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ADSORPTION OF URANIUM FROM AQUEOUS SOLUTION BY DRY AND CHEMICAL MODIFIED WATER HYACINTH ROOTS

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ABSTRACT: Adsorption of uranium using dried roots of water hyacinth plant *(E. crassipesas*) has been investigated. The plants were collected from Ismailia canal, Sharkia Governorate, Egypt. And pretreated with different activating agents as organic or metallic acids, using fixed concentration from each activator (5%). The adsorption were examined as a function of initial uranium concentration, contact time, pH, temperature, volume, dose of roots and size. Citric acid has advantage and the optimum condition was 94% about pH of 5.

Keywords: Uranium, water hyacinth, adsorption, solvent extraction, citric acid.

INTRODUCTION

Uranium, a toxic and very radioactive heavy metal, is relatively widespread in the environment, and as a naturally occurring element it is found at low levels in virtually all rocks, soils and waters (Shawky *et al.,* 2005). Increased uranium in the biosphere originates from mining, beneficiation of uranium ores and various processes related to the production of nuclear reactor fuel as well as the use of depleted uranium (DU) in civil and military applications (Bleise *et al.,* 2003).

Uranium is of fundamental importance in the nuclear fuel cycle. It starts as a source and ends up as a final waste component. Pollution of the environment with uranium and associated health effects to human have recently become of major concern, particularly due to the use of DU in armour-breaking bullets. Nevertheless, uranium in environmentally relevant concentrations is found near to uranium mining and processing facilities and usually involves large volumes of wastewater. In aquatic solutions and aquifers, uranium exists predominantly in its hexavalent oxidation state. Removal of uranium from large volumes of wastewaters requires a cost effective remediation technology. Several methods are utilized to remove uranium from wastewater and process effluents. These include reduction followed by chemical precipitation, ion exchange, electrochemical precipitation, solvent extraction, membrane separation and biosorption *etc*. However, these technologies are costly and ineffective, particularly when the concentration of uranium is a very low (Bla´zquez *et al.,* 2005). Adsorption process using agricultural material is an important technique in the wastewater treatment processes. Numerous research works have been carried out an using of low cost and eco-friendly adsorbents, such as *E. crassipesas* (Brown *et al.,* 2000; Ho, 2003).

The aim of the current study was to evaluate the adsorption capacity of water hyacinth plant as well as to investigate the adsorption equilibrium and kinetic of uranium divalent ions in single and binary component systems.

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MATERIALS AND METHODS

Water Hyacinth Sampling

The adsorption experiment was conducted for removal of uranium from contaminated water using dried roots of water hyacinth plant *Eichornia crassipes* as aquatic plant. Collected from Ismailia canal, Sharkia Governorate, Egypt. Plant samples were carefully washed by tap water then by distilled water to remove visible debris (Sadler and Rynja, 1992; O'Halloran *et al.,* 1997)., dried for 72 hour under sun ray then by oven at 70°C for 72 hour, then ground in porcelain mortar, and sieved through 2 mm sieve "with homogenous particle size portion of 35, 18, 10 and 7 mesh".

Adsorption experiments

Dried plants materials were pretreated with 1000 ml 0.1 M NaOH for 30 min then washed with deionized water till the pH of the wash solution reached 7.0 (Xinjiao, 2006). The second step was treatment with different activating agents as organic or metallic acids (Citric acid, Oxalic acid, tartaric acid, ethylene diaminetetraacetic acid disodium, ascorbic acid), Tri-n-octylamine (TOA), Tributyl phosphate (TPP), HNO3, and HCL)], using fixed concentration from each activator (5%). Stock solutions (1000 µg/g) of $UO_2 (NO_3)_2.6H_2O$ were prepared by deionized water.

