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# Extraction of Uranium from the Radioactive Pegmatite Recorded at central Eastern Desert, Egypt

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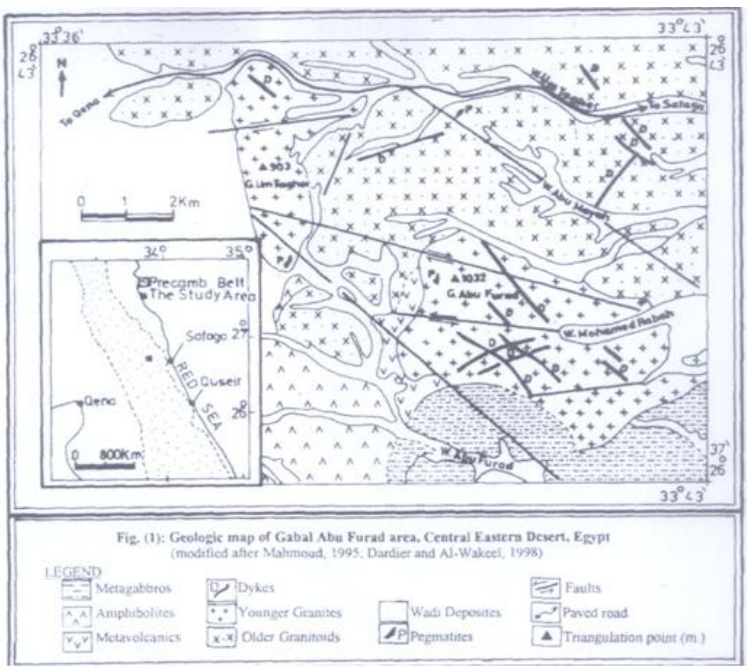
***Abstract:*** *One of the most famous radioactive pegmatite is recorded at Gebel Abu Furad area which is located 40Km west of Safaga City on the Red Sea coast and is bounded by Latitude 26° 37' and 26° 43' N and Longitude 33° 36' and 33° 43' E. The high radioelements in the high uranium pegmatites are mainly attributed to the presence of thorite, uranothorite, zircon, euxenite, carnotite, thorianite, allanite, bastnasite, fluorite and iron oxides.For the importance of this radioactive occurrence, a technological study was done to contribute with the previous mineralogical study. Uranium leaching process concluded that about 97% of uranium existed where (uranium concentration 2020 ppmor 505 mg/kg in the studied sample was leached under the studied optimum conditions; 60 g/L sulfuric acid concentration, 6 hours contact time, at room temperature (25°C), - 60 mesh size and 1/5 solid /liquid ratio. Extraction of uranium was achieved using ion exchange resin technique where 2 g of dry Chinese anionic resin D263B type wetted by 5 ml distilled water and activated by 50 g/L $H_2SO_4$.After loading of uranium, elution was conducted using acidified sodium chloride and its pH was adjusted to 1using 1 M $H_2SO_4$. Finally, precipitation of uranium was performed.Lanthanides recoded in the study sample was precipitated and identified by the ESM.*

***Keywords:*** *Gabal Abu-Furad; uranium; leaching; ion exchange; precipitation.*

## I. Introduction

Gebel Abu Furad area is located 40Km south west of Safaga City on the Red Sea coast and is bounded by Latitude 26° 37' and 26° 43' N and Longitude 33° 36' and 33° 43' E. It is covered by metavolcanic, amphibolites, metagabbros, older and younger graintoids. These lithologic units are dissected by dykes of different composition as well as pegmatitic bodies (Fig. 1). The older granitoids are generally weathered and foliated with gneissose textures. The younger granites intrude the older granitoids with typical intrusive contacts and usually send several offshoots into the surrounding rocks. They are characterized by pinkish colours, massive appearance and absence of foliation. Pegmatites occur as pockets and vein-like bodies and show wide variation in both length and thickness.

Pegmatites are of the simple type and are similar to the younger granitoids, especially in their major mineral constituents.



Concerning radioactive anomalies, **Mahmoud (1995)** recorded four anomalies which are sorted into anomalies in pegmatite (two anomalies), anomaly in felsite and anomaly in alpite. These recorded in the pegmatite justified by possessing the highest radioactivity intensity (maximum 5000 c.p.s.) and by exhibiting visible showing of radioactive minerals. X-ray diffraction analysis revealed the existence of masuyite ($UO_3.2H_2O$) and zircon associated with hematite.

**Dardier and El Wakeel (1998)**, studied the radioactivity at Gabal Abu Furad and Gabal Umm Tagher where the younger granite possesses the highest radioactivity level among the rocks cropping out in the area. U and Th are mainly concentrated in accessory and secondary minerals (monazite and zircon).

