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Insight on Uranium Recovery Valorization From El Sela Highly Altered Granitic Rocks, South Eastern Desert, Egypt

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Abstract

One of the more difficult problems affecting leaching process is the presence of clayey materials. The latter act as natural adsorbent for dissolved uranium (U) from one hand, and a selling surface which complicate solid liquid separation from the other hand. The materials that are clay-like were created as a result of substantial weathering of the pre-formed granitic rocks. This is the case in the kaolinitized two mica mineralized granite of Gabal (G.) El Sela area, which is situated in the extreme southeastern part of Egypt. The present work is oriented towards solving the problems of low uranium leaching efficiency as well as poor filtration process. Agitation leaching process using H_2SO_4 was first applied upon mineralized raw sample assaying 850 ppm of U. Different leaching parameters include acid concentration, solid/liquid ratio, agitation time and temperature as well as the concentration of added NaCl were studied. About 89% of U content was dissolved using 15% H_2SO_4 at 90ºC for 2h in the presence of 0.25M of NaCl the purpose was to facilitate the permeability of the pulp. The experimental data were interpreted with a shrinking core model with diffusion control through a porous product layer for El Sela ore material. The leaching process follows the kinetic model: $1-3 (1-X)^{2/3} + 2 (1-X) = k_1 t$ with an apparent activation energy of 19.49 kJ/mole.

Key words: Leaching process, valorization, uranium, El Sela, South Eastern Desert.

I. Introduction

To the utmost a recent discovery of U mineralization was made in the Halaib environ southeastern part of Egypt in G. El Sela [1-3]. This discovery increases the region's economic significance because it was known for producing Mn-oxide ore from G. Elba and Mn-W from G. Qash Amir. [4, 5]. The studied area of G. El Sela (560 m. a. s. l.) at Halaib environ, which spans a region of around 20 km west of Abu Ramad City, about 128 km². It is approximately assured by longitudes 36º 8` - 36º 17` E and latitudes 22º 13` - 23º 20` N [6]. Geological and mineralogical studies of G. El Sela two mica granite confirmed the prevalence of the secondary U minerals besides the primary ones [7-11]. A good source of U mineralization and a significant prospect for U mining is the northern half of G. El Sela. In addition to the other radio element-bearing minerals such xenotime, monazite, and zircon, the principal radioactive minerals are confirmed to be pitchblende, uranophane, and uranothorite. The present study focuses upon investigating the detailed leaching process of U from this important ore material.

In fact, the recovery of U from their ores requires applying some hydrometallurgical processes. The acidic and alkaline leaching methods are most common used for U leaching from its ores; however, acid leaching is extra broadly used than the alkaline. The choice of the suitable leaching method and agent type is mainly depending on the ore's chemical and mineralogical composition of ore materials as they are considered as pre-requisites for the realization of successful processing and recovery of the present metal values [12-18]. In this context, the first trial to recover about 99% of U content from G. El Sela granitic rocks was done by **Abu Khoziem [19]** through applying 300 g/L H_2SO_4 for 4 h at 100˚C and S/L ratio of 1/2. Also **Khawassek et al., 2015 [20]** achieved 91.5 % U dissolution efficiency for El Sela ore using 1.0M H_2SO_4 and L/S mass ratio, ml/g of 3 at 40°C with 400 rpm and 4 h leaching time.

It is worthy to mention herein that, pelletizing is the most popular method for reducing the size of numerous thermoplastic materials, including unprocessed ores and blended compounds. Also, pelletizing processes (known as agglomeration)

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involves assembling or clumping small solid particles to create objects with larger dimensions, such as spheres, bricks, or even cylindrical pellets. [21, 22]. In this process additional materials or mixture are included into the ore to achieve the demands of the finished pellets and to adjust the chemical composition and the metallurgic properties within the pellets. The goal of creating raw ore pellets, sometimes referred to as pelletizing, is to produce pellets with a suitable range of sizes and high-useful mechanical qualities under the stresses of transference, transport, and usage excellent physical and metallurgical properties of ore pellets [23,24].

The current work focused on studying mineralogical and leaching characteristics of the representative sample from G. El Sela kaolinitized two mica granites. The processing of the ore material under consideration will be presented in detail through applying H_2SO_4 acid agitation to optimized leaching conditions. The present work represents the first trial to enhance the permeability and leaching efficiency via applying pelletization process together with applying percolation leaching techniques over pelletized and non-pelletized (raw) samples. It will be noticed that, NaCl enhances the dissolving efficiency of U by increasing the porosity and permeability.