Equilibrium Adsorption Experiments

The adsorption experiments were carried out in closed Erlenmeyer flasks of 100 ml, where about 0.2 g of modified adsorbents material used as absorbent contacted with 25 ml of the uranium solution, each controlling factor was studied while all other factors were fixed. The applied ranges of the controlling factors were: 1 to 9 pH, 5 - 240 min contact time, from 0.1 - 0.5 g adsorbent dosage, 20 to 1000 mg/g initial uranium concentration, 25 - 75 temperature, solution volume to solid 25 – 125 ml and 7 – 35 mesh. In each experiment, solution pH was adjusted using 0.1 M HNO_3 and/or 0.1 M NaOH. The flasks were gently shaken and samples were obtained at different time intervals. At the end of the experiments, the mixture was centrifuged and filtrated, then each metal system was determined in the filtrate. The adsorption capacity (q_e) and removal efficiency were obtained using the Eqs. (1) and (2):

$$q_e \text{ (mg/g)} = (C_o - C_e) \times V/M \quad (1)$$

$$\text{Removal efficiency (\%)} = C_o - C_e/C_o \times 100 \quad (2)$$

Where q_e is the quantity adsorbed at equilibrium, mg g^{-1} C_o and C_e are the uranium concentration in the initial solution and at equilibrium (µg/g) respectively, V is the volume of the solution (L), M is the weight of adsorbent (g). A control was also set up with no reagent addition. The following models have been widely used (Ho and McKay 1999). Lagergren pseudo first order model can be expressed by Eqs. (3) and (4):

$$dq/dt = k_1(qe-q) \quad (3)$$

$$\log (qe-q) = \log(qe) - k_1 t/2.303 \quad (4)$$

The pseudo-second order models are given by Eqs. (5) and (6):

$$dq/dt = k_2(qe-q)^2 \quad (5)$$

$$t/q = t/qe + 1/k_2 qe^2 \quad (6)$$

Where q and qe are the amount of metal adsorbed per unit weight of adsorbent (mg g^{-1}) at time t, and at equilibrium, respectively, and k_1 and k_2 are the adsorption rate constants. The initial adsorption rate (h) is equal to $k_1 qe$ and $k_2 qe^2$ (mg g^{-1} min^{-1}) for first and second order models, respectively.

Equilibrium Experiments of Case Study of Talet Seleim ore

This part is mainly concerned with defining the optimum conditions for both the leaching and extraction of uranium with the studied ferruginous shale ore material of Talet Seleim area. The effect of H_2SO_4 concentration was studied at acid concentrations in the range of 40%, while fixing the other factors at a solid/ liquid (S/l) ratio of 1/3, 4 hr., agitation time at temperature of 75 °C.

Chemical Analyses

Chemical analyses were carried at the laboratories of Nuclear Materials Authority (NMA) of Egypt. At the end of experiment, the loaded root by uranium concentration, in the filtrate was determined. Equilibrium concentration, the metal ion in the filtrate was analyzed by UV-VIS Spectrophotometer model SP – 8001.

Uranium concentration was determined using Arsenazo III method. Absorbance was measured at 655 nm against the blank reagent (Marczenko, 1976).

RESULTS AND DISCUSSION

Characterizations of Adsorbent

Water hyacinth (*Eichornia crassipes*) plant was studied using IR spectra and scanning electron microscopy (Figs. 1, 2 and 3).

Infrared Spectroscopy (IR)

The obtained IR spectra for water hyacinth modified by citric acid is shown in Fig. 1 and show that at wave length 3424, 1433 and 1064 cm^{-1} stretching OH group resulted from OH of cellulose appears, while stretching alkane group CH_3-CH_2 is found at 2925 cm^{-1}. The group at 1725 cm^{-1} is back to anhydride C=O, while that at 1641 cm^{-1} is due to bending C=N. and that of C-C=O appears at wave length 519 cm^{-1}. After adsorption the band at 1725 cm^{-1} disappears while a band at 1064 cm^{-1} is shifted to 1031 cm^{-1}.

