



Selective Separation of Uranium and Thorium Using Mesoporous Modified Nano-Alumina from Abu Rusheid Leach Liquor

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This study focuses on the synthesis and modification of mesoporous alumina monoliths in order to be used as a highly sensitive separating material for extraction of both U(IV) and Th (IV) ions selectively from real leach liquors. The adsorbent is prepared through functional immobilization of alumina with 2-Amino-1-thia-3,4-diazole. TEM, N₂ adsorption/desorption isotherm, TGA, and elemental analysis were carried out to demonstrate the fabricated mesoporous adsorbent. The optimum adsorption conditions such as pH, time, and initial concentrations were investigated to study the adsorption behavior of the modified alumina for U(VI) and Th(IV). The obtained results demonstrate that, the adsorbent allow extremely efficient adsorption for U (VI) and Th(IV) ions at different pHs from the real matrix (Abu Rusheid, Egypt). The adsorption efficiencies of thorium and uranium are 80 and 85 % respectively. The loaded thorium is eluted firstly by 6M HCl then loaded uranium is eluted by 2 M HNO₃. Moreover, the present study proved that for the separation of U (VI) and Th (IV) from sulfuric acid from Abu Rusheid leach liquor, alumina-ATDZ material should be used in about 3 stages of sequential separation.

Keywords: Mesoporous materials, Adsorption, Uranium, Thorium, Alumina

Introduction

From the economic perspective, energy represents a key element for the functioning of the global economy, being an important input to nearly all of the goods and services. In order to maintain and improve the living standards throughout the world, energy needs to be available and affordable.[1] To achieve that goal, continuing and reliable supplies of uranium are critical to nuclear power projects due to it is an inevitable mineral resource to produce the energy in atomic power plants [2]. In fact, uranium determination and separation from water, soil and other samples have therefore acquired a considerable importance. Hence, uranium is currently the preferred actinide in modern industries due to its use in power generation. It is also considered to be an ecologically toxic element [3]. While, the main sources of thorium in nature are soil, rock, plants,

sand and water. Thorium has numerous uses in industry as well as being used as fuel for nuclear reactors [4]. ²³³U, which can be obtained by neutron capture and decomposition of ²³²Th, can be used as a nuclear fuel. Thorium is a possible nuclear fuel and the availability of thorium on the earth is 3-4 times more abundant than uranium [5]. Uranium and thorium are always associated with rare earth elements in different ores, especially monazite and bastnaesite [6].

Traditional methods for the extraction and separation of U and Th from rare earth elements suffer from solid and/or liquid waste disposal problems, as well as the significant loss of rare earth elements to waste [7, 8]. For this reason, in the past years, there has been a need for investigations studies containing different methods of separating U and Th. In fact, solvent extraction

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and precipitations are the oldest common methods to efficiently remove uranium and thorium. On the other hand, solvent extraction is very costly if it is widely applied and leads to major environmental problems, the most important of which are toxic organic diluents. Besides, the use of flammable solvents makes solvent extraction very dangerous. Also, the application of precipitation in a complex system such as industrial wastewater makes it undesirable because of its extreme difficulty, high cost and consumption of time, as well as the contamination of uranium and thorium with the co-precipitated other metal ions, and this is one of the biggest obstacles [9]. Nowadays, there is an increasing interest in potential applications of adsorption technology in mineral separation, ore processing, water treatment and wastewater management, separation of metal ions. Therefore, there are considerable research activities in the study of new sorbents. Recently, a number of innovative adsorption materials have been developed and reported for the removal of uranium, thorium and heavy metal cations in general, from their aqueous solutions [10-18]. However, many anion exchange resins have been used to extract uranium and thorium ions from both strong acidic and basic solutions, although the most commonly used adsorbents for the extraction of these radionuclides are cation exchange ones [19, 20]. For example, ion exchange has many advantages over traditional precipitation and organic solvent extraction. This is because direct precipitation involves low reallocation of rare earth elements, disposal of precipitation and contamination from radioactive deposit storage. It also has no common complication in solvent extraction, namely, loss of solvent, formation of third phase, effluent disposal problems, and phase separation [21].

The great invention of mesoporous materials has led to an urgent demand for new decorated adsorbents for metal ion separation. The immobilization of organic ligands onto inorganic substrate materials is of great benefits in various applications. Hence, mesoporous alumina is one of the most important and extensively used nonsiliceous mesoporous materials that offer a wide range of applications. Such applications include catalysis, sensors and separation. Their acidic surfaces, high surface area and tunable and uniform pore size make alumina versatile hosts for organic ligands. The mesostructured and high

surface area of alumina render it to be used as an efficient substrate for simple immobilization and host for various organic molecules [1, 22]. Furthermore, the synthesis of mesostructured frameworks of alumina that show the ability of simple immobilization onto the interior mesopores remains a challenge. However, to control the successful decoration of substrates with large organic molecules without remaining attached to adsorbent surfaces, the synthesis of actively acidic alumina with uniform and large mesopores is a key requirement for good adsorbents for metal ions separations.