2. Experimental work
2.1. Materials and Methods
The representative sample was collected from highly altered granitic rock (kaolinitized rock) assays about 0.085% U. The raw material was firstly analyzed chemically to determine its major and minor constituents. Followed by mineralogical studies in order to determine its mineralogical composition.

The pelletizing process comprises the raw materials are mixed, formed into pellets, and then baked at a high temperature to transform the soft raw pellets into hard spheres. The raw material is formed into a ball and burned in a kiln or on a moving grate to fuse the particles together into a solid sphere. [25]. Pelletization process is the primary consumer of binders which is usually water and organic or lingo sulphonate chemical agents), for the production of high-quality pellets at a fair price, choosing the right binder type and dosage is crucial.

2.1.1. Chemical Characterization
The chemical composition of the working sample was determined for major and trace elements using Axios advanced WDXRF-PAN analytical XRF (Netherlands). In addition, U was determined during the leaching and kinetic studies by an oxidimetric titration approach using sodium salt of diphenyl amine-4-sulfonic acid as an indicator against ammonium meta-vanadate [26]. A Shimadzu UV-160 visible-ultraviolet spectrometer was used to measure the total REE quantitatively at 654 nm with 0.05% arsenazo III as Ce reference [27]. Semi-quantitative analysis was carried out using an X-ray analyzer (EDX unit system) and scanning electron microscope (SEM-EXL 30 Philips type) of the picked mineral grains.

2.1.2. Mineralogical Characterization
With respect to mineralogical studies, the identification of minerals was done through applying a number of physical treatment procedures. The samples were ground firstly to 0.5mm to liberate its heavy minerals. Then, the ground part was washed with H_2O for eliminating slimes. After drying, the sample was then sieved, the size intervals of -0.5 to +0.063mm. Bromoform (sp.gr. 2.8) was used in a heavy liquid separation technique to extract the heavy fraction. Under the binocular microscope, the identical-colored mineral grains in the heavy fraction were picked up one by one. EDX analysis was used to study and identify the separated mineral grains.

2.2. Leaching Procedures
Two atmospheric leaching processes (agitation, percolation) were applied upon the mineralized raw material and pelletized samples from G. El Sela area.

2.2.1. H_2SO_4 Acid Agitation Leaching Upon Raw Material
For this purpose, by combining a weight of the ground sample (10g), many experiments were carried out through different concentration of H_2SO_4 acid as leachant with various solid/liquid (S/L) ratios over various time scales and temperatures, and adding different NaCl concentration. In this process, a heated plate with a magnetic stirring device was used. At the end of leaching experiments, the resulting slurry was filtered after which it was brought up to volume and rinsed with distilled water. In order to determine the leaching efficiency in each stream of agitation leaching, U was estimated as the following equation:

$$\text{Leaching efficiency (\%)} = \frac{\text{Metal content in the leach liquor} \times 100}{\text{Original metal content in the ore}}$$

2.2.2. H_2SO_4 acid Percolation Leaching Upon Pelletized Material
This was conducted by applying the optimum H_2SO_4 leaching condition upon the pelletized sample. On the other hand, in a trial for enhancement of the U leaching efficiency, percolation technique was also used

2.3. Kinetics of H_2SO_4 Agitation Leaching Process
The kinetic analysis was tested according to the shrinking core model (SCM). Accordingly, the solid reactant is initially surrounded by a fluid film that allows mass transfer between the solid particle and the majority of the fluid.

2.4. Optimization of Extraction Procedures

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A sample weight of 500 gm was employed to prepare the pregnant sulfate leach liquid necessary for the U extraction process. The anion exchange resin D263B in its chloride form was used. Accordingly, batch studies were carried out utilizing varying pH values and stirring times in volume ratios of wet settled resin (wsr) and leach liquid (R/L). Due to high concentration of SO_4^{2-} anions in leach liquor and its competition effect, it is convent to adding different amounts of CaO. The extraction efficiency was estimated after the raffinate solutions were examined for U. The loaded resin underwent elution procedure to renew the loaded uranium; the eluate solution was then subsequently treated with H_2O_2 for U precipitation.

3. Results and Discussion
3.1. Characterization of the Studied Sample
In order to determine the suitable leaching method for the working ore material under consideration, it was decided to study its chemical and mineralogical composition.