Effect of Different Organic and Metallic Acids as Extractant of Uranium

The obtained results in Table 1 show that citric acid is the highest activating agent followed by oxalic, tartaric, HCl, TOA, ascorbic, TBP, HNO_3 and finally EDTA-Na_2, respectively. As for the metallic acids, hydrochloric acid is more efficient than nitric acid.

Effect of Initial Uranium Concentration

The effect of initial uranium concentration has been studied by varying the uranium concentration from 20 to 140 µg u g^{-1}.

The results in Table 2 show that uranium adsorption efficiency increases with the increase in the initial uranium concentration and reaches maximum at initial concentration of 60 µg g^{-1} with 98.3% efficiency and any further increase above the initial concentration was not associated with any increase in adsorption efficiency. This may be due to the following: at low uranium concentration, uranium ions move freely in the solution in the time all the binding sits are vacant, with the increase in the uranium concentration most of binding sites become occupied with the uranium ions and any increase in the uranium concentration lead to a competition on the free binding sites. These results agree with those obtained by Aly *et al.* (2009). Who used water hyacinth roots with the initial thorium range of 20–200 mg l^{-1} at pH 5, which caused the highest capacity of thorium of 97.24%.

Adsorption Isotherm

Results of uranium adsorption (Table 3) show that, the obtained results fit well with Langmuir isotherm rather than the correlation coefficient (r^2) is 0.99. The maximum adsorption value obtained in accordance to Langmuir (1918) is 8 ml g^{-1} at room temperature. The obtained value for n in according to Freundlich (1906) is less than one indicating normal adsorbent.

The Effect of Shaking Time

The effect of shaking time on uranium adsorption using water hyacinth roots was done using varying contact time from 5 to 240 min. Results (Table 4) indicated that with the increase in the contact time, the uranium adsorption efficiency increased from 65% with 30 minutes and 94% with 120 minutes that beyond which no further increase, therefore120 minute would be chosen as the optimum contact time, these results agree with those of Mohamed (2013) who tested uranium adsorption by orange peels up to 120 min and found no further increase in efficiency beyond 60 min.

Adsorption Kinetics

The obtained result of uranium adsorption kinetics listed in Table 5 show the correlation coefficient of pseudo first order is 0.95 while that pseudo second order is 0.99 suggesting that pseudo second order can express well the uranium adsorption this results has been confirmed.

Effect of Temperature

Results of temperature on uranium adsorption at temperatures from 25 to 75^{o}C are shown in Table 6. Temperature had negative effects on uranium adsorption efficiency. This indicates the exothermic nature of the reaction

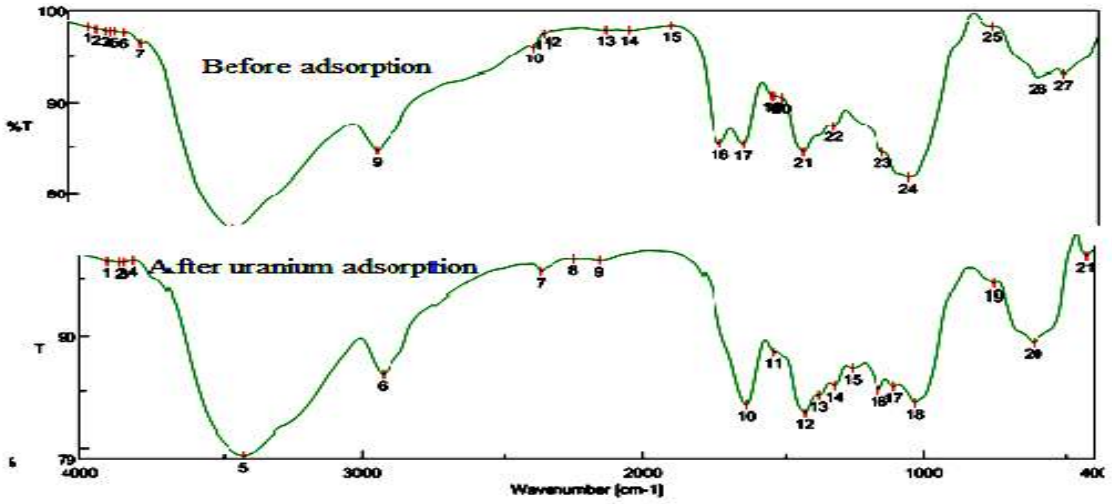

Fig. 1. (IR) Spectroscopy of modified water hyacinth by citric acid before and after treatment with uranium