In the present study, mesoporous-adsorbent is prepared and successfully enabled a highly selective extraction of uranium and thorium ions by designing the 2-Amino-1-thia-3,4-diazole (ATDZ) ligand-doped nanoscale carrier of mesoporous network matrixes. The scope of the present investigation is to synthesize an innovative material having high selectivity adsorption for uranium and thorium ions from acidic sulfate media and to evaluate the potential application of this material to remove traces uranium and thorium ions from hydrometallurgical processing liquors. On the basis of the results here, the synthesized mesoporous material showed the sensitive extraction of uranium and thorium ions to a selective sequential separation with evidence of stability and selectivity in a rapid kinetic appreciation.

Experiments

Chemicals

All the chemicals and substances used in this study were used without additional purification because they were of analytical grade. Aluminum nitrate $\text{Al}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$, Polyoxyethylene (20) cetyl ether (Brij 58), $\text{C}_{16}\text{H}_{33}(\text{OCH}_2\text{CH}_2)_2\text{OOH}$, (molecular weight average about = 1124) and 2-Amino-1-thia-3,4-diazole, $\text{C}_2\text{H}_3\text{N}_3\text{S}$ (ATDZ) which are obtained from Sigma-Aldrich Company Ltd. Dodecane was supplied by Alpha Aesar, Company Ltd. The U (IV), Th (IV) sulfates, 0.2 M KCl-HCl, and $\text{CH}_3\text{COOH}-\text{CH}_3-\text{COONa}$ (acetate) buffer solutions used in the pH adjustment (1-6 range). KCl & CH_3COONa and HCl & CH_3COOH and the other chemicals were from Sigma-Aldrich Inc., Missouri, United States and Fluka Chemical Corp.

Synthesis of nano-alumina monolithic adsorbent

The alumina synthesis was used on the basis of a direct template synthesis for the quaternary crystalline liquid microemulsion of the CTAB / dodecane / Al (NO₃) / H₂O-HCl / ethanol combination to form a nano-mesoporous alumina monolith [22]. (Scheme 1). The solution was diluted for 10 minutes consisting of the mixture Al(NO₃)₃, Brij 58, dodecane, HCl solution (pH 1.3), and ethanol weight 1 5, 2, 0.5, 2.5 and 10 g, respectively to form a homogeneous sol- gel solution . The liquid viscosity of the material increases with continuous fluxing and hydrolysis reactions / condensation for two hours until the material, similar to the resulting visual generation acquires the shape and size of the reaction vessel. The solid / surface alumina is completely dried at 40 ° C overnight after large medium structures are formed and open due to the addition of the dodecane and ethanol swelling and co-coagulant agents under the continuous stirring. Then the organic fairness was removed by calcinations at 550 °C in air for 5 hours [22].

The alumina meso-adsorbent for uranium/thorium removal was prepared as follows: Mesoporous modified alumina adsorbent was prepared through the immobilization of 2-Amino-1-thia-3,4-diazole directly into 5 g of alumina prepared by monolith carrier. This was followed by impregnation under vacuum at 25 °C until chelating ligand saturation was achieved. Then a vacuum rotary evaporator was connected to get rid of ethanol and direct contact of the dye probe into the monoliths was occurred. The analysis of equilibrium adsorption capacity of the 2-Amino-1-thia-3,4-diazole molecules is spectrophotometrically performed with repeating the step of immobilization several times until reaching saturation. Finally, deionized water was used to wash the synthesized material adsorbent to no organic ligand elution was observed and drying at 65 °C for 2 h was achieved.

Characterization of alumina monolith adsorbent

All available analyzes have been carried out to have complete description of the fabricated material such as FTIR, TGA, TEM, and Zeta potential. FTIR spectra were performed in KBr discs using Nexeus-Nicolite-Model 640-MSA.