3.1.1. Chemical Composition
From the attained chemical results of the studied material given in Table (1), it is clearly evident that G. El Sela two mica granite is mainly composed of SiO_2 (70.09%) besides Al_2O_3 (14.6%) and total iron oxides (3.76 %). Also, it is significant to refer that, the main alteration process acting upon the studied sample namely hematization and kaolinitization as indicated from the relatively high Al_2O_3 and Fe_2O_3 contents. Also, the presence of high Na_2O (3.42%) and K_2O (2.97%) contents support the presence of relatively high clay material. Actually, these oxides reflect the presence of alumino-silicate minerals including two micas, feldspars and clays, free silica besides low carbonate gangue minerals. The latter may be in favour of using an acidic leaching technique.

In terms of the significant metal values in the studied sample, it was established that U was amounted to 0.085 %, which reflects the relatively high-grade type of mineralization.

Table (1): Chemical composition of the study G. El Sela raw materials.

Major oxides (%)	Wt. (%)	Trace elements	(ppm)
SiO_2	70.09	U	850
Al_2O_3	14.6	REE	332
TiO_2	0.41	Th	16
$Fe_2O_3^{total}$	3.76	Mn	36
CaO	1.22	V	48
MgO	0.46	Zn	79
Na_2O	3.42	Pb	139
K_2O	2.97	Zr	177
P_2O_5	0.31		
L.O.I	2.01		
Total	99.56		

3.1. 2. Mineralogical Characteristics of the Studied Sample
The heavy liquid portions of the economic minerals have an average concentration of approximately 2.3% (w/w) with respect to the bulk sample. The achieved data of EDX analyses of the picked grains indicated the existence of notable uranium minerals associated with non-radioactive ones. Consequently, the considered sample refer to the presence of the following mineral associations:

Autunite [Ca $(UO_2)_2(PO_4)_2$. 10-12 H_2O] and uranophane (Ca (UO_2) $(SiO_3)_2(OH).5H_2O$) are the main secondary uranium minerals recorded in G. El Sela two mica granite sample. Autunite existing in profit amount than uranophane. The latter was mainly associated with apatite. Also, EDX analysis data refer to the association of autunite mineral associated as adsorbed over Al-silicate minerals (clay minerals) (Fig. 1) or as covered the all silicate grains (Fig.2).
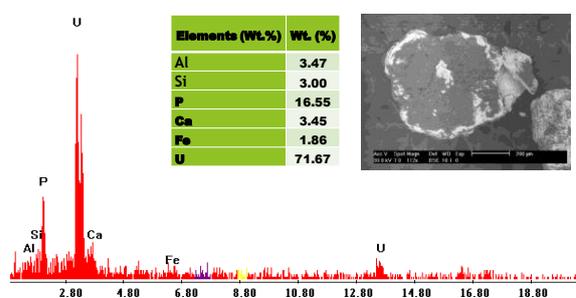
Fig. (1): EDX data of autunite (bright) mineral, covered aluminum- silicate minerals
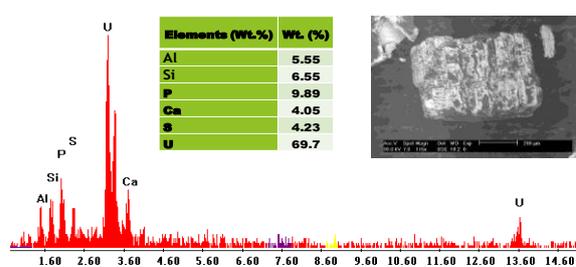
Fig. (2): EDX data for autunite mineral completely covered aluminum- silicate minerals

On the other hand, the studied sample refers to the presence of some non-radioactive minerals associated with the radioactive ones and considered in some heavy fractions as major constituent. These include kaolinite, phlogopite, biotite, hematite and goethite.
Finally, from the previous mineralogical study, the principal radioactive minerals of the studied sample were represented by autunite and uranophane. However, these minerals are found associated with clayey material in the studied sample. The latter's may

cause some of the difficulties during hydrometallurgy test work.