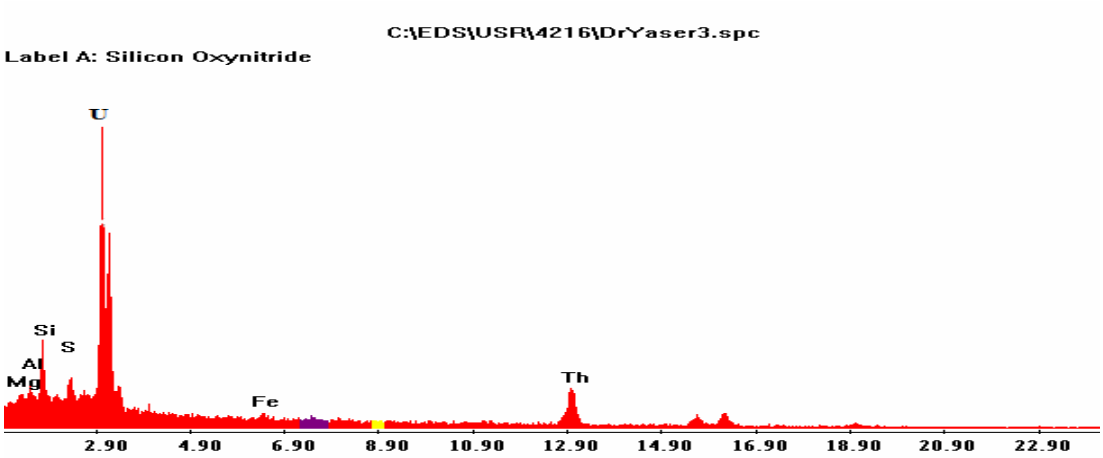

Fig. 2. Scanning electron microscope of the root material of water hyacinth showing the intricate, porous and structure after treatment by uranium

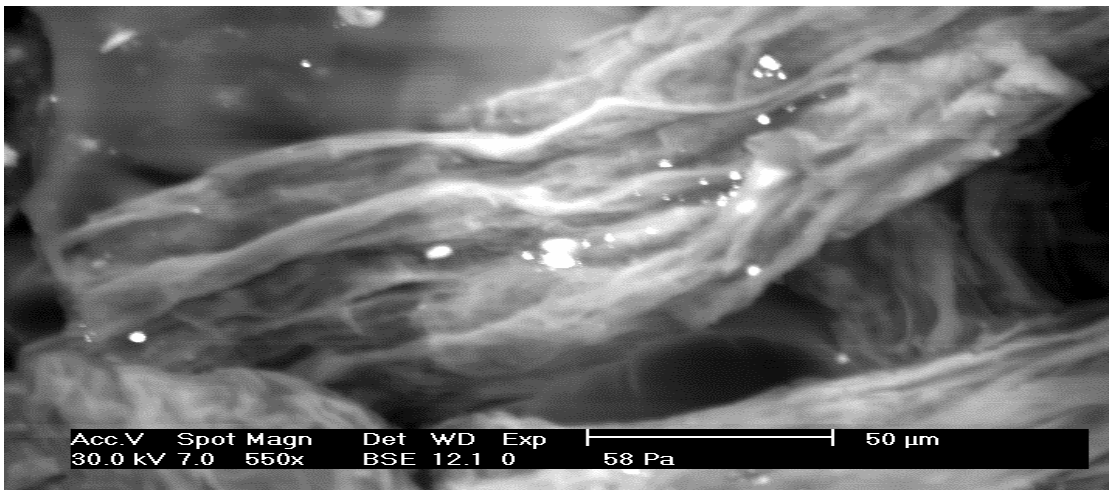

Fig. 3. Scanning electron microscope of the root material of water hyacinth showing the intricate, porous and structure after treatment by uranium