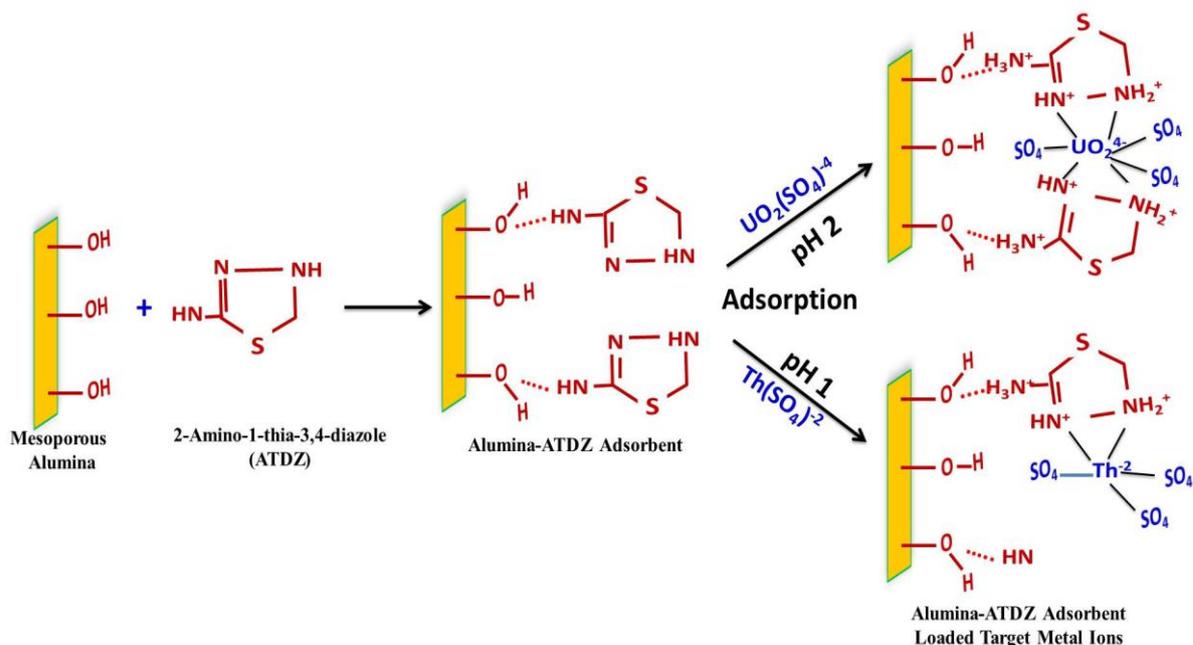
FTIR, Thermo Electronics Co. (USA).). X-Ray diffraction (XRD) analyses were carried out using a Philips X-ray generator model PW 3710 = 31. Thermo-gravimetric analysis (TGA) was carried out using Shimadzu DT = TG-50 with a heating rate of 10°C/min. The particle size distribution of the modified alumina was evaluated through Dynamic Light Scattering (DLS). The zeta potential was measured using a Nano Series Zeta Sizer, Malvern; Worcestershire, the UK. The specific surface area, pore volume and the pore structure were determined utilizing the N₂ adsorption technique using a BELSORP MIN-II analyzer (JP. BEL Co. Ltd) at 77 K. High-resolution transmission electron microscopy (HRTEM), was performed using a JEOL JEM model 2100F microscope, Japan.

Batch experiments for adsorption of U (VI) and Th (IV) ions

In a typical uranium/thorium ion-adsorption experiments, 10 mg of the fabricated modified alumina were mixed with 50 mg/L concentration of specific U or Th in invariable volume of 10 mL at the suitable pH (1–6). Then, a mechanical shaker was used for shaking the mixtures at 25 °C for the fitting time at 300 rpm agitation speed. The mixture was filtered off after equilibrium achievement and the concerned metal residual concentration was spectrophotometrically determined applying Arsenazo III technique [23] and the adsorption capacity was calculate using the following equation;

$$q_e = (C_i - C_e) V / m \quad (1)$$

where q represents the uptake (mg/g), C_i and C_f represent the initial and final metal ion concentrations (mg/L), V be the volume (L) and m represents the adsorbent weight (g).



Scheme (1): Fabrication of the mesoporous alumina-ATDZ nano-adsorbent through the assisted pressure approach under vacuum at 25 °C using rotary evaporator

Results and Discussion

Characterization of Fabricated Monolith Adsorbent

Mesoporous worm-like alumina meso-structures with regular and uniform cavities and porous entrance fissures were made-up directly using template liquid emulsion technique. The functional use of alumina with nano-scale size in a three-dimensional structure was simply synthesized in terms of fabrication times and Al/Brij58 ratio as shown in the high-resolution transmission electron microscope (HRTEM) images Fig. (1). The progress of disordered 3D structures feature, worm-like twisted and identical pore sizes, and Single – dispersion porous to nano-scale size (12 nm) could effectively extend the applicability of alumina as carriers for an extract of U and Th ions depending on the pH variations. TEM images Fig. (1) revealed that there are disordered mesoporous array over oversized areas of meso-adsorbent, in spite of the immobilization methods of the loading coverage of large organic molecules without steric hindrance. The HRTEM resulting images in Fig. (1) show clearly the attendance of a wormlike pore showing that the material has a mesoporous disordered structure.

