact time and initial metal concentration on the uranium biosorption by this biomass was determined. Obtained results showed that the adsorption equilibrium data fitted very well to the Langmuir model in the studied concentration range. Kinetics data of this biosorption were analyzed using the saturation type adsorption kinetic model and kinetic constants were calculated depending on temperature. The action energy of the biosorption process was evaluated. Also, the thermodynamic of the biosorption process was investigated and obtained results showed that biosorption of uranium by this biomass is spontaneous, exothermic and reversible (Khani *et al*., 2006; Khani *et al*., 2008).

Assessment of biosorption mechanism, reusability of biosorbent and using of biosorbent in continuous system are important in biosorption process. Therefore, in this research, biosorption of uranium (II) from aqueous solution by *Cystoseira indica* biomass and the effect of pretreatment in a continuous packed bed column are studied. The biosorption mechanism is investigated and also, the biosorption-desorption (biosorbent regeneration) in a batch and continuous system is examined.

MATERIALS AND METHODS

Preparation of biosorbent

Cystoseira indica brown alga (obtained from Persian Gulf on the coast of Qeshm, Iran) was extensively washed with deionized water and dried in an oven at 70 ºC overnight. The dried biomass was ground in a laboratory blender and sorted using the standard test sieves. The batch of biomass with particle size of 1-2 mm was selected for the experiments. Pretreatment of the biomass was carried out as follows: samples of biomass were treated with 0.1 M HCl and 0.1 M $CaCl_2$ solutions at pH=2.5, 4 and 9.7 (10 g biomass per liter of solution) for 3 h under slow stirring (150 rpm and 25°C). Then pretreated biomass was washed several times with deionized water to remove excess hydrogen or calcium ions from the biomasses. The protonated and Ca-pretreated biomasses were then dried overnight in an oven at 70 ºC.

Chemicals

The synthetic solutions were all prepared by use of deionized water and analytical grade salts of $UO_2(NO_3)_2.6H_2O$, NaCl, and $CaCl_2.2H_2O$ (Merck Co.). The pH of influent solutions was adjusted with a pH meter (Metrohm, Model 780) by using 0.1 M HCl and/or 0.1 M NaOH.

Continuous flow column system

The column was a simple glass tube with inner diameter of 1.5 cm and length of 10 cm (Fig. 1). Two plastic sieves both with pore size of 0.5 mm were sealed using cap holders and installed at the top and bottom of this column. The experiments were conducted by pumping a metal solution in up flow mode through the packed bed column with a peristaltic pump (Watson Marlow Pumps, Model 205U).

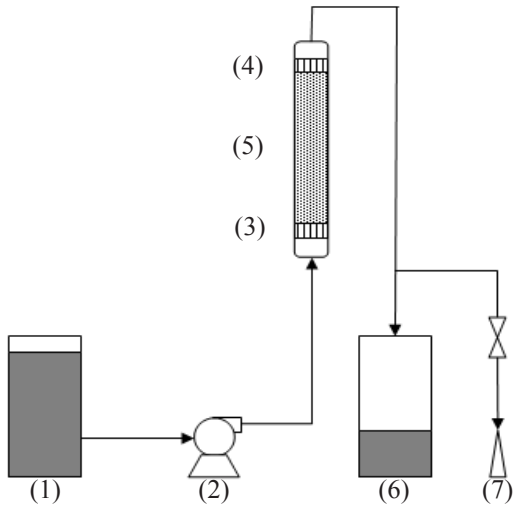


Fig. 1: Experimental arrangement of the biosorption packed bed column: (1) feed storage, (2) peristaltic pump, (3) bottom holder, (4) top holder, (5) column, (6) effluent storage, and (7) sampling vessel

Metal analysis

Liquid samples were analyzed for residual metal ions concentration by an inductively coupled plasma spectroscopy (ICP, Varian, Model Liberty 150 AX Turbo).

Biosorption experiments

All of the experiments were performed at room temperature (25±2°C). Previous study in a batch system indicated that the optimum pH for uranium biosorption by *Cystoseira indica* biomass was about 4 (Khani *et al*., 2006); therefore, in this study, the pH of the column influent and batch system was adjusted to 4.