The relatively high content of eU and eTh in some samples of the younger granites is attributed to their enrichment in zircon, allanite, sphene, apatite and iron oxides. Zircon is partially metamicted due to high radioelement content.Pegmatites are distinguished into two types; high uranium pegmatites in which the average content of eU is 198 ppm and that of eTh is 290 ppm and low uranium pegmatite (ave.eU=12 ppm and that of eTh= 19 ppm). The high radioelements in the high uranium pegmatites are mainly attributed to presence of thorite, uranothorite, zircon and iron oxides(**El Galy, 2000)**.

**Essam and Ashraf (2009)**, studied the fluid inclusion of radioactive mineralized pegmatites at G. Abu Furad area and stated that change in pH plays the main role in remobilization and precipitation of some rare metals such as U, Th, Nb, Zr, Y and REE in minerals assembly such as euxenite, zircon, carnotite, thorianite, allanite, bastnasite and fluorite.

The above mentioned reference paid a great attention to the study area as one of the promising occurrences of uranium. Therefore, a technological study was contributed with the previous mineralogical study and uranium recovery study was planned. This is always done through leaching and extraction processes.

The general principle for leaching process, is that the active agents present in a solid matter are extracted and dissolved in a liquid (usually, but not always a solvent), either in nature or through an industrial process. In general, leaching is the process in which inorganic, organic contaminants are released from the solid phase into the water phase under the influence of mineral dissolution(**Simpson, 2000**).

Generally, leaching process can be classified into two major methods namely 1- conventional, 2- Non conventional. The conventional method is the agitation technique for both acidic and alkaline leaching, while the non conventional includes: pressure, bacteria, natural, chlorination, fluorination leaching. The natural leaching technique is also subdivided into: heap, insitue and percolation leaching. Bioleaching refers to the conversion of metals into their water soluble forms by microorganism (**Ndlovu, 2008**). According to (**Nagwa H. E., 1988**) each technique has its advantages for certain materials and drawbacks for others. Agitation leaching is by far the most used technique in uranium industry and also considered highly promising.

The acid agitation leaching method is characterized by its low cost, requires short leaching time, give higher extraction efficiency, convenient for subsequent recovery process and effective on the silicious ores.

The main objective of this paper is the study of the optimum conditions for uranium leaching, extraction and precipitation as sodium diuranate crystals.

## II. Materials And Methods

### 1. Reagents and solutions

The used reagents and solutions are as follow: Hydrochloric acid (37%, POCH, Poland). Nitric acid (65 % Merck, Germany). Sulfuric acid (95.97%, Sigma, Germany), oxalic acid, sodium hydroxide (98%, Winlab, U.K.), arsenazo I (pure, Sigm USA). Ferrous sulphate, salfosalysilic acid (pure, Kochlight labs. Ltd., England), diphenylamine-4- sulfonic acid sodium salt and boric acid (99%, Hungary).

### 2. Uranium determination

Uranium was determined in the pregnant leach solution and the crude uranium concentrate using the oxidimetric titration procedure with a standard solution of $NH_4VO_3$ till the appearance of a purplish red color represents the end point**(Davies, W. and Gray, W. 1964)**. Uranium concentration in the working sample solution was calculated according to the following equation

$U\ (g/L) = T.V_1.1000/V$

T: titration intensity of $NH_4VO_3$

$V_1$: consumed $NH_4VO_3$ (ml)

V: volume of sample (100 ml)

Uranium leaching experiments were performed using a three openings flask 250 mil. where 10 g of the ore was subjected to the studied leaching experiments.

Table (1) shows the chemical composition of the studied radioactive pegmatite while Table (2) shows the radioelements concentrations in the high uranium pegmatite.

**Table (1):** Major oxides and trace elements analyses for the studied radioactive pegmatite (El Galy, 2000)

| .Major oxides | Average (wt.%) | Trace Elements (ppm) | Average |
|---|---|---|---|
| $SiO_2$ | 74.45 | Zr | 112 |
| $TiO_2$ | 0.11 | Y | 34 |
| $Al_2O_3$ | 13.47 | Sr | 37 |
| $Fe_2O_3$ | 1.12 | Ba | 38 |
| FeO | 0.29 | Rb | 63 |
| MnO | 0.4 | Nb | 31 |
| MgO | 0.30 | Cu | 32 |
| CaO | 0.84 | Ni | 6 |
| $Na_2O$ | 3.64 | Cr | 11 |
| $K_2O$ | 4.42 | Zn | 26 |
| $P_2O_5$ | 0.98 | Ga | 17 |
| LOI | 0.70 | Pb | 5 |
| Total | 99.51 | S | 4 |
| | | V | 11 |

**Table (2):** Radioelement concentration of the high U pegmatite (in ppm) (El Galy, 2000)

| | **eU** | **eTh** | **Ra** | **K** | **U** |
|---|---|---|---|---|---|
| **High U pegmatite Ave.** | **319**<br>**76.86**<br>---------- | **450.4**<br>**129.42**<br>---------- | **150.44**<br>**45.12**<br>---------- | **3.61**<br>**3.34**<br>---------- | **195**<br>**51**<br>---------- |
| | **198** | **290** | **98** | **3.47** | **123** |