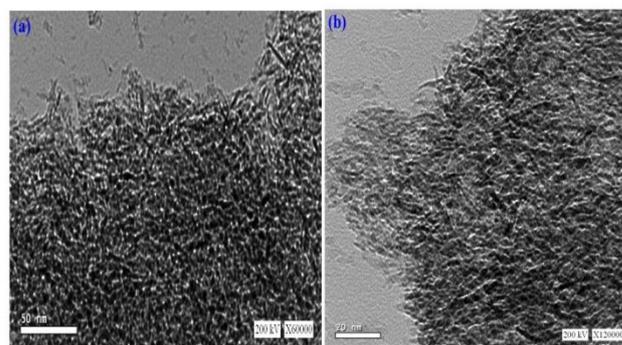


Figure (1): Representative HRTEM images show evidence of the formation of hexagonally worm like mesoporous structures

The FT-IR spectrum of the alumina- ATDZ and alumina- ATDZ loaded uranium results show that a number of distinctive bands are displayed, such as the band at 3450 which refers to the vibration stretching of H-bonded of silanol group ν (Al–OH) alongside with water physisorbed molecules ν (OH) also by the side with some bands occur at 3420, 2925, 2862, 771 which is an indicator of the presence of ν (N-H), ν (-CH₂), ν (S-H), respectively. Also, other four bands come into sight at 1631, 977, 878, 763 cm⁻¹. These bands are

assigned to ν (C=N), ν (C-N), ν (C-H) and ν (C-S) which are present in thiadiazole formation ring [1]. On the other hand, the N_2 isotherms results show that ultimate type IV adsorption performance, with a well-known intelligent adsorption/desorption inflection Fig. (2b) and significant shifting of the adsorption branches toward lower relative pressure (P/P_0) also is achieved. In addition, this fabricated material has great advantages, shown by the above results, which is the high surface area and the size of the large pores to increase the extraction efficiencies of U (VI) and Th (IV) from their leach liquors. The formations of uniformly-sized worm-like pores with pore openings about 12 nm are explained from isothermal shape and capillary evaporation. Moreover, our synthesized alumina feature surface area (S_{BET}) of support material and modified with ATDZ was $198 \text{ m}^2 \text{ g}^{-1}$, pore volume (V_p) of alumina modified with ATDZ, were $0.30 \text{ cm}^3 \text{ g}^{-1}$, respectively, and pore diameter (D) of alumina hold up material, modified with ATDZ was 12 nm, respectively. The distribution of particle size to the synthesized alumina was determined using Dynamic Light Scattering (DLS) with sizes ranging from 70–90 nm Fig (2d).

Moreover, the thermo-gravimetric curves display weight losses of about 7.33% from modified alumina in the temperature range from 25 to 205°C and these losses correspond to the water physisorbed molecules as shown in Fig. (2c). Also, the higher weight loss in the temperature range $210.3\text{--}270.47^\circ\text{C}$ confirmed the occurrence of modification to the fabricated alumina adsorbent Fig. (2c). These weight losses correspond to material decomposition of the organic ligand of modified alumina. The observed weight loss in the temperature range $270.5\text{--}586.13^\circ\text{C}$ is attributed to the remaining organic matter of burned ATDZ. The DTA curve of modified alumina shows three well-pronounced endothermic peaks at 60, 150 and 260°C . These endothermic peaks are due to the desorption of water and degradation of the organic matter. In addition, the obtained results proved that the alumina is thermally very stable up to 1000°C because no weight loss peaks are observed in the range $590\text{--}1000^\circ\text{C}$, Fig. (2b). Elemental analyses of the modified alumina give 6.74 (C), 2.26 (H), 2.8 (S) and 7.92 (N) % for the modified alumina.