Effect of pretreatment

About 1 g of natural, protonated, and Ca-pretreated biomasses were packed within the column. Subsequently, the 0.5 mM uranium solution was fed through the bed at 2.3 mL/min flow rate. Samples were collected periodically and operation of the column was stopped when the effluent metal concentration reached a constant value (equal to the influent concentration).

Biosorption mechanism

A variety of mechanisms exist for the removal of heavy metals from aqueous solution by biosorbent e.g. ion exchange, complexation, coordination, and microprecipitation (Borba *et al*., 2006). With measurement of pH in the column effluent with protonated biomass and Ca^{+2} ions in the three effluents of columns with Ca-pretreated biomasses, the main mechanism of uranium biosorption by *Cystoseira indica* biomass was investigated.

Raw samples (natural, protonated, and Ca-pretreated biomasses) and biomasses loaded with uranium were analyzed using a Fourier transform nfrared spectroscopy (FTIR) Model Vector22 Bruker corporation. Also, raw and loaded with uranium biomasses were analyzed using an X-ray fluorescence analyzer (XRF) Model ED 2000 Oxford Instruments corporation. FTIR and XRF analyses were performed to find the main biosorption mechanism.

Biosorbent regeneration

Biosorbent regeneration was investigated in batch and continuous experiments. Batch experiments were conducted in 250 mL Erlenmeyer flasks containing 100 mL of different solutions and 0.3 g of biomass, Ca-pretreated biomass by 0.1 M $CaCl_2$ solution at pH=4. The flasks were agitated at 150 rpm and 25°C in a shaker. After 3 h of contact time for sorption stages, a sample was taken from solution for analysis and also, after 0.5 h for desorption stages. In sorption stages, 0.25 mM uranium solution was used. The uranium loaded biomass was eluted by various desorbents, H_2O, 0.1 M HCl, 0.1 M CH_3COOH, 0.1 M $CaCl_2$, and 0.1 M NaCl in desorption stages. After each sorption and desorption stage, the biomass was washed by 250 mL deionized water.

For Continuous experiments, about 1 g of the biomass, Ca-pretreated biomass by 0.1 M $CaCl_2$ solution at pH=4, was packed within the column. During the column sorption operation, the aqueous solution containing 0.25 mM uranium was pumped upward through the column at a constant flow rate of, 2.3 mL/min, continuously. After the biomass in the column became saturated, the column was washed at the same flow rate by deionized water for 30 minutes, before a subsequent uranium elution with 0.1 M HCl solution. The outlet sample collection and analysis were the same as those used in the sorption uptake run.

RESULTS

Effect of pretreatment

In this research uranium biosorption was investigated by natural, protonated, and Ca-pretreated *Cystoseira indica* biomasses. Fig. 2 shows breakthrough curves of uranium biosorption by these biomasses. Results show that uptake capacity of uranium ions with natural biomass is 284.06 mg/g. On the other hand, addition of 0.1 M HCl solution to the biomass changed the uptake capacity to 182.95. Also, addition of 0.1 M $CaCl_2$ solutions at pH=2.5, 4 and 9.7 to the biomass changed the uptake capacity to 287.21, 371.39 and 359.70 mg/g, respectively.