Table 1. Effect of different activating agents on the modification of dry water hyacinth roots for U retention

Activating agent	Final plant dry weight, g^{-pot}	Initial U conc., µg g^{-1}	U conc., remaining in solon., µg g^{-1}	Adsorption efficiency of biomass (%)
Citric	0.2	100	38	62
Oxalic	0.2	100	44	56
Tartaric	0.2	100	62	38
Ascorbic	0.2	100	72	28
EDTA-Na_2	0.2	100	85	15
TOA	0.2	100	71	29
TBP	0.2	100	74	26
Metallic acids				
HNO_3	0.2	100	80	20
HCl	0.2	100	70	30
Control	0.2	100	96	4.0

(Concentration 100 µg g^{-1} in 25 ml Solution of U, modified by NaOH, loaded by citric acid, 0.2 g biomass, 7- 35 mesh, contact time 0.5 hr, temp 25°C, Shaking at 170 rpm). TOA: Tri-n-octylamine, TPP: Tributyl phosphate.

Table 2. Effect of initial uranium concentration on uranium adsorption efficiency by modified water hyacinth roots

Initial conc., U of U µg g^{-1}	Conc., remaining U., in solution, µg g^{-1}	Adsorption µg g^{-1}	Adsorption efficiency of biomass (%)	Adsorption capacity qe (%)	Ce/qe
20	0.5	19.5	97.5	2.44	0.21
40	0.0	40.0	100	5.00	0.20
60	1.0	59.0	98.3	7.38	0.14
80	18.0	62.0	77.5	7.75	2.32
100	37.0	63.0	63.0	7.88	4.71
120	57.0	63.0	52.5	7.88	7.24
140	77.0	63.0	45.0	7.88	9.78

(Various concentrations, µg g^{-1} in 25 ml Solution of U, modified by NaOH, loaded by citric acid, 0.2 g biomass, 7-35 mesh, contact time 0.5 hr, temp 25°C, Shaking at 170 rpm)

Table 3. Langmuir and Freundlich constant of adsorption system of uranium

	Langmuir Constant			Freundlich Constant		
Element	**b ($mg.l^{-1}$)**	**Q_0 mg.g**	**r^2**	**Kf mg.g**	**n**	**r^2**
U	1.86	8	0.999	4.56	0.689	0.526

Table 4. Effect of shaking time on uranium adsorption efficiency by modified water hyacinth roots

Extraction time/minute of U	Initial conc., of uranium	U conc., remaining in solution, µg g^{-1}	Adsorption efficiency of biomass (%)	Adsorption capacity (qe) (%)
5	100	75.0	25	3.13
15	100	44.0	46	5.75
30	100	35.0	65	8.13
60	100	8.0	92	11.50
120	100	6.0	94	11.80
180	100	6.0	94	11.80
240	100	6.0	94	11.80

(Concentration 100 µg g^{-1} in 25 ml Solution of U, modified by NaOH, loaded by citric acid, 0.2 g biomass, 7-35 mesh, temp 25°C, Shaking at 170 rpm)

Table 5. Kinetics of adsorption of Uranium onto water hyacinth

Element	Experimental	Pseudo-first-order kinetics			Pseudo-second-order kinetics		
	qe (mg.g^{-1})	K_1 (1 min)	qe (mg.g^{-1})	r^2	K_2 (g mg.min)	qe (mg.g^{-1})	r^2
U	11.75	0.01233	15.78	0.953	0.006	12.66	0.997