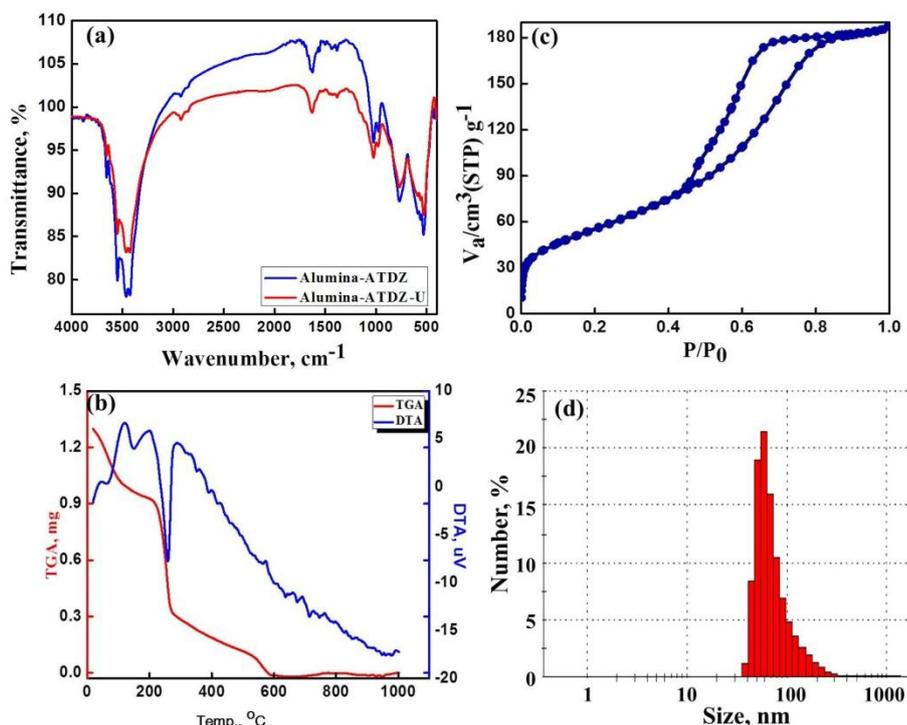


Figure 2 a): FTIR spectra for the synthesized alumina-ATDZ and uranium ions adsorbed on mesoporous alumina-ATDZ nanoparticles, (b) TGA and DTA, (c) N_2 adsorption- desorption isotherm, and (d) particle size distribution of the mesoporous alumina-ATDZ nanoparticles

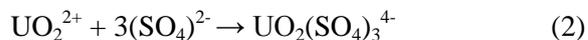
Adsorption of U (VI) on the fabricated meso-adsorbent

Effect of pH

Thorium and uranium ion adsorption experiments were geared up in a 100 mL quartz flask. The thorium and uranium solutions were diluted from a 1000 ppm aqueous stock standard solution into a flask at the appropriate pH (1-6) for 5 min. In the present study, sets of experiments were performed in the form of batch contact-time to define and evaluate systematically the suitable conditions and the specificity of the synthesized meso-adsorbent towards $\text{Th}(\text{SO}_4)_2^{2-}$ or $[\text{UO}_2(\text{SO}_4)_3]^{4-}$ ions which was controlled by means of pH adjustments. The adsorption procedure of $\text{Th}(\text{SO}_4)_2^{2-}$ and $[\text{UO}_2(\text{SO}_4)_3]^{4-}$ ions on the mesoporous adsorbent was studied after equilibration. The obtained results, shown in Fig. (3a), revealed that the adsorbent is strongly susceptible in expressions of its high uptake and selectivity towards the pH of the $[\text{UO}_2(\text{SO}_4)_3]^{4-}$ or $\text{Th}(\text{SO}_4)_2^{2-}$ ions solutions.

The effectiveness of the fabricated modified alumina-ATDZ for the adsorption of target metal ions was evaluated through quantitative studies at definite pH values Fig. (3a), to scientifically determine suitable pH conditions for the donor/acceptor combinations among Alumina-ATDZ as well the concerned metal ions. The highest uptakes value of $\text{Th}(\text{SO}_4)_2^{2-}$ and $[\text{UO}_2(\text{SO}_4)_3]^{4-}$ ions were observed at pH 1 and 2 respectively. The obtained of adsorption data Fig. (3a) show that uranium adsorption uptake increases with increasing the pH values then begins to decrease again after pH 2 while the best results were conducted at pH of 2. These results are in agreement with those obtained from Zeta potential measurements Fig. (3b), which reveals that the zero charges point (pzc) is about pH 5.9. The shift in the pzc to a higher pH, relative to the pzc of pure alumina supports indicate the probability of immobilization of the chelating moiety (ADTZ) occurrence to alumina surface. This may be attributed to the decrease of the negative charge generated from the dissociation of OH of alumina surface [24]. Below the pzc of alumina-ADTZ, the N sites become protonated (NH^+) and the surface charge of the particles tends to be positive and increases as the pH decreases. Above pH 5.9, the measurements showed negative values of zeta potential. This may be attributed to the dissociation of the -SH groups contained on the alumina-ATDZ surface giving ($-\text{S}^-$) and