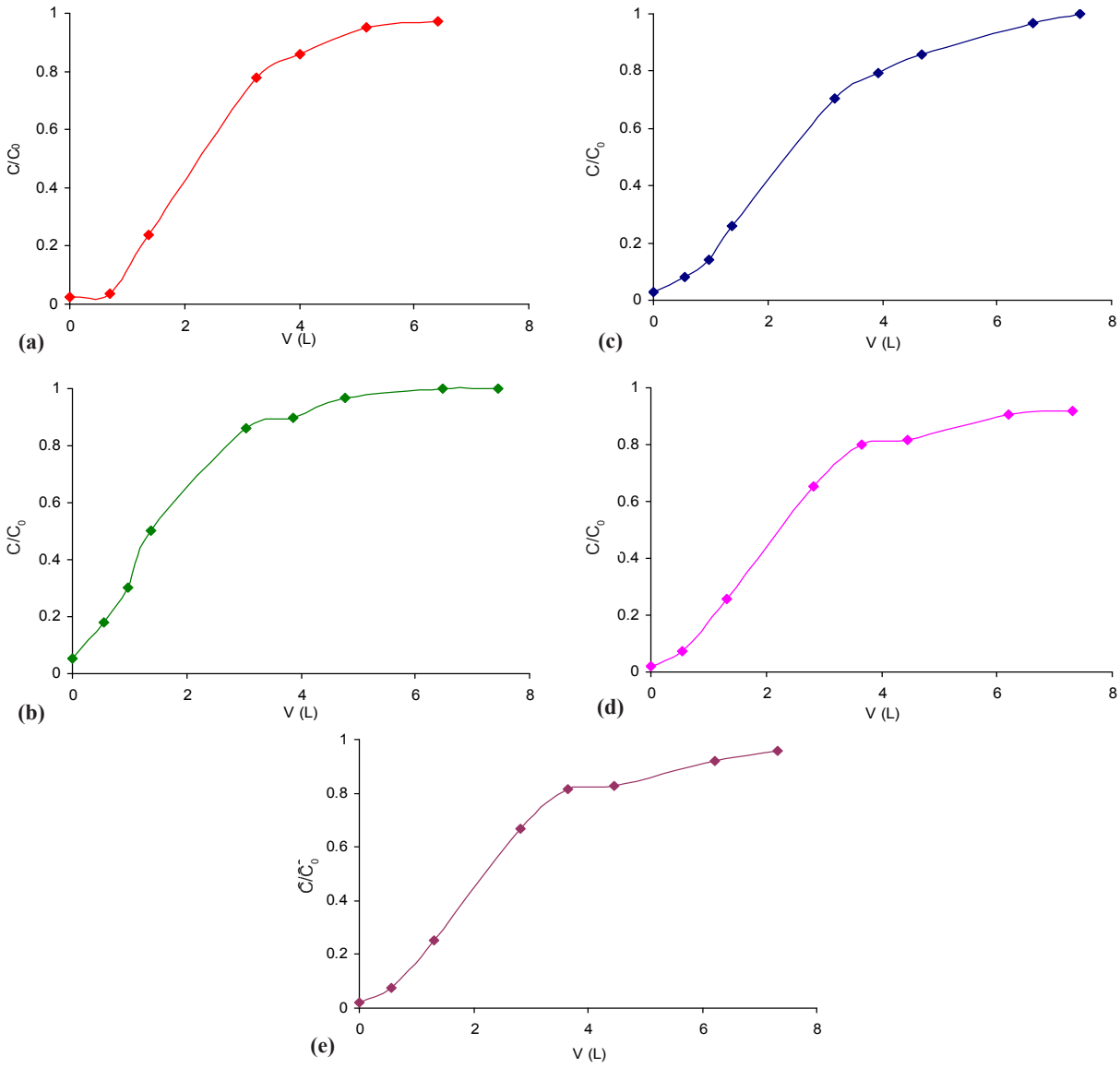


Fig. 2: Experimental breakthrough curves for UO_2^{+2} biosorption by different biomasses: (a) natural biomass, (b) protonated biomass, and (c, d, and e) Ca-pretreated biomasses by 0.1 M $CaCl_2$ at pH=2.5, 4 and 9.7 solutions, respectively

Biosorption mechanism

The plot of effluent pH versus effluent volume for UO_2^{+2} biosorption is given in Fig. 3. Also, the plot of Ca^{+2} ions in effluent versus effluent volume for UO_2^{+2} biosorption is given in Fig. 4. Fig. 5 shows spectra of biomasses before and after uranium contact and Table 1 shows results of XRF analysis.

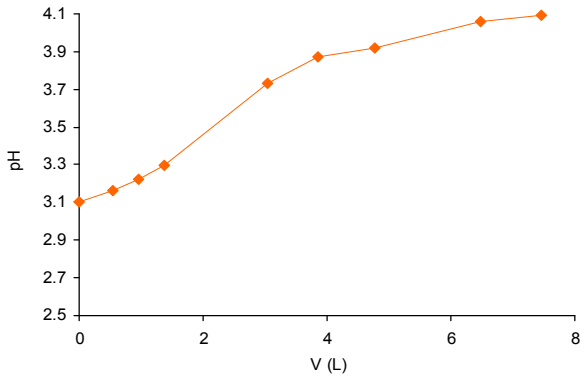


Fig. 3: Effluent pH vs. effluent volume of column with protonated biomass for UO_2^{+2} biosorption