Table 6. Effect of temperature on uranium adsorption efficiency by modified water hyacinth roots

^{o}C Value	Initial conc., of uranium	U Conc., remaining in solution, µg g^{-1}	Adsorption efficiency of biomass (%)	Adsorption capacity (qe) (%)
25	100	36	64	8.00
35	100	20	80	10.00
45	100	29	71	8.88
55	100	40	60	7.50
75	100	45	55	6.88

(Concentration 100 µg g^{-1} in 25 ml Solution of U, modified by NaOH, loaded by citric acid, 0.2 g biomass,7 -35 mesh, contact time 0.5 hr, Shaking at 170 rpm)

Kadirvelu *et al.* (2004), and obtained studied sorption of Hg by water hyacinth-derived activated carbon, the maximum capacity of Hg at 28.4 µg g^{-1} at 25°C.

Effect of pH

The effect of pH on uranium adsorption on water hyacinth roots was studied at pH from 1 to 9. The results (Table 7) show that pH 5 is the optimum for uranium adsorption with efficiency of 94% beyond which there was a decrease in efficiency, Patil *et al.* (2006) and Shin *et al.* (2007) studied adsorption capacity of Cd and Zn, and found that highest capacity occurred at, pH 5 and 6, respectively and attributed this to decrease availability of H^+ to compete with uranium for adsorption sites of biomass.

Effect of Solution Volume

The obtained results (Table 8) show that 50 ml solution was the most appropriate volume where maximum adsorption occurred. Any further increase above this volume was not net with any increase in adsorption. This may be due to chemistry of the solution where the probability of it binding on surface of the adsorbent is high. Increasing the volume make the movement of the uranium ions difficult for competing for the binding sites leading to a decrease in uranium adsorption. This result agree with those of Aly *et al.* (2009) who studied sorption of thorium by water hyacinth roots using volumes of 20 to 60 ml and obtained 94% efficiency on thorium adsorption.

Effect of Adsorbent Dosage

The results present in Table 9 indicate that with the increase in the adsorbent dosage, the uranium adsorption efficiency increased and reached its maximum at 0.4 g, attaining 95%. After that, the efficiency decreased to 93%. Further increase of adsorbent did not, cause exhaustive effect of uranium adsorption. This may be due to overlapping adsorption sites as a result of crowded adsorbent particles. In addition, the amount of ions bound to the adsorbent and the amount of free ions remained constant with further dose of adsorbent, Amarasinghe and Williams (2007) studied the effect of adsorbent of tea wastes on removal of Pb and Cu, and obtained increased efficiency with the decrease of absorbent dose (using 0.25 to 1.5/g).

Effect of Particle Size

Results of the effect of particle size on uranium adsorption using water hyacinth roots are shown in Table 10. The particle size of 35 mesh was the most appropriate size, with an efficiency of 90%. Mesh size below 35 was associated with decreased efficiency. Reaching lowest (34%) at mesh 7. More adsorbent binding sites cause high efficiency Patricia and Muñoz (2011) noted highest sorption capacity of water hyacinth with biomass of 0.114 and 0.203 mmol g^{-1} (7.45 and 13.27 µg g^{-1}).

Uranium Elution

Elution system was studied using 1M sodium chloride solution for 95 µg g^{-1}. This eluant solution was passed through the modified water hyacinth roots and saturated with uranium adsorption at a flow rate of 0.3 ml min^{-1} which corresponds to a contact time of 20 min .The obtained eluant solution was collected every 10 ml for uranium analysis. The obtained results (Table 11). Show that a 60 -cm height glass columns with 1 cm inner diameter permits to pack of the dry water hyacinth sample to 3cm height, with efficiency of elution of 88.6 mg l^{-1}.

Uranium Case Study

The obtained results of Talet Selem ferruginous shale ore material indicated that the leaching efficiency of uranium was 196 mg l^{-1}.