consequently its basic character increases [25]. Hydrogen ion concentration plays an important role in uranium adsorption on an anion exchanger that at pH values below 1.5 there is no sufficient SO_4^{2-} ions to furnish the uranium sulfate complexes since HSO_4^- ions are the main. In addition, the uranium uptake from sulfate solution is a character of SO_4^{2-} concentration due to the influence of uranium anion formed under equilibrium conditions. As a matter of fact, the uranium uptake is favored until the ratio of $(\text{SO}_4)^{2-}/[\text{U}]$ is less than 2 but if this ratio increases above 2, the uranium uptake decreased. This is why the excess SO_4^{2-} compete with the uranium complex for active sites. In fact, uranium exists in the sulphate solutions as an uncharged $\text{UO}_2(\text{SO}_4)$ complex, and the anionic $[\text{UO}_2(\text{SO}_4)_2]^{2-}$ and $[\text{UO}_2(\text{SO}_4)_3]^{4-}$ complexes due to the amount of $(\text{SO}_4)^{2-}$ ion in the media which can also be adsorbed [26]. On the other side, the obtained results of thorium adsorption proved that the highest efficiency of thorium adsorption is at pH value of 1 which reaches about 52.1 % then decreases again and both of uranium and thorium begin to precipitate at a pH value higher than 5. Generally, thorium and uranium react with sulfuric acid and form thorium and uranium sulfate according to the following equations:



The obtained results have shown that the adsorption progression of the composite material is fundamentally dependent on acid concentration. Also, 2 sequential stages are sufficient to complete selective separations of uranium and thorium from sulfate solution.

Effect of Contact Time

The effect of contact time on the adsorption of target metal ions at room temperature and pH= 1, 2 for Th and U respectively, is illustrated in Fig. (4). Within 10 min, $\text{Th}(\text{SO}_4)_2^{2-}$ and $[\text{UO}_2(\text{SO}_4)_3]^{4-}$ the uptake represents 93 and 81% at the plateau, respectively. The equilibrium was attained within 10 and 15 min for $\text{Th}(\text{SO}_4)_2^{2-}$ and $[\text{UO}_2(\text{SO}_4)_3]^{4-}$, respectively. Moreover, the pseudo-second-order model is applied to explain the adsorption kinetics, according to equation 4 [16];

$$t / (q_t = 1 / k_2 q_e^2) + t/q_e \quad (4)$$

Where k_2 represents overall rate constant of the pseudo-second order (g/mg min) by plotting t/q_t versus t as shown in fig.4a. The obtained results clearly show that there is an adequate harmony between the calculated and experimental values of q_e which means that the adsorption process progresses obeying a pseudo-second order kinetics Fig. (4b).

Adsorption isotherms

In fact, there are many theories and different precise equations that have been recommended for adsorption isotherm studies, Adsorption data of uranium and thorium are analyzed applying the linear form of both Langmuir and Freundlich isotherms. The initial concentrations of the concerned metal ions effect on their uptake capacity are studied and the obtained results are based on the application of the Langmuir adsorption isotherm Fig. (4d), according to the following equation 5 [27]

$$C_e/q_e = 1/K_L q_m + C_e/q_m \quad (5)$$

where q_m represents amount of metal ions adsorbed to form monolayer reporting (mg/g) and K_L is the Langmuir adsorption equilibrium constant. The latter two values q_m and K_L were obtained from the slope and intercept respectively, of the linear areas of the Langmuir plot (Fig. 4d). It is clear from the obtained data that the equilibrium uptake capacity increases with increasing the initial metal ions concentration. In addition, the obtained straight line of the C_e/q_e against C_e plot of this adsorption attempt reveals the formation of the monolayer treatment of metals on the meso-adsorbent of alumina-ATDZ interior pore surfaces. For illustration, the obtained q_m data results indicated that the practical extraction of the concerned metal ions from the sulfate medium with high uptake efficiencies reaches 96–98% from dilute solutions. Thus, the extraction of 1g of both $\text{Th}(\text{SO}_4)_2^{2-}$ and $\text{UO}_2(\text{SO}_4)_3^{1-}$ from an sulfate solution would involve about 10 and 11 g of Alumina-ATDZ respectively. In addition, the values of K_L values are accepted with the adsorption/desorption rates, which represents completely reversible metal adsorption assays. The comparison of the adsorption capacities of uranium and thorium onto our fabricated adsorbent with various adsorbents are listed in Table (1).