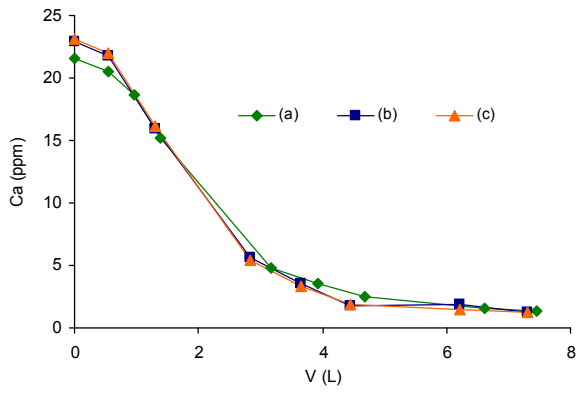


Fig. 4: Concentration of Ca^{+2} ions in effluent vs. effluent volume of columns with Ca-pretreated biomasses by 0.1 M $CaCl_2$ at pH=2.5 (a), 4 (b) and 9.7 (c) solutions for UO_2^{+2} biosorption

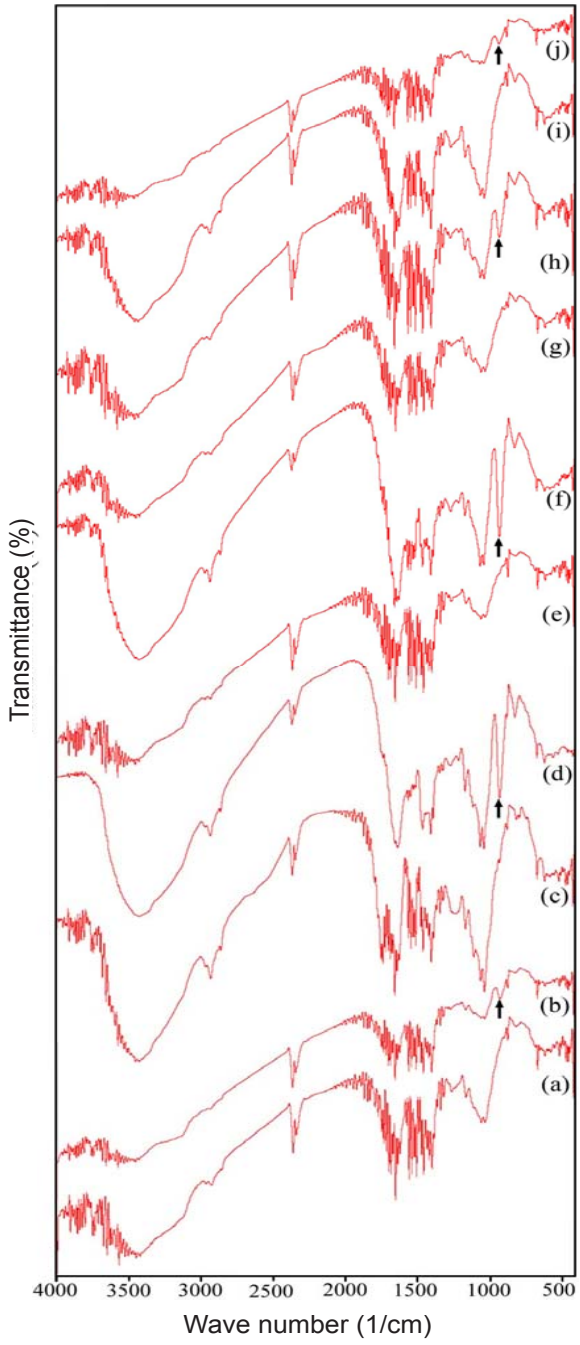


Fig. 5: FTIR spectra of (a) natural biomass, (c) protonated biomass, (e, g, and i) Ca-pretreated biomasses by 0.1 M $CaCl_2$ at pH=2.5, 4, and 9.7 solutions, respectively, and (b, d, f, h, and j) uranium loaded biomasses

Biosorbent regeneration

In the batch experiments, the uranium loaded biomass was eluted by various desorbents and obtained results for three sorption-desorption cycles are shown in Table 2. Also, in the continuous experiment, *Cystoseira indica* biomass was reused for three sorption-desorption cycles. In regeneration cycles the column operation was stopped when the effluent metal concentration reached to the influent concentration. Biosorption column breakthrough curve and elution curve for the column acid wash and recovery of uranium during three cycles are shown in Fig. 6.