Uranium Elution of Leaching Liquor Shale ore Material

A case study for the obtained results from the controlling factor has been performed under the following condition: 250 ml leach liquor solution from Talet Selem having 196 mg l^{-1} uranium concentrations contacted with about 1.5 g from chemically modified water hyacinth roots at mesh 35 for 60 min at room temperature and pH 5. The obtained results show that 40 µg g^{-1} uranium concentrations were found in the solution indicating 80.3% adsorption efficiency. The adsorbed uranium has been eluted by using 150 ml of 1 M NaCl solution for three successive cycles and the obtained results show that the efficiency of uranium elution was 92.3%.

Table 7. Effect of pH on uranium adsorption efficiency by modified water hyacinth roots

pH value	Initial concentration of uranium	U Conc., remaining in solution, µg g^{-1}	Adsorption efficiency of biomass (%)
1	100	53	47
2	100	34	66
3	100	22	78
4	100	14	86
5	100	6	94
6	100	20	80
7	100	47	53
8	100	65	35
9	100	81	19

(Concentration 100 µg g^{-1} in 25 ml Solution of U, modified by NaOH, loaded by citric acid, 0.2 g biomass, 7 - 35 mesh, contact time 0.5 hr, temp 25 ^{O}C, Shaking at 170 rpm)

Table 8. Effect of Solid/liquid on uranium adsorption efficiency by dry and modified water hyacinth roots

Solid/liquid (vol)	Initial conc., of uranium	U Conc., remaining in solution (µg g^{-1})	Adsorption efficiency of biomass (%)	Adsorption capacity (qe) (%)
25	100	39	61	7.630
50	100	26	74	18.50
75	100	47	53	19.88
100	100	64	36	18.00
125	100	69	31	19.38

(Concentration 100 µg g^{-1} of U, modified by NaOH, loaded by citric acid, 0.2 g biomass, 7 -35 mesh contact time 0.5 hr, temp 25 ^{O}C, Shaking at 170 rpm)

Table 9. Effect of dose on uranium adsorption efficiency by modified water hyacinth roots

Dose (g)	Initial conc., of uranium	U Conc., remaining in solution (µg g^{-1})	Adsorption efficiency of biomass (%)	Adsorption capacity (qe) (%)
0.1	100	47	53	13.25
0.2	100	36	64	8.00
0.3	100	13	87	7.25
0.4	100	5	95	5.94
0.5	100	7	93	4.65

(Concentration 100 µg g^{-1} in 25 ml Solution of U, modified by NaOH, loaded by citric acid, 7 -35 mesh, contact time 0.5 hr, temp 25 ^{O}C, Shaking at 170 rpm)

Table 10. Effect of particle size on uranium adsorption efficiency by modified water hyacinth roots

Particle size (mesh)	Initial conc., of uranium	U conc., remaining in solution (µg g^{-1})	Adsorption efficiency of biomass (%)	Adsorption capacity (qe) (%)
35	100	10	90	11.250
18	100	22	78	9.750
10	100	45	55	6.875
7	100	66	34	4.250

(Concentration 100 µg g^{-1} in 25 ml Solution of U, modified by NaOH, loaded by citric acid, 0.2 g biomass, contact time 0.5 hr, temp 25 ^{O}C, Shaking at 170 rpm)

Table 11. Results of sodium chloride molarity efficiency uranium elution efficiency µg g^{-1}

Water	1st	2nd	3rd	4th	5th	Total
26	21.7	18.5	13.3	6.8	2.3	88.6

Column received 5successive 10 ml of added elution system.