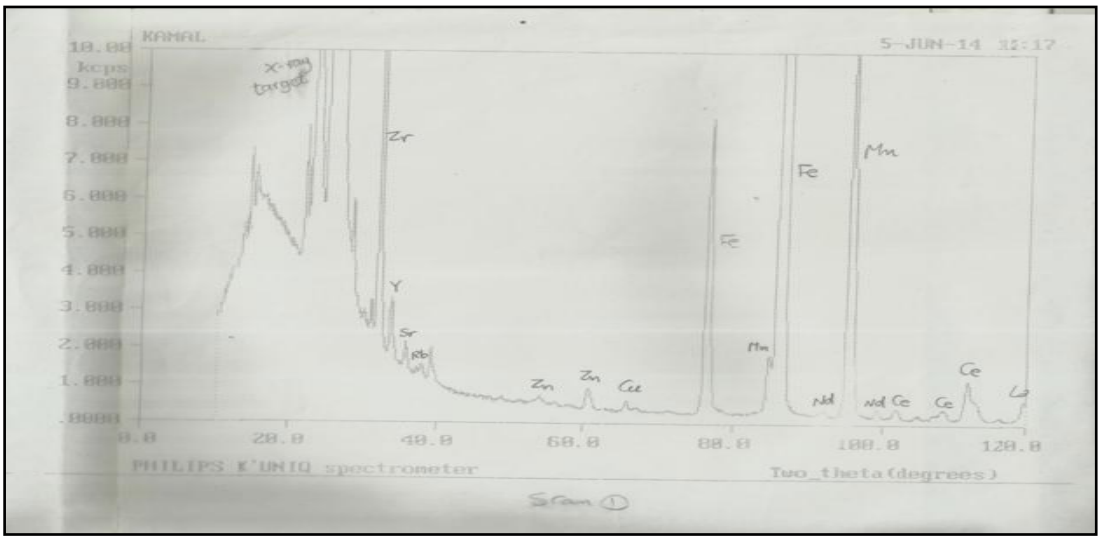
In the present work, the first stage was performed using acid agitation leaching technique where the most effective factors controlling leaching efficiency were studied. The experimental conditions were fixed at acid concentration 40 g/L, 4 hours agitating time, 1/2 solid / liquid ratio at room temperature (25$^{o}$C) and –60 meshgrain size. The studied sample contains originally:

Total Fe= 5.8 wt.% lanthanides = 2.3% and U= 2020(ppm)

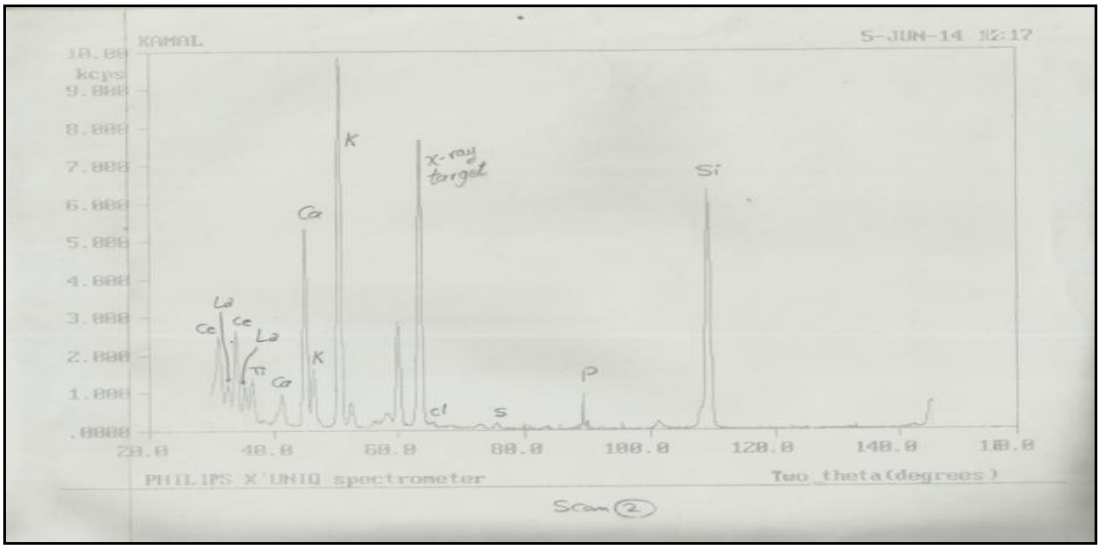
The quantitative XRF analysis and charts scan for the trace elements of the studied sample is shown in Table (3) and Fig. (2).