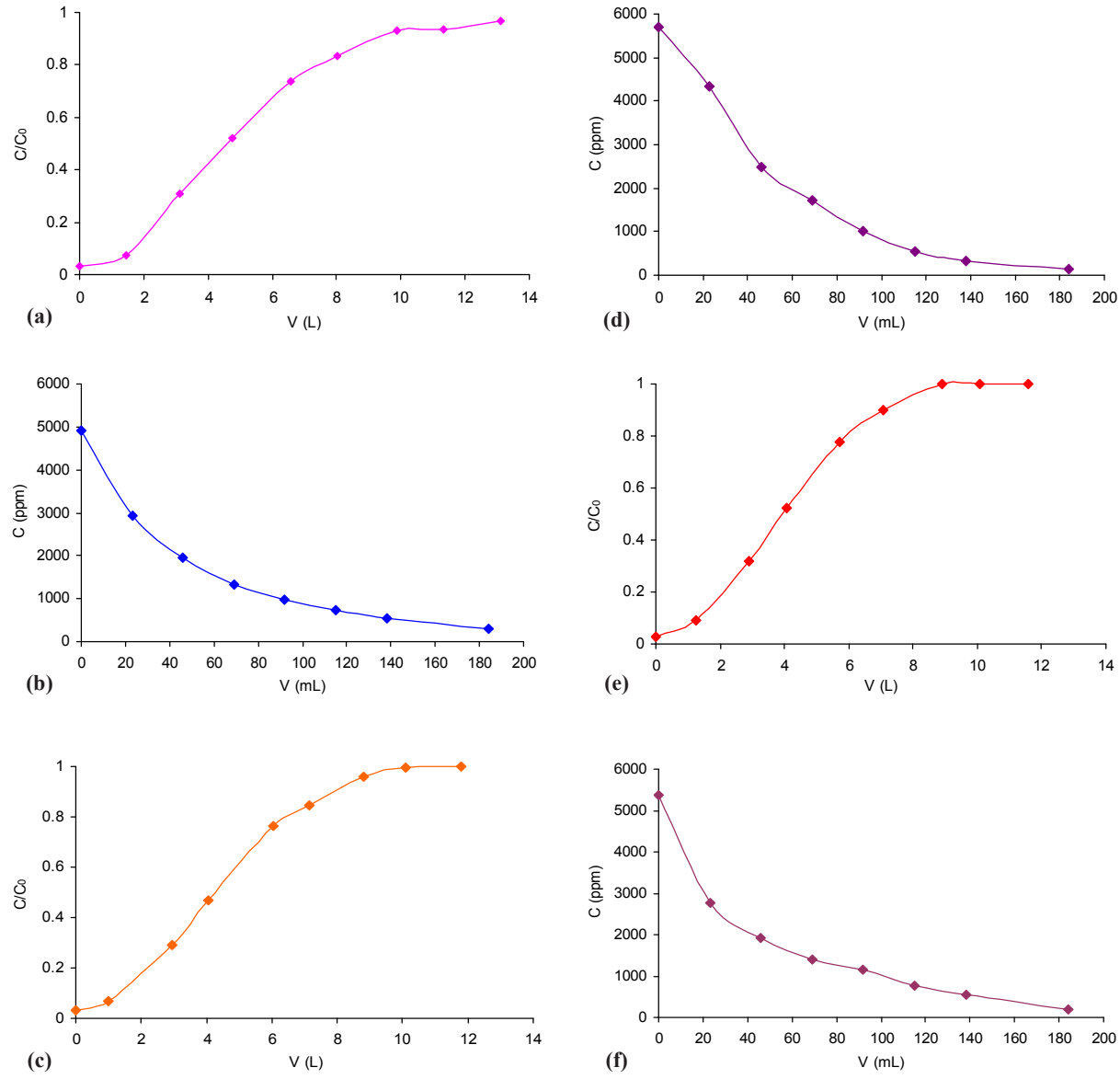


Fig. 6: Biosorption column breakthrough curve and elution curve for the column acid wash and recovery of uranium during (a and b) cycle no. 1, (c and d) cycle no. 2, and (e and f) cycle no. 3