3. 2. Results of H₂SO₄ Acid Agitation Leaching Process

Since the chemical and mineralogical characteristics of the considered sample confirmed the application of H_2SO_4 acid leaching process. The leaching experiments were conducted for studying the optimum condition as following:

3. 2. 1. Effect of the H₂SO₄ Acid Concentration

Many leaching experiments were conducted at different concentrations of H_2SO_4 acid ranging from 5 to 20% were performed at room temperature (30±5°C), stirring time for 2h and S/L ratios of 1/2. Data in Fig. (3) showed that, U leaching efficiency gradually improved from 38.3 to 60.8% as the acid Conc. increased from 5 to 15%. However, additional increase of acid concentration up to 20% showed decreasing in U leaching efficiency. This might be because sulfate complexing processes are kinetically preferred over uranium hydrolysis due to an overabundance of sulfate ions [28].
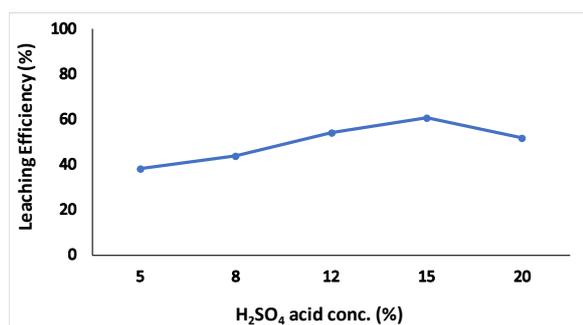
Fig. (3): Effect of H₂SO₄ acid concentration upon U leaching efficiency

3. 2. 2. Effect of Solid/Liquid Ratio

Several S/L ratios ranging from 1/2 to 1/5 were examined to clear the effect of S/L ratio over U leaching efficiency using 15% of H_2SO_4 acid concentration and stirring for 2h at ambient temperature. The achieved data Fig. (4) illustrated that U leaching efficiency for the studied sample increased by increasing S/L ratio from 1/2 up to 1/5.
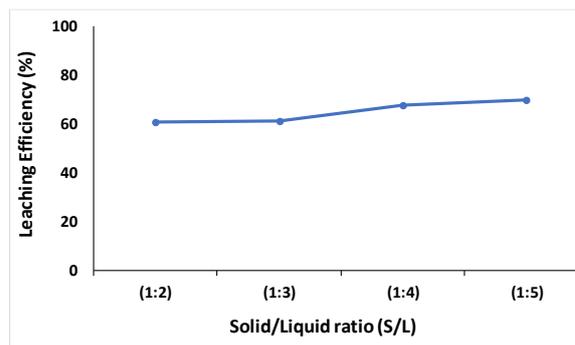
Fig. (4): Effect of Solid/Liquid ratio upon U leaching efficiency

3. 2. 3. Effect of Leaching Time

This factor was considered at the acquired leaching conditions of 15% H_2SO_4 acid conc., S/L ratio 1/2 at room temperature and leaching time periods from 1 to 4h. The corresponding leaching efficiencies in Fig. (5) showed that, the leaching time of 2h is very suitable to dissolve about 61% of U.
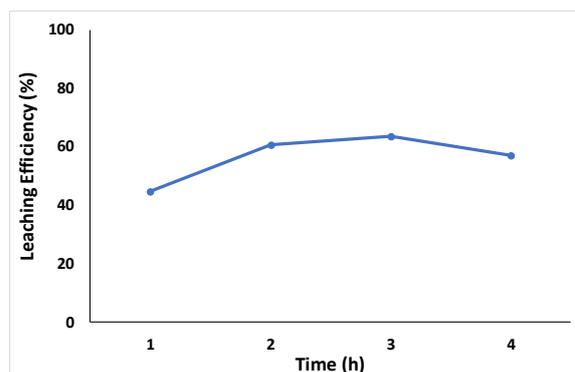
Fig. (5): Effect of time leaching upon U leaching efficiency

3. 2. 4. Effect of Leaching Temperature

The striking impact of varying leaching temperatures from room temperature (35 to 100°C) upon U leaching efficiency was studied and shown in Fig. (6). The other leaching circumstance were fixed at acid concentration of 15%, 1/2 of S/L ratio and 2h leaching time. Data proved that the leaching efficiency of U was improved from 60.8% to 81.9% at 90ºC.
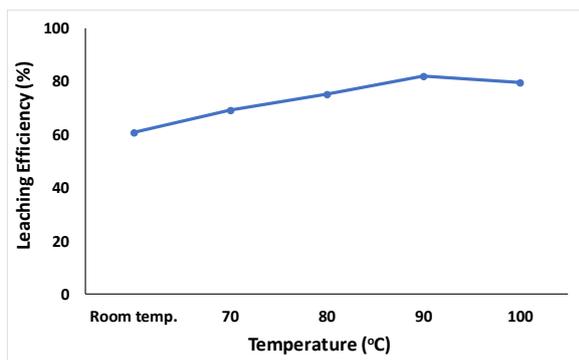
Fig. (6): Effect of temperature upon U leaching efficiency

From the forgoing H_2SO_4 acid atmospheric agitation leaching, the obtained optimum leaching conditions were 15 % H_2SO_4 concentration, S/L ratio of 1/2 at 2h as leaching time and 90 ºC as leaching temperature. These results indicate low U leaching efficiency (81.9%) and difficulty of filtration process. This may be attributed to the high amount of clay minerals in the studied materials which require applying pelletization technique over grains in a trial to solve these problems.