**Table (3):** XRF trace analysis of the studied radioactive pegmatite sample

| **Element** | **Concentration (ppm)** |
|---|---|
| Cr | 29 |
| Ni | 18 |
| Cu | 27 |
| Zn | 172 |
| Zr | 1822 |
| Rb | 35 |
| Y | 837 |
| Ba | 666 |
| Pb | 28 |
| Ga | 27 |
| V | 222 |
| Nb | 307 |




**Scan (1)**




**Scan (2)**

**Fig. (2):** XRF analysis charts of the studied Abu Furad radioactive pegmatite, Central Eastern Desert, Egypt

## III. Results And Discussion

***1- Effect of acid type***

Different acids were studied such as nitric, hydrochloric, and sulfuric acids. The obtained uranium analysis data revealed that nitric acid (leaching efficiency 75 %) was the most effective leaching agent but as long as sulfuric acid is economic and available and gave considerable uranium leaching efficiency (50 %), it was thus used in the leaching process (Fig. 3).

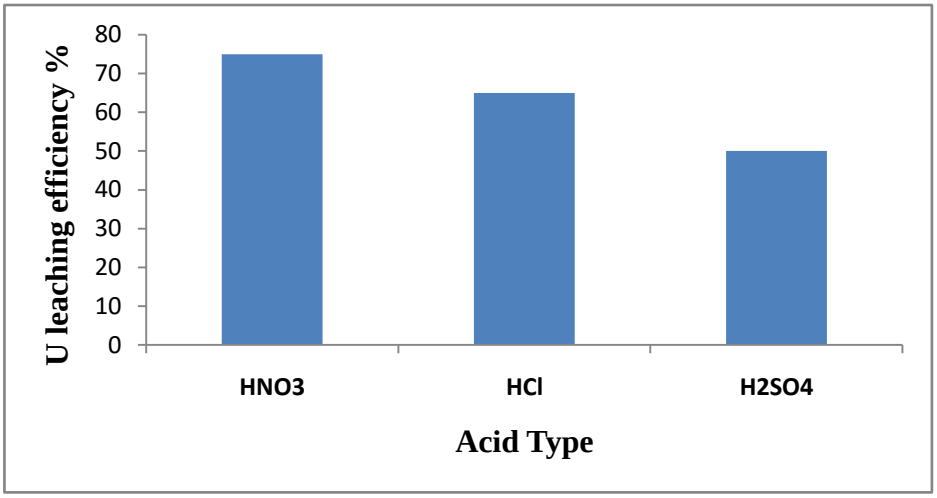



**Fig. (3):** Effect of acid type on U leaching efficiency from Abu Furad mineralized rocks,Central Eastern Desert, Egypt

***2- Effect of acid concentration***

Different concentrations of sulfuric acid were used (40, 60, 80 and 100 g/L) as a leaching agent for uranium andthe other factors have been fixed at 2 hours leaching time, solid/liquid ratio ½ and room temperature. The obtained results indicated that a concentration of 100 g/L gives 82 % uranium leaching efficiency while that of 60 g/L is 75 % (Fig. 4). It is preferred to continue the following experiments with sulfuric acid concentration with 60 g/L to avoid element interferences at high acid concentration.

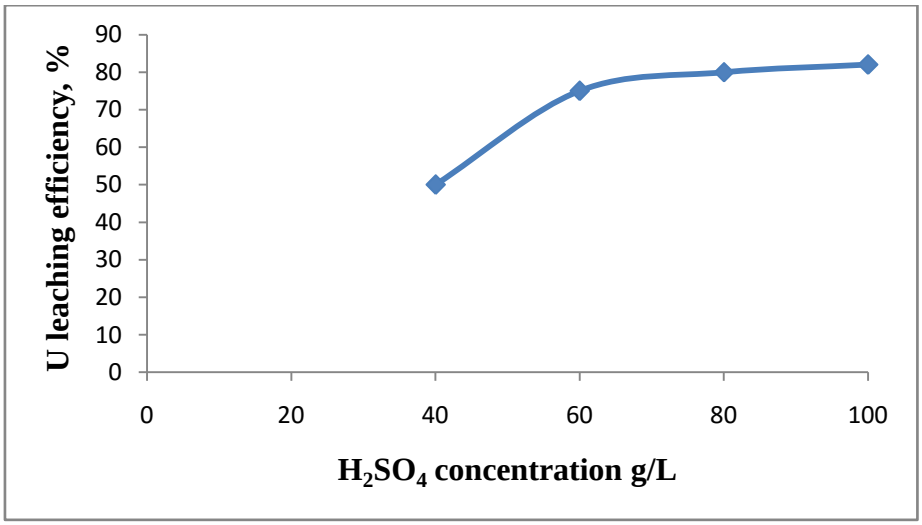



**Fig. (4):** Effect of $H_2SO_4$ acid concentration on U leaching efficiency from Abu Furad radioactive pegmatite, Central Eastern Desert, Egypt

***3- Effect of contact time***

Leaching experiments were performed over a range from 2 up to 12 hours. Other variables were fixed at the leaching conditions of 60 g/L sulfuric acid, 1/2 solid /liquid ratio, at room temperature and grain size of – 60 mesh. The obtained data show that uranium leaching efficiencies increase with increasing contact time achieving its maximum after 8 hours. Increasing time over 8 hours was found to be ineffective (Fig. 5).