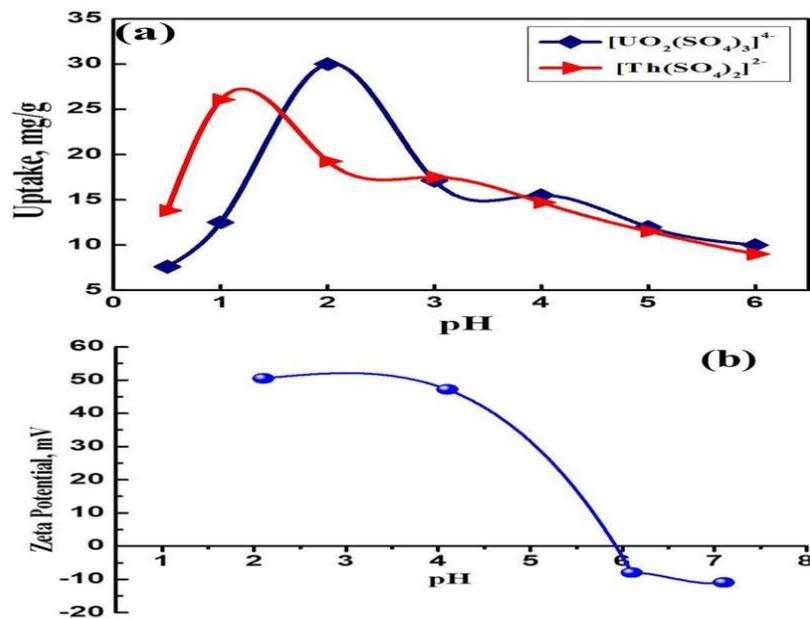


Figure (3): (a) Effect of pH upon U and Th adsorption by Alumina-ADTZ; initial metal concentration 50 mg/L, alumina-ATDZ weight 10 mg, solution volume 10 mL, contact time 20 min at 25°C and (b) Zeta potential of Mesoporous- alumina-ATDZ

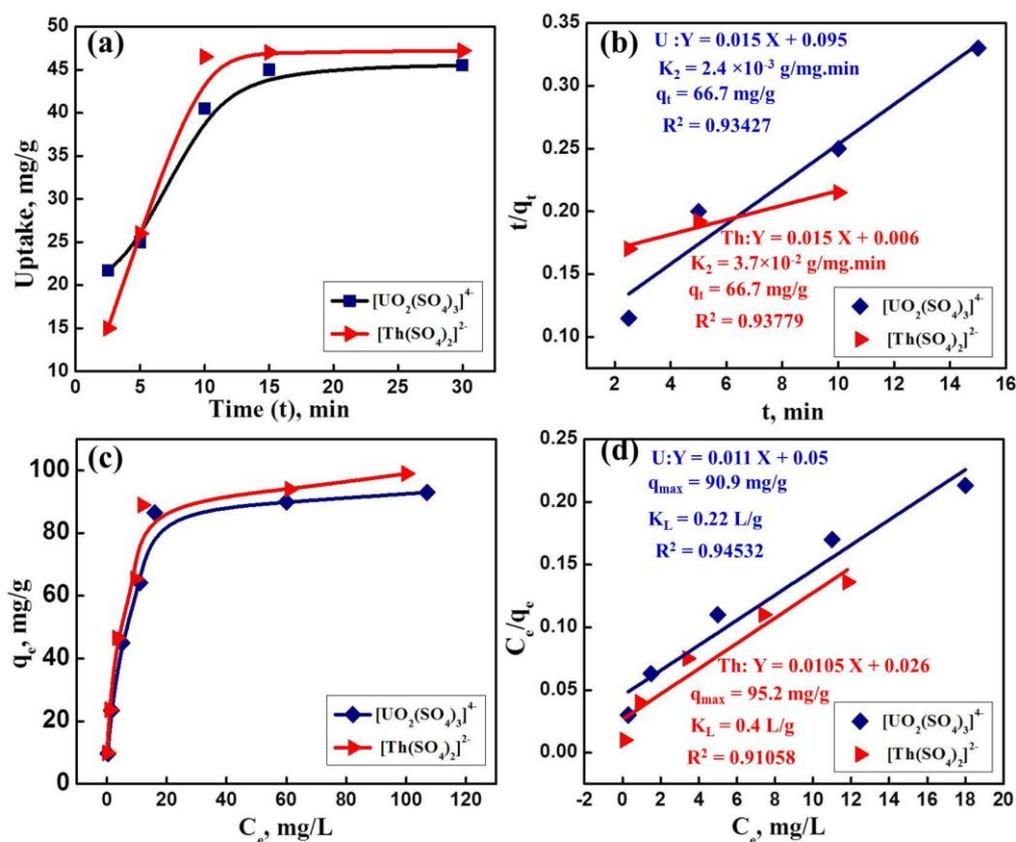


Figure (4): (a) Effect of contact time on U and Th adsorption by Alumina-ADTZ from individual ion solution, (b) the pseudo-second-order plot at the optimal adsorption conditions. (c) Adsorption isotherm of the adsorption of U and Th ions on Alumina-ADTZ from a single ion solution, and (d) Langmuir scheme of U and Th uptake by Alumina-ADTZ at the optimum conditions.