DISCUSSION

Effect of pretreatment

Cell wall of this biomass consists of two layers (internal and external layers). External layer plays the main role in biosorption of heavy metals (Davis *et al*., 2003). Addition of 0.1 M HCl solution to biomass as pretreatment in long time (3 h) leads to destruction of this layer. Therefore, uptake capacity reduces to 35.59% (Fig. 2). But simultaneous utilization of H^+ and Ca^{+2} in pretreatment solution, solutions of 0.1 M $CaCl_2$ at pH=2.5, 4 and 9.7, leads to increasing of uptake capacity. Due to replacement of cations in the binding sites (presented in sea water and adsorbed on biomass) with H^+ and Ca^{+2} ions, binding sites of biomass is activated. Subsequently, uptake capacity is increased because of easy replacement

Table 1: Weight percentage of analytes in (a) natural biomass, (c) protonated biomass, (e, g, and i) Ca-pretreated biomasses by 0.1 M $CaCl_2$ at pH=2.5, 4, 9.7 solutions, respectively, and (b, d, f, h, and j) uranium loaded biomasses

Analyte	Concentration (wt %)									
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
Al_2O_3	2.90	2.30	4.50	2.00	2.70	0.20	2.50	1.80	2.80	1.80
BaO	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.08	0.00
Bi	0.00	1.80	0.00	1.70	0.00	0.00	0.00	1.90	0.00	1.70
Br	0.30	0.00	0.60	0.00	0.30	0.00	0.30	0.00	0.30	0.00
CaO	29.9	0.00	8.40	0.00	47.90	0.10	55.10	0.00	55.50	0.00
Cl	0.30	0.20	0.60	0.10	0.10	0.20	0.10	0.20	0.20	0.20
Cr_2O_3	0.00	0.00	0.07	0.00	0.00	0.00	0.04	0.00	0.00	0.00
Cu_2O	0.06	0.10	0.10	0.10	0.08	0.10	0.08	0.10	0.09	0.20
Fe_2O_3	1.50	0.40	2.30	0.40	2.00	0.40	2.30	0.30	1.90	0.40
GaO	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
GeO_2	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HgO	0.00	0.20	0.00	0.20	0.00	0.30	0.00	0.20	0.00	0.20
I	0.45	0.00	0.00	0.00	0.04	0.00	0.05	0.00	0.05	0.00
K_2O	20.10	8.70	1.50	7.90	2.70	8.80	0.20	8.60	0.20	8.60
MgO	2.80	0.00	0.00	0.00	1.60	0.00	0.00	0.00	1.20	0.00
MnO	0.30	0.00	0.05	0.00	0.20	0.00	0.05	0.00	0.05	0.00
MoO_2	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Na_2O	0.00	0.00	0.00	0.00	2.70	0.00	2.10	0.00	2.30	0.00
Nb_2O_5	0.00	6.50	0.08	7.20	0.00	7.10	0.00	0.70	0.00	7.10
NiO	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00
P_2O_5	1.2	0.50	2.50	0.40	1.40	0.30	1.50	0.50	1.10	0.40
Rb_2O	0.00	0.70	0.00	0.70	0.00	0.00	0.00	0.80	0.00	0.90
Sc_2O_3	0.20	0.00	0.00	0.00	0.30	0.00	0.40	0.00	0.50	0.00
SiO_2	2.70	2.20	6.00	2.90	4.10	3.50	3.50	1.80	3.30	2.20
SnO	0.00	0.08	0.04	0.00	0.00	0.07	0.00	0.08	0.00	0.06
SO_3	31.90	9.90	67.00	6.90	31.80	9.70	29.10	9.90	28.60	10.00
SrO	2.50	0.20	0.50	0.00	1.40	0.00	1.00	0.07	1.00	0.06
Ta_2O_5	0.00	0.40	0.00	0.40	0.00	0.50	0.00	0.40	0.00	0.40
TeO_2	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TiO_2	0.10	0.00	0.30	0.00	0.08	0.00	0.10	0.00	0.10	0.00
U_2O_3	0.00	63.30	1.30	67.00	0.00	63.50	0.00	63.60	0.00	64.30
V_2O_5	0.00	0.06	0.00	0.05	0.04	0.06	0.04	0.06	0.05	0.06
ZnO	0.10	0.10	0.20	0.10	0.09	0.10	0.09	0.10	0.10	0.10
ZrO_2	0.04	0.00	0.07	0.00	0.00	0.00	0.10	0.00	0.06	0.00