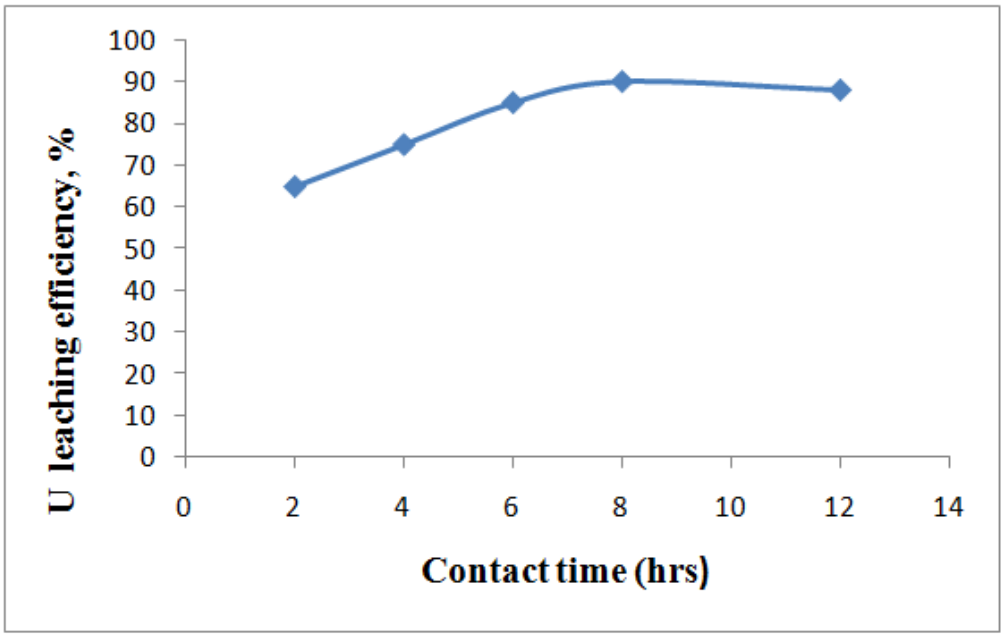



**Fig. (5):** Effect of contact time on U leaching efficiency from Abu Furad radioactive pegmatite,Central Eastern Desert, Egypt

***1- Effect of temperature***

It was necessary to study the effect of temperature of leaching in a series of experiments in which other factors were fixed at 60 g/L sulfuric acid, 1/2 solid /liquid ratio, 8 h contact time and grain size of – 60 mesh. Effect of temperature covered a range from room up to 100 $^{O}$C. From (Fig. 6) uranium leaching efficiency was increased by increasing temperature but from economic point of view room temperature(25$^{O}$C) was chosen for the next factors.

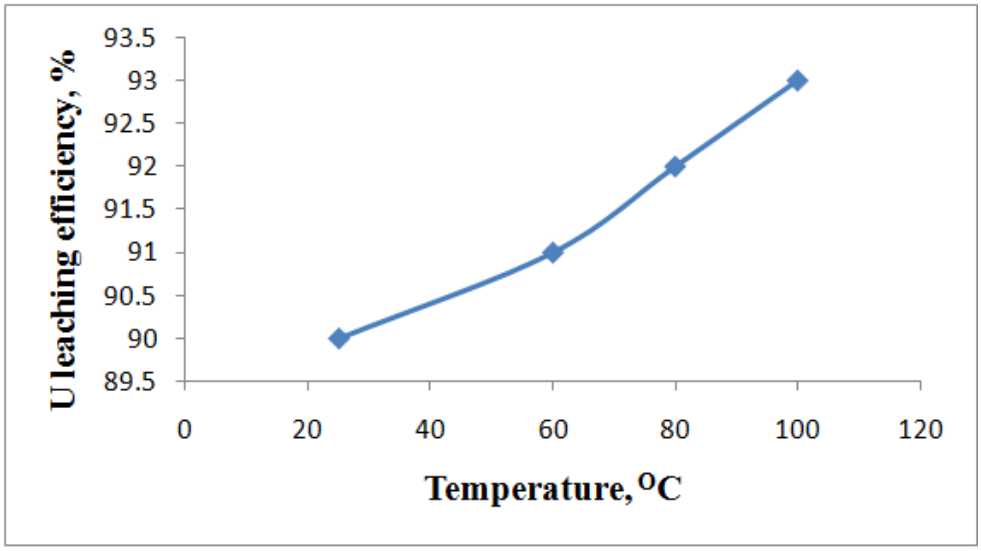



**Fig. (6):** Effect of temperature on U leaching efficiency from Abu Furad radioactive pegmatite

***4- Effect of Solid / liquid ratio***

Although good uranium leaching efficiencies were obtained, it was important to study the effect of solid/liquid ratio upon uranium leaching efficiency. Thus a series of experiments under the following conditions were performed: 8 hours contact time, 60 g/Lsulfuric acid concentration, at room temperature and grain size of –60 mesh. The solid/liquid ratios were varied between ½, 1/3, 1/4 and 1/5. Results obtained were plotted in Fig. (7). Hence agitation leaching technique is recommended since the optimum uranium recovery is obtained at 1/5 ratio. However at more dilute pulp a sudden drop in uranium leaching is noticed, probably because the actual acid concentration is greatly decreased giving the large volume of solution used, in a manner which adversely affected the rate of acid attack.