3.3. Result of H_2SO_4 Acid Leaching of the Studied Pelletized Samples

Pelletized sample also subjected to percolation leaching process in order to improve the leaching efficiency of U from one hand and solving the difficulty of filtration process on the other hand. In fact, the present leaching study is considered as the initial contribution of hydrometallurgy to the recovery of U from the pelletized samples of El Sela two mica granite.

Another trial for enhancing the leaching efficiency of uranium from the study El Sella pelletized sample was done by applying percolation leaching process. In this process, the column was first packed with pelletized sample (20g) followed by passing H_2SO_4 in concentration 15% was then passed through the column for leaching of uranium. Unfortunately, it is noticed that passing of leachant through the ore material is very slowly and blocked the column together with changing the spherical shape of sample into mud shape (Fig.7). This may be due to bad pelletization.

Figure (7): Percolation leaching upon pelletized sample using glass column

3. 4. Result of Adding NaCl

Due to the bad results of U leaching from the study ore material when using either H_2SO_4 acid type leachat or percolation leaching upon the original ore sample and /or pelletized one. Different NaCl concentrations ranged from 0.25-1.25 M were used to consider the effect of different concentration over the leaching efficiencies of the U element. The other leaching conditions were fixed at 15% H_2SO_4 and 90°C for 2h with S/L ratio of 1/2. From the attainedresults (Fig. 8), it was found that by adding 0.25 M NaCl to the leeching process, the leaching efficiencies of U reach to 89.7% as well as the filtration process was significantly improved as distinguished during the experimental work. While more increasing in NaCl concentration indicated decreasing upon its leachability to 82.7%.
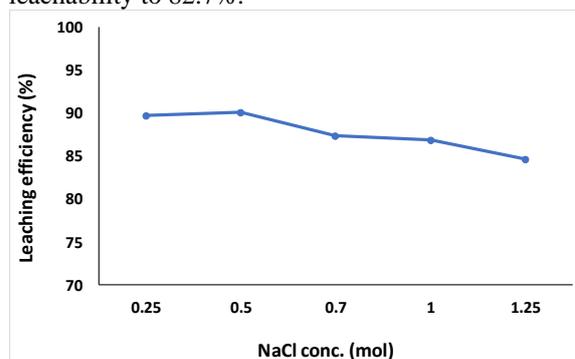
Fig. (8): Effect of NaCl concentration upon U leaching efficiency

From the foregoing study, it might be supposed that this method is more effective and increase U leaching efficiency (89.7%) from the studied ore material at the optimum leaching conditions as 15% H_2SO_4 and adding 0.25M NaCl with a 1/2 solid/liquid ratio at 2h and 90ºC.

3.5. Application of Leaching Kinetics of Uranium
3.5.1. Effect of Temperature

The dissolution of mineral from Sella uranium ore takes place through the following stages:

1. Diffusion of reactant through the diffusion layer
2. Adsorption of the reactant on the solid
3. Chemical reaction between the reactant and the solid
4. Desorption of the product from the solid
5. Diffusion of the product through the diffusion layer. Any of these may be rate controlling depending on its relative speed to the others. Understanding the mechanism of a leaching system is the main objective of this study. In order to establish the kinetic parameters and rate-controlling step for the dissolution of G. El Sela uranium ore using sulfuric acid, the experimental data can be analyzed according to the heterogeneous reaction models. According to the model, the reaction between a fluid and a solid may be written as:

$$F \text{ (fluid)} + S \text{ (solid)} \rightarrow Products$$

The rate of the ore dissolution was analyzed with the shrinking core models based on the assumption that the concentrate is a homogenous spherical solid phase. The shrinking core model considers that the leaching process is controlled either by the diffusion of reactant through the solution boundary layer, or through a solid product layer, or by rate of the surface chemical reaction. The simplified equations of the shrinking core model when either surface or the diffusion chemical reactions are the slowest step can be expressed as follows, respectively (**Habashi, 1980**)

$$X \quad k_1 t \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \text{ (1)}$$

$$1 - 3(1-X)^{2/3} + 2(1-X) \quad k_2 t \dots\dots\dots\dots\dots \text{(2)}$$

$$1 - (1 - X)^{1/3} = k_3 t \dots\dots\dots\dots\dots\dots\dots\dots \text{ (3)}$$