Table (1): Comparison of the adsorption capacities of uranium and thorium onto various adsorbents

Carrier	Ligand	Uptake, mg/g		Ref.
		U(VI)	Th(IV)	
Aluminosilica	2-Amino-1,3,4-thiadiazole	83.30	---	[1]
Silica	Tetraethylene-pentamine	112.00	96.00	[2,4]
XAD	Carminic acid	194.05	194.96	[30]
Graphene aerogel	N,N,N',N'-tetraoctyldiglycolamide	---	66.8	[31]
Activated carbon	Polyethylenimine	115.31	---	[32]
SBA-15	Thenoyltrifluoroacetone	---	39.8	[33]
Chitosan	Triethylene-tetramine	---	133.3	[34]
Silica	Humic acid	31.3	28	[35]
SBA-15 silica	Ethylenediaminepropylesalicylaldimine	105.3	81	[36]
Silica	3-aminopropyl trimethoxysilane	268.94	---	[37]
Silica	Sulfasalazine	273.7	---	[38]
Alumina	2-Amino-1-thia-3,4-diazole	90.9	95.2	[This work]

Real applicability

Abu Rasheid locality is considered one of the promising areas for containing various mineralizations of such important elements such as rare earth elements, uranium and thorium. The location of Abu Rasheid is about 50 km away from Marsa Alam and located southeast of Egypt between the longitudes 34 and 46'00 "34-46'35" E and the latitudes 24°37'16 " - 24°38 '00 'N, [28]. A leaching experiment was carried out to about 0.5 kg of a representative sample obtained from Abu Rusheid locality applying the optimum leaching conditions applied by Afify *et al.*, (2018) [29], with some modification to prepare the leach liquor for studying the ability of the concerned material in the extraction separation of uranium and thorium. The applied optimum leaching conditions are 100 g/L H₂SO₄ acid with a solid/liquid ratio of 1/5 for 2 h agitation time at 90 °C leaching temperature with -200 mesh grain size. The leaching system is then filtered off after cooling and the obtained leach liquor has a concentration of uranium and thorium of 570 and 685 ppm respectively and the concentrations of other impurities present with uranium and thorium in the leach liquor are given in Table (2). The obtained leach liquor pH is adjusted at 1 using ammonia solution, and applied the thorium adsorption conditions of 10 min. contact time at room temperature then the pH raised to 2 and contact time to 15 min at room temperature also to remove

uranium with solid/liquid ratio of 10. The obtained data revealed that the adsorption efficiencies of thorium and uranium are 80 and 85% respectively, and the separation of the two concerned metal ions achieved sequentially. The loaded thorium and uranium are then eluted applying the elution conditions used by Iyer *et al.*, (1977) [29] that thorium is eluted firstly using 6 M HCl then uranium is eluted by 2 M HNO₃. Finally, this study proved that for the complete separation of U (VI) and Th (IV) from sulfuric acid of Abu Rusheid leach liquor, this needs about 3 stages of sequential separation using alumina-ATDZ material.

Conclusions

Alumina in the worm-like mesoporous architecture was used as stage substrate to produce an economically inexpensive anion exchanger material that is effective and useful in selective extraction of Th(SO₄)₂²⁻ and UO(SO₄)₂²⁻ from its solutions. The design-made meso-adsorbent, through the direct immobilization of 2-Amino-1-thia-3,4-diazole ligand onto worm like mesoporous carriers, enabled the creation of selective extraction of thorium and uranium from real leach liquor under specific pH values. This study has demonstrated the ease of applying this technology on a large scale through the promising results achieved Th/U separation.

Table (2): chemical composition of Abu Rusheid leach liquor

Metal Conc., (ppm)	Abu Rusheid leach liquor	After Th adsorption	After U adsorption
U	570	475	72
Th	685	136	105
Fe	789.3	701	586
Ca	505.8	504	414
Co	7.8	6	2.8
Cu	380	375	357
Ni	19.4	19.4	19.4
Zn	425.2	423	423
Mo	28	26	18
Cd	2	2	2
As	125	124	120
Pb	7.2	7.2	6.5
Mg	47.6	44	35
Cr	7.3	5	3.3

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