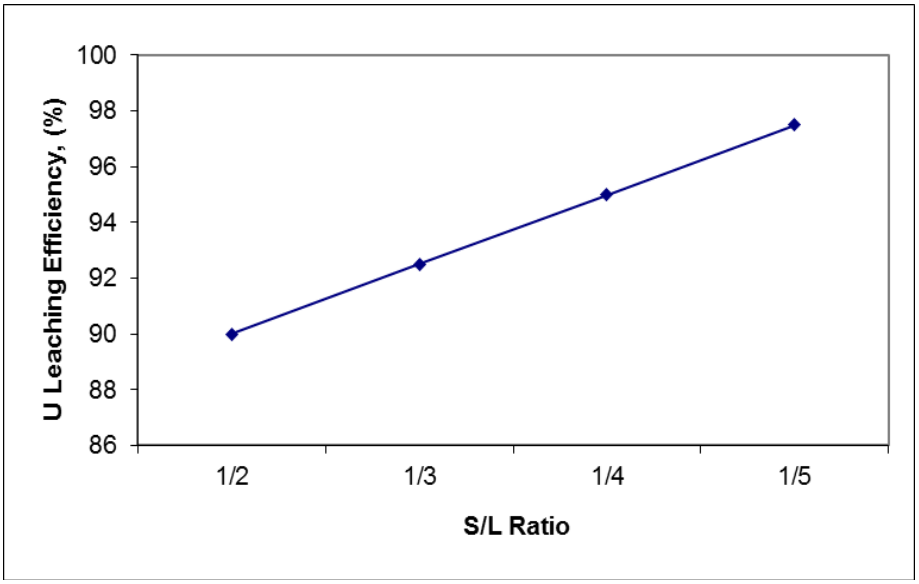



**Fig. (7):** Effect of solid / liquid ratio on U leaching efficiency from Abu Furad radioactive pegmatite

***5- Uranium separation using ion exchange***

From the obtained optimum results of uranium leaching process, a stock solution was prepared for further uranium extraction process. For this step, 50g (containing 101 mg uranium)of ore sample was subjected to acid agitation leaching using the following optimum conditions; 60 g/L sulfuric acid, 8 hours contact time, at room temperature, - 60 mesh size and1/5 solid /liquid ratio giving250 ml uranium leach liquor assaying 85 mg/250 ml but in case of 50 g sample uranium with leaching efficiency about 84.2%. After filtration, the obtained leach liquor stock solution was subjected to iron precipitation at pH 3- 3.5 due to the content of iron in the study ore (5.8%). The obtained solution suffers a decrease in the uranium content to be 82 mg/250 ml in 50 g sample uranium.

- ***Uranium adsorption***

Separation ofuranium was achieved using ion exchange resindry Chinese anion resin (type D263B) which has been specially developed for the extraction of uranium from sulfate solution and have a capacity higher than that of other strong base resins. It has high adsorption rate and its elution is more rapid. About 2 g. of the resin was treated by wetting by 5 ml distilled water and activated by 30 ml of 50 g/L $H_2SO_4$. Uranium leach liquor was adjusted to pH 1.7-2 before loading on the resin then about 250 ml of the leach liquor was allowed to pass through the resin under the conditions applied by **Mahmoud et al., (2006)** where 8 bed volumes were obtained as follow: first 4 bed volumes ranged from 97-95 % loading 4 * 16.4 (every 50 ml) = 65.6 mg. Next 4 bed volumes (15 ml) 3.4 mg + 65.6 = 69 mg with loading efficiency 84.1 % (Table 4 Fig. 8).

**Table (4):** Effect of uranium loading efficiency on the anion exchanger resin (total concentration 82 mg/250 ml)

| Bed volume no. | Uranium loading efficiency % |
|---|---|
| 1 | 97 |
| 2 | 96.5 |
| 3 | 96 |
| 4 | 95 |
| 5 | 28.4 |
| 6 | 16.49 |
| 7 | 11.4 |
| 8 | 11.4 |

- ***Uranium elution***

Elution of the adsorbed uranium was then performed by an acidified ($H_2SO_4$)sodium chloride where 2.9 g of NaCl was dissolved in 100 ml distilled water and its pH was adjusted to 1. Along 8 bed volumes, 100 ml of the eluted solution was obtained and their uranium elution efficiency % was estimated (73.5%) (Table 5 and Fig. 9).