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إمتزاز اليورانيوم من المحاليل السائلة باستعمال جذور نبات ورد النيل المجففة والمعدلة كيميائياً

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تهدف هذه الدراسة الي قياس قدرة جذور نبات ورد النيل كأحد النباتات المائية علي استرجاع عنصر اليورانيوم من المياه المحملة به، ولتحقيق هذا الهدف تم تجميع نباتات ورد النيل من ترعة الإسماعيلية بمنطقة بلبيس بمحافظة الشرقية، حيث أجريت التجارب باستخدام وزنة مقدارها ٠,٢ جرام من جذور ورد النيل المجففة والمعدلة كيميائياً بأيدروكسيد الصوديوم ٠,١ عيارى ثم حمض الستريك بتركيز ٥%، و كمية محلول ٢٥ ملى ثم وضعها فى كأس سعة ١٠٠ ملى وتعريضها لتركيزات مختلفة من العناصر من ٢٠ حتى ١٤٠ مليجرام/ لتر، ولحرارة من ٢٥ حتى ٧٥، ولوقت من ٥ حتى ٢٤٠ دقيقة، عند أس هيدروجينى من ١ إلى ٩، وكمية جذور من ٠،١ حتى ٠،٥ جرام، حجم المحلول ٢٥ حتى ١٢٥ ملى، ثم المقاس من ٧ حتى ٣٥ مش، من النتائج لوحظ أن جذور نبات ورد النيل المجففة والمعدلة كيميائياً لها قدرة مرتفعة لإحتجاز عنصر اليورنيوم، وقد أثبتت النتائج أن التركيز المناسب لليورانيوم هو ٦٠ جزء فى المليون،عند ١٢٠ دقيقة، وأس هيدروجينى ٠,٥م المحلول المناسب ٥٠ ملى، ودرجة حرارة ٣٥° م، ووزنة ٠,٤جرام من الجذور عند مقاس ٣٥ مش على التوالى، تم دراسة معدل الإزاحة باستخدام عمود زجاجى بطول ٦٠ سنتيمتر وقطر ١ سنتيمتر وتعبئته بجذور ورد النيل التى تم تحميلها سابقاً ب ٩٥ مليجرام/ لتر بعنصر اليورانيوم، ثم تمرير محلول ١عيارى من كلوريد الصوديوم على العينات عند معدل سريان ٠,٣ ملى/ الدقيقة، وتم تجميع العينات المزاحة كل ١٠ ملى على ٥ مرات بعد الغسيل مبدئياً بعشرة ملى ماء، وكان معدل الإدمصاص هو ٨٨,٦ ملى جرام/ لتر يورانيوم، تم تطبيق استخدام جذور نبات ورد النيل المجففة والمعدلة كيميائياً على عينات خامة طفلية من منطقة طلعة سليم جنوب غرب سيناء بعد طحنها حتى ٢٠٠ مش، ثم عمل استخلاص ل٧٥٠ جرام من هذه الخامة بحامض الكبريتيك بنسبة ٤٠%، عند درجة حرارة ٧٥ ونسبة ١- ٣ كتلة / حجم لمدة أربع ساعات، وكانت كفاءة عملية الإذابة للخامة هى الحصول على ١٩٦ ملى جرام/ لتر يورانيوم، وفى نهاية التجارب تم إضافة ٢٥٠ملى من محلول إذابة عينات منطقة طلعة سليم بسيناء والمحمل بتركيز ١٩٦ ملى جرام/ لتر يورانيوم إلى ١,٥ جرام من جذور نبات ورد النيل المجففة والمعدلة كيميائياً بمقاس٣٥مش عند أس هيدروجينى ٥، ودرجة حرارة ٣٥ مئوية، ووقت ٦٠ دقيقة ثم التقليب على سرعة ١٧٥ وكانت النتيجة بعد المعاملة ١٥٧ ملى جرام/ لتر يورانيوم تم ادمصاصها، ثم تمرير ١٥٠ ملي محلول ١ عيارى من كلوريد الصوديوم على العينة المدمصة لليورانيوم على ثلاث مراحل لإزاحة هذه الكمية، وكانت النتيجة إزاحة ٩٢,٣% ملى جرام/ لتر يورانيوم.ص

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