of hydrogen and calcium ions with uranium ions. In another study, similar effects of 0.1 M HCl and 0.1 M $CaCl_2$ solutions on cell wall of *Sargassum wightii* brown alga were seen (Vijayaraghavan *et al*., 2006).

Biosorption mechanism

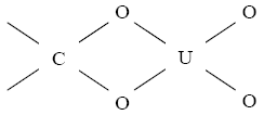
Monitoring of pH in the column effluent with protonated biomass at different operation phases presented the simultaneous release of H^+ with the uptake of heavy metals, because the effluent pH was decreasing when the biosorption of UO_2^{+2} was being performed. As indicated in Fig. 3, the plot of effluent pH versus effluent volume was similar to breakthrough curves. In the beginning of the column operation, the effluent pH decreased to about 3.1 by the most replacement of hydrogen ions in the binding sites with UO_2^{+2}; then by reduction of protonated binding sites as well as decrease of UO_2^{+2} biosorption rate, the effluent pH increased gradually until the effluent pH became equal to the influent pH (about 4.1) at complete

Table 2: Sorption and desorption efficiency (SE & DE) during three sorption–desorption cycles in the batch system

Eluant	Cycle No. 1		Cycle No. 2		Cycle No. 3	
	SE (%)	DE (%)	SE (%)	DE (%)	SE (%)	DE (%)
H_2O	98.55	0.00	98.47	0.05	98.42	0.00
HCl (0.1 M)	98.55	81.57	98.68	78.61	98.25	79.70
CH_3COOH (0.1 M)	98.55	12.21	97.01	7.22	96.30	8.29
$CaCl_2$ (0.1 M)	98.55	0.71	98.90	1.89	99.28	4.34
NaCl (0.1 M)	98.55	0.39	99.50	0.40	100.00	1.23

exhaustion of the biosorption bed, so the rate of metal ions biosorption was proportionate to the release of hydrogen ions. Also, measurement of Ca^{+2} ions in the three effluents of columns with Ca-pretreated biomasses at different operation phases (Fig. 4) presented the simultaneous release of Ca^{+2} with the uptake of uranium, because the Ca^{+2} ions in effluent were increasing when the biosorption of UO_2^{+2} was being performed. These observations confirm that ion exchange is one of the main biosorption mechanisms. In another study Naddafi *et al.* showed that monitoring of pH in the effluent of the column presented the simultaneous release of H^+ with the uptake of heavy metals; Hence ion exchange was confirmed to be one of the main biosorption mechanisms (Naddafi *et al*., 2007).

Fig. 5 shows spectra of biomasses before and after uranium contact. In the spectra of uranium loaded biomasses an intense peak around 1000 1/cm region indicates the absorption of O-C and O-U bounds. This peak suggested the chelating (bidentate) character of the uranium biosorption onto –C=O groups. The structure of the uranium bound to –C=O groups on the biomass is likely to take the form:



Also, the peaks which correspond to –OH group around 3350 and 2500 1/cm as well as –CH bond around 1400 and 2950 1/cm are observed. Furthermore, there is no difference between the spectra of (a) natural biomass, (c) protonated biomass, and (e, g, and i) Ca-pretreated biomasses. FTIR analyzer just shows the structure changes of active sites of biosorbent. Ca^{+2} and H^+ ions do not change in the structure of active sites of biosorbent. Therefore, no change in these spectra (a, c, e, g and i) is not observable. But uranium changes the active sites of biosorbent and FTIR showed it. Sheng *et al.* also investigated biosorption of lead, copper, cadmium, zinc, and nickel by marine algal biomass. FTIR analysis showed that the functional groups involved in bivalent metal biosorption included carboxyl, ether, alcoholic, and amino groups. Sulfonate groups did not play a major role in the binding of bivalent ions (Sheng *et al*., 2004). In another study, biosorption of cadmium and nickel by functionalized husk of *Lathyrus sativus* was investigated. In this study the involvement of the hydroxyl groups mainly in the functionalization process was demonstrated by FTIR (Panda *et al*., 2008). Gaur and Dhankhar also studied the functional groups involved in zinc biosorption by using FTIR. Spectroscopic analysis of algae revealed the presence of carboxyl, hydroxyl, amino, amide and imine groups, which were responsible for biosorption of zinc ions (Gaur and Dhankhar, 2009).