- ***Uranium precipitation***

Precipitation of uranium was achieved at pH 7.5 by adding Na OH solution gradually to the elute solution rich in uranium concentration where crystals of sodium diuranate were precipitated in a percentage of precipitation equals 64% (Fig. 10).

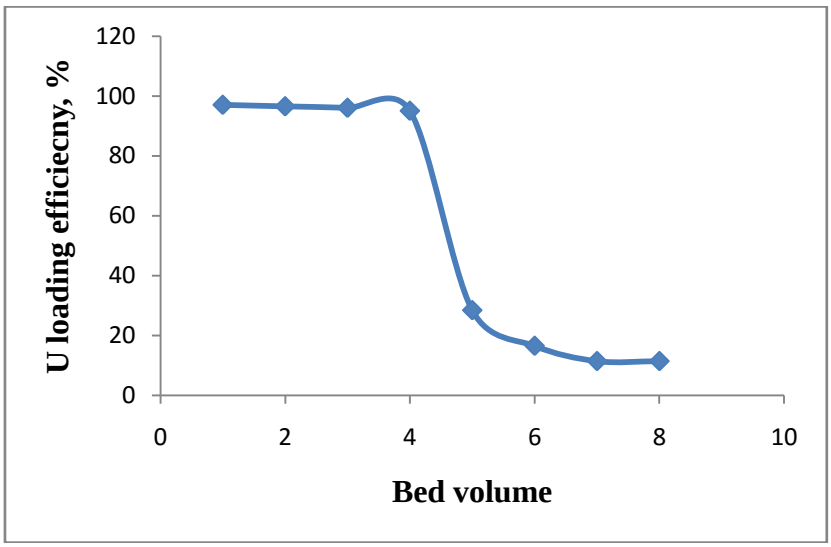



**Fig. (8):** Uranium loading efficiency percent on the ion exchange resin

**Table (5):** Effect of uranium elution efficiency from the anion exchanger resin

| Bed volume no. | Uranium elution efficiency % |
|---|---|
| 1 | 2.5 |
| 2 | 3.0 |
| 3 | 4.5 |
| 4 | 6.0 |
| 5 | 15.5 |
| 6 | 30 |
| 7 | 10 |
| 8 | 2.0 |