Where k_1, k_2 and k_3 are the apparent reaction rate constants (min^{-1}) for each case respectively and t is the leaching time (min) and X is the fraction reacted expressed as

$$X = \text{extraction/100 \%} \dots\dots\dots\dots\dots\dots\dots\dots \text{(4)}$$

Figure (9) displays how the reaction temperature affects the rate of uranium leaching in the range of 70°C to 100°C with 75μm particles, 15% H_2SO_4 and a solid/liquid ratio of 1/2. The findings indicate that when the temperature rises, the rate at which uranium leaches increases. The conversion fraction X of U increased from roughly 0.84 to 0.97, indicating that the

conversion fraction X of U rises as the temperature rises. The observed results demonstrate that film diffusion cannot adequately characterize the reaction. As shown in Figures (10 and 11), the other two shrinking core models might be examined at various temperatures. It is evident from the graphs that only Figure (10) yielded a completely straight line with an average correlation of 0.99. Hence, equation 2 satisfactorily explains the experimental findings, and this may be infer that diffusion through the product's ash layer regulates the dissolution of U from El Sela ore material. The computed slopes of each line in Figure (12), which show the apparent reaction rate constants K, are the result.
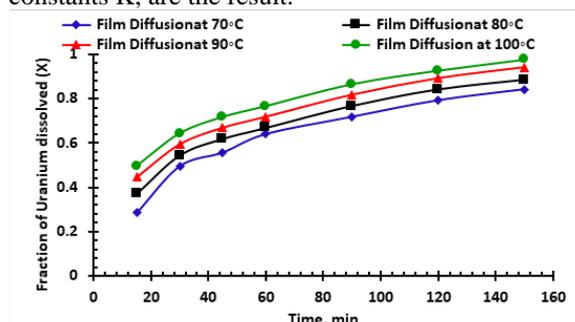
Fig. (9). Impact of various temperatures on the effectiveness of uranium leaching (ore particle size 74μm, 15% H_2SO_4, 1:2 solid/liquid at stirring rate 600 rpm)

The apparent activation energy was determined from the Arrhenius equation [30, 31]:

$$\ln k = \ln A - Ea/RT \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \text{(5)}$$

Ea is the apparent activation energy, k is the reaction rate constant, A is the frequency factor, and R is the ideal gas constant. Figure (12) provides the data for the four temperatures plotted, and the regression analysis for these plots likewise demonstrates the significance of the linear relationship. It was found that the apparent activation energy (Ea) was 19.94 kJ/mol.

It is worthy to mention that, for temperatures of 70°C, 80°C, 90°C, and 100°C, the computed activation energy implies a diffusion-controlled process for El Sela low grade uranium ore material. Table (2) summarizes the various apparent rate constants k_2 and k_3 at various temperatures and the related correlation coefficient rate.

Table (2) The correlation between the apparent rate constants, k_2, and k_3, min^{-1}, at various temperature

Temp., ^{o}C	Apparent k_2, min^{-1}	R^2	Apparent k_3, min^{-1}	R^2
70	0.0029	0.993	0.0028	0.815
80	0.0034	0.992	0.0030	0.790
90	0.0042	0.994	0.0035	0.813
100	0.0051	0.992	0.0041	0.838

ranges
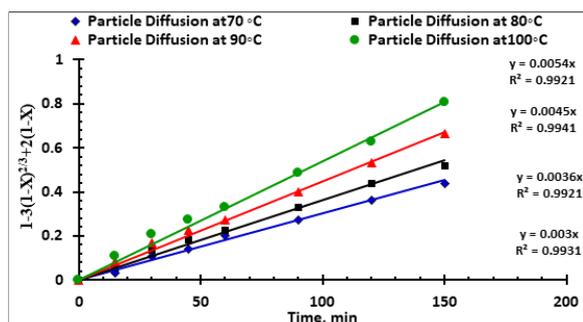
Fig. (10): Affiliation between $1-3 (1-X)^{2/3} + 2 (1-X)$ and leaching time for uranium at several temperatures (2.5 M H_2SO_4, ore particle size 74μm, solid/liquid of 1/2, at stirring rate 600 rpm)

Fig. (10): Affiliation between $1- (1-X)^{1/3}$ and leaching time for uranium at several temperatures (ore particle size 74μm, 15% M H_2SO_4, 1:2 solid/liquid, at stirring rate 600 rpm)

Fig. (12): Arrhenius plot for uranium leaching (ore particle size 74 μm, 2.5 M H_2SO_4, 1:2 solid/liquid, at stirring rate 600 rpm).