Table 1 shows results of XRF analysis. These results indicate that the calcium concentration of Ca-pretreated biomasses by 0.1 M $CaCl_2$ solutions at different pH is very high. Furthermore, the uranium concentration of biomasses after uranium contact is significant. As seen in Table 1, the concentration of uranium ion in Ca-pretreated biomasses by 0.1 M $CaCl_2$ solutions at different pH after uranium contact is high, whereas calcium concentration is about zero. It confirms the replacement of calcium ion in binding sites with uranium ion. The observation also proves that ion exchange is the main mechanism of

uranium biosorption by this biomass.

Biosorbent regeneration

The attractiveness of biosorption process is enhanced when a possibility of the recovery of the biosorbed metal exists. The optimal eluent must be effective, non-damaging to the biomass, non-polluting and cheap. Sorption efficiency was determined by the ratio of the metal mass bound to the biosorbent to the metal mass in the solution before sorption, and desorption efficiency was determined by the ratio of the metal mass in the solution after desorption to the metal mass initially bound to the biosorbent (Vijayaraghavan *et al*., 2006). According to Table 2, washing of uranium laden biomass by 0.1 M HCl released greater than 78% of the metal ions. H_2O, 0.1 M $CaCl_2$, and 0.1 M NaCl were not able to elute biosorbed uranium ions, indicating strong affinity that biomass possesses toward uranium ions. Also, 0.1 M CH_3COOH eluting solution showed lower desorption capacity than 0.1 M HCl. The results clearly suggest that 0.1 M HCl proved to be quite efficient in eluting uranium from the biomass.

Cystoseira indica biomass was reused for three sorption-desorption cycles. Uptake capacity of uranium ions in three cycles were 315.43, 270.34, and 248.61 mg/g, respectively. Uranium uptake decreased as the cycles proceeded, indicating gradual deterioration of the biomass due to repeated usage. The area below uranium concentration in effluent versus volume effluent (Fig. 6), obtained through numerical integration, was used to find the quantity of uranium ions recovered in the column. Therefore, desorption efficiencies in three cycles were 84%, 98%, and 100%, respectively. These results show that uranium removal/recovery by *Cystoseira indica* biomass is viable. Vijayaraghavan *et al*. also determined the elution efficiency for Ni-desorption from *Sargassum wightii* brown alga for distilled water, boiled water, HCl, H_2SO_4, HNO_3, $CaCl_2$, $MgCl_2$, NaCl, KCl, NH_4Cl, NaOH, KOH, NH_4OH and EDTA (Na). Among these elutants, 0.1 M $CaCl_2$ (in HCl, pH=2.5) exhibited elution efficiencies greater than 98% and also not markedly affected the biomass (Vijayaraghavan *et al*., 2006). In another study, Biosorption of uranium by *Sargassum* biomass was studied. The results of this study showed that the uranium could be easily recovered from the metal-loaded biomass by elution with 0.1 N HCl. Desorption was complete and the damage to the biomass was slight (Yang and Volesky, 1999). Naddafi *et al.* investigated the regeneration of Pb-saturated *Sargassum glaucescens* biomass in a continuous packed bed column. The result indicated that the desorption agent (0.1 M HCl) had not suitable efficiency in the biosorbent recovery (Naddafi *et al*., 2007).

According to the obtained results in this study the pretreatment of *Cystoseira indica* biomass by 0.1 M $CaCl_2$ solution at pH=4 led to increase in the uptake capacity of the biomass. Also, obtained results showed that ion exchange is the main mechanism of uranium biosorption by this biomass. This biomass can be used in the continuous packed bed column as a potential biosorbent for treatment of uranium polluted aqueous solutions because of high uptake capacity and its reusability.

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