**Uranium elution efficiency 73.5%**

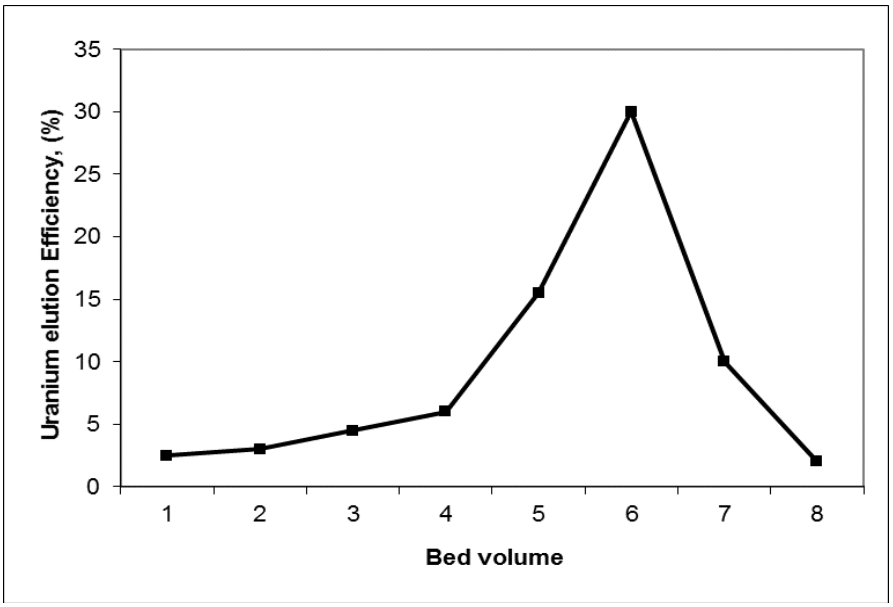



**Fig. (9):** Uranium elution efficiency percent from the anion exchanger resin

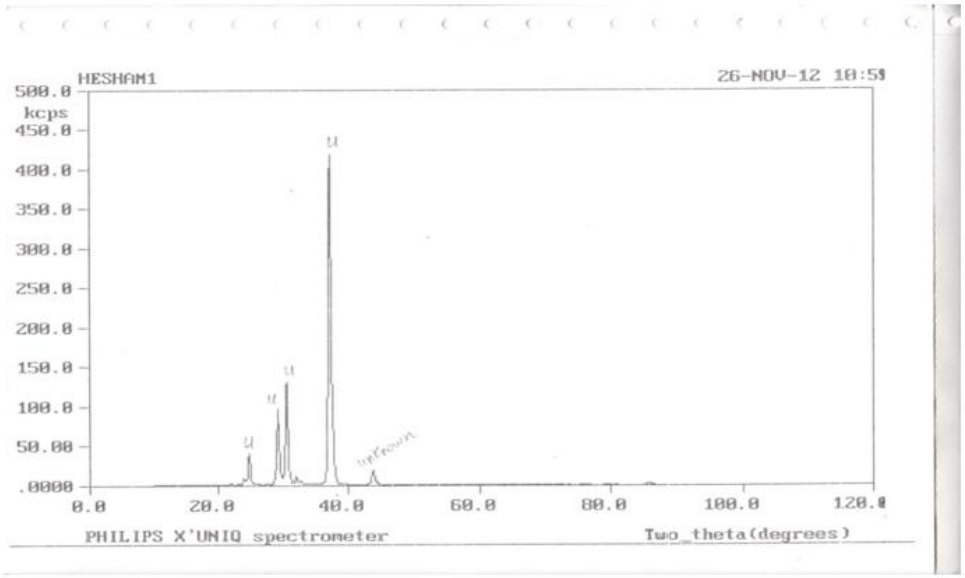
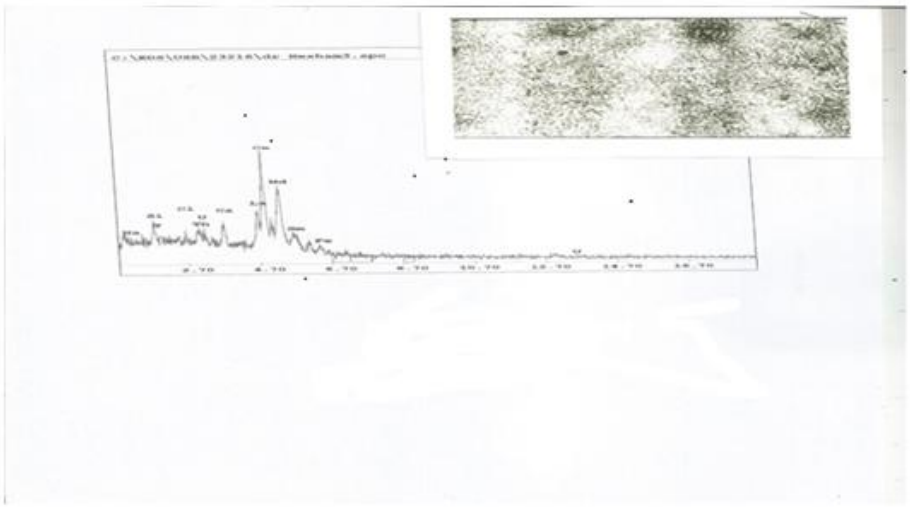



**Fig. (10):** XRF analysis of sodium diauranate product

6- ***Lanthanides precipitation***

According to the importance of lanthanides to the Nuclear Materials Authority of Egyptand due to the lanthanides existed in the analysis of Abu Furad radioactive pegmatite, another stock solution of the obtained optimum uranium leaching conditions was prepared. This solution was subjected to lanthanides precipitation using 10% oxalic acid solution added with stirring until precipitation stopped. After filtration and drying the obtained lanthanide oxalate precipitate was examined by the environmental scanning electron microscope (ESM) (Fig. 11) indicating the presence of most lanthanide elements (Y, Nd, Sm, Ce and La).



| Element | Na | Si | Y | Cl | Th | Ca | Ce | La | Nd | Sm | Fe | U |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wt % | 1.72 | 4.16 | 1.22 | 0.55 | 6.36 | 3.08 | 45.80 | 18.13 | 11.36 | 0.58 | 1.76 | 5.28 |

**Fig. (11):** ESEM micrograph and the corresponding EDX spectrum of the lanthanides oxalate precipitate

A proposed technical flow sheet was designed (Fig. 12) for the uranium separation from Abu Furad mineralized pegmatite. This flow sheet shows the practical application of the present study.

## IV. Conclusions

The present work revealed that uranium recorded in the radioactive pegmatite of G. Abu Furad is feasible to leaching. The acid agitation leaching technique was chosen according to the mineralogy of the ore. It was concluded that that about 97% of uranium existed in the studied sample was leached under the obtained optimum conditions; 60 g/L sulfuric acid concentration, 8 hours contact time, at room temperature, - 60 mesh size and in 1/5 solid /liquid ratio.

Extraction of uranium was achieved using ion exchange resin technique where 2 g of dry resin of D263B type. After loading of uranium, elution was then conducted using an acidified sodium chloride. Precipitation of uranium was achieved at pH 7.5 where crystals of sodium diuranate were precipitated.

Lanthanides existed in the radioactive pegmatite of Abu Furad sample was subjected to precipitation from a stock solution prepared according to the studied optimum conditions for uranium. The obtained product was investigated by the ESM showing the presence of(Y, Nd, Sm, Ce and La).

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