3.6. Results of Uranium Extraction

By applying the above-mentioned optimal leaching conditions upon 500g of El Sela highly altered granitic rocks resulted 1.250L of sulfate solution of pH 0.3 and assaying 0.34g/L of U as given in table (3). The extraction procedure of U from the sulfate solution through equilibrium batch technique includes two main steps namely; loading and elution.

Table (3): Chemical composition of the prepared carbonate leach liquor at (pH=0.3)

Constituents	Conc. (g/L)
U	0.34
REE	0.058
Cl	2.5
Fe	2.7
Na⁻	2.4
SO^{-4}	120

3.6.1. Optimization of Uranium Loading Process

Several experiments were performed using the D263B anion exchange to determine the optimum conditions of the adsorption process of U from the sulfate solution. These factors include; pH values, stirring time and CaO/ liquid volume ratios (CaO/L wt/v ratio).

3.6.1.1. Effect of pH Value

The influence of various solution pH values upon the loading efficiency of anion exchange resin D263 in its chloride form using R/L ratio of 2ml of (w.s.r.)/100 (theoretical optimum ratio) and stirring time of 30 min was considered at pH values ranging from 1.6 up to 2. Results in Fig. (13a) showed that the loading efficiency of U reached its maximum value (30.7%) and 85.9 for Fe at pH 2. However, pH 1.8 was selected as optimum (U reach 32.2%). to decrease the amount of Fe up take upon the resin sites (70.1%).
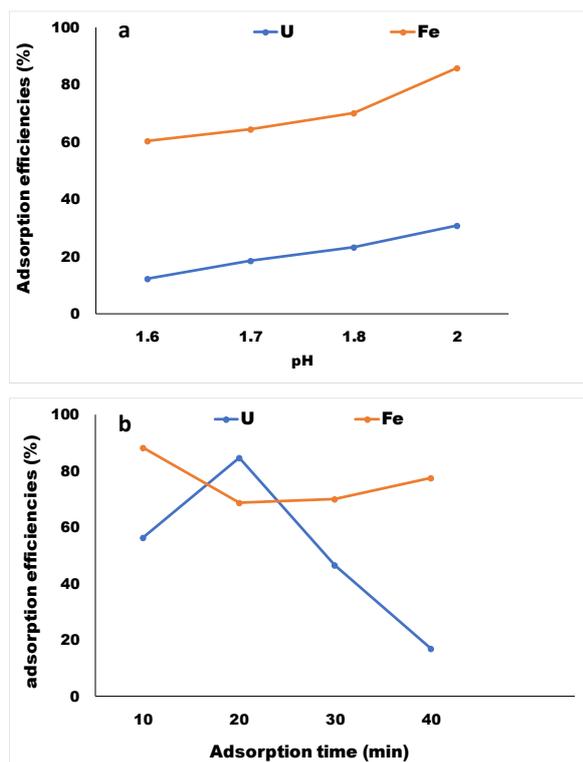
Figure (13): (a) Effect of pH (b) Effect of stirring time upon U adsorption efficiencies

3.6.1.2 Effect of Adding CaO (w/mL) ratios:

The presence of interfering anions, particularly HSO_4^-, SO_4^{2-}, and $H_2PO_4^-$, as well as the cation of Fe^{3+}, which compete with U anionic complexes on the resin sites and reduce its loading capacity. **Amer et al., 2017** [14]. In this context, the lower extraction efficiency of U (32.2%) emphasized the presence of high concentration of interfering SO_4^{2-} anions (120 g/L). These relatively high concentrations of SO_4^{2-} anions would make the U loading process more difficult when

using D216 anion-exchange resin [32-34, 14]. Consequently, it was very important to reduce the concentration of sulfate anions to solve this difficult and increasing U loading efficiency. For this tenacity, the pregnant sulfate solution was treated with milky solution of CaO, Table (4). Where the excess SO_4^{2-} anions were already precipitated as $CaSO_4$ cake according to the following equation:

$$CaO + SO_4^{2-} (aq) + 4\ H_2O\ (l) \rightarrow CaSO_4.2H_2O\ (s)$$
$$cake + 2H_2O \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..\ldots(6)$$
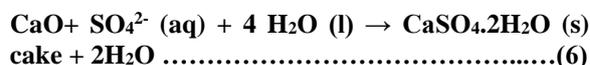
The addition of solid CaO also increased the pH value of the pregnant solution via decreasing the concentration of free SO_4^{2-} to be suitable for U loading by the anion exchange resin as represented by Table (4).

The pregnant sulfate solution was treated by adding 50 g of CaO solid/L in order to precipitate $CaSO_4.2H_2O$ and lower the interfering SO_4^{2-} anions' concentration to an acceptable level, (30.8 g/L). A result which achieved maximum value of U uptake (82.4%).

3. 3.1.4. Effect of Stirring Time

A volume of 100 mL leach solution was stirring with 2mL (w.s.r) resin (R/L ratio 2/100) at pH value 1.8 and 5g CaO /100mL for different time periods; 10, 20, 30 and 40 min. The achieved data in figure (13b) showing that U adsorption efficiency increase from 82.4% to 90.8% by increasing the stirring time from 10 to 20 min. while more increasing the stirring time up to 40 min the loading efficiency of U decreased to 75.9 %. On the other hand, at 20 min the Fe adsorption efficiencies reach to 68.8% and showed slightly increasing with time.

3.6.2. Elution Process and Uranium Precipitation

Elution is a method used to regenerate loaded resin as well as to produce an eluate solution high in U that may be used to make the desired U product. The resin bed was quickly cleaned with a sufficient amount of distilled water to remove any impurities once it had been fully saturated with U, and then directed to the regeneration process by using 100 ml of a 10% $NaHCO_3$ solution while stirring for 40 minutes [17]. The U eluated from the loaded resin attended about 92.1%.

Table (4): Effect of addition of solid CaO to sulfate solution

Added CaO, g/ L sulfate solution	SO_4^{2-} Conc., g/L	Cl^- Conc., g/L	pH value	Lost U, mg/L
20	88.1	2.4	0.6	0
30	70.9	2.1	1.1	0
40	52.5	1.9	1.5	0
50	30.8	1.8	1.8	10
60	12.1	1.7	2.2	65

Finally, the attained U rich eluate solution of pH 8.1 and assaying (3.2 g/L) was reacted with 3% H_2SO_4 solution to modify pH to 3.0 and treated with H_2O_2 solution for U precipitation. Around 99% of U was precipitated as $UO_4.xH_2O$ at pH 2 with stirring time of 4h at room temperature. After filtration and washing, the obtained precipitated uranyl peroxide cake was dried at 120°C and was identified by using EDX analysis technique as shown in Fig (14) while the purity was already estimated as 89.64% in association with 8.2% Fe 0.2% S and Na.
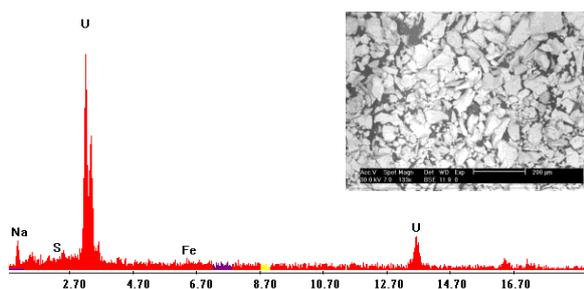
Fig. (14): EDX analysis of UO4.XH2O.

Conclusions

The obtained mineralogical results refer to the presence of autunite and uranophane (U minerals) beside the clay minerals, which are surrounding the uranium minerals with different amount and rations. On the other hand, leaching process upon the pelletized sample did not show any progress upon the permeability and leaching process. The adding of NaCl during leaching process has been improved the permeability with increasing the U leaching efficiency from 81.9 to 89.7%. A kinetic study of the uranium leaching of G. El Sela mineralized two mica granite sample in sulfuric acid media has been investigated. The dissolution of uranium in sulfuric acid was discovered to be a diffusion-controlled process, and it is regulated by the shrinking core concept. Value of 19.94 kJmol^{-1} was obtained for the activation energy at the optimum conditions. The adding of CaO to the leach liquor was found to increase the uptake of U upon the resin sides due to the reduction of the amount of SO_4^{-2} which compete U upon the resin sites. Finally,

uranium peroxide cake was prepared from the G. El Sela granitic rocks with over all recovery of 65.6%.

Conflict of Interest

There were no potential conflicts of interest revealed by the authors.

Disclosure Statement

Authors confirm that there are no relevant financial or non-financial competing interests to report

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