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SUCCESSIVE RECOVERY OF COPPER AND URANIUM FROM CARBONATE - RICH LATOSOL, UM BOGMA FORMATION, ABUTHOR LOCALITY, SOUTH WESTERN SINAI, EGYPT

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ABSTRACT

A technological sample of a copper/ uranium mineralization in carbonate rich latosol rock sequence of Um Bogma Formation Abu Thor locality at southwestern Sinai, Egypt, has been properly processed. The working sample assaying 12.5 % CuO and 875 ppm U was subjected to adipic acid leaching for copper followed by bioleaching of uranium in a manner to avoid excessive acid consumption in the classical leaching procedure. It is thus possible to achieve leaching efficiencies of 95% for Cu in the first stage and 82% for U in the second stage. From the two separately obtained leach liquors of Cu and uranium, pure products have conveniently been prepared. Accordingly, Cu adipate product was first prepared by crystallization, followed by acid dissolution and alkali precipitation of copper hydroxide. In case of uranium, the impure precipitate of the bioleach liquor is purified via Amberlite IRA-400 anion exchanger resin.

INTRODUCTION

An extensive exploration program conducted by the Nuclear Materials Authority for uranium and nuclear raw materials in Egypt has led to the discovery of several uranium mineralizations in different regions. Recovery of uranium and possible associated valuable elements (e.g. Th, V, Mo, Cu, REEs, etc) is indeed another concern of the Nuclear Materials Authority. Among the discovered mineralizations, the Carboniferous rock sequence at SW Sinai represents indeed a promising terrain for uranium and other valuable economic metals in association with Um Bogma Formation. The latter includes mainly Cu, V, REE, besides the famous Fe/Mn deposits in different concentrations in several localities and rock facies of this Formation; viz, Allouga, Talat Selim, Abu Thor, etc.

The main object of this study is to recover both uranium and copper from the carbonate-rich latosol of Um Bogma Formation at Abu

Thor locality. In this regard, several studies have previously been undertaken using sulfuric acid leaching and have proven that both metal values are amenable to acid leaching. However, this has been realized on the expense of relatively high acid consumption (El-Hazek et al., 2008 and Amer et al., 2010 etc.). This is due to the fact that the carbonate content of these ore materials is generally very high as it exceeds 50-60%. On the other hand, separation of Cu and U from their leach liquors in these studies has mainly been undertaken by several techniques e.g. anion exchange resins, solvent extraction, cementation, etc.

To realize the objectives of this work, a technological sample assaying 12.5% CuO and 875 ppm uranium has been collected from the mentioned carbonate-rich latosol ore material of Abu Thor locality. To avoid excessive consumption of sulfuric acid, adipic acid as an organic acid for Cu leaching is applied while for the associated uranium, bioleaching is applied upon the ore residue left behind.

As the matter of fact, the versatile α ,- ω -dicarboxylic acid can accept various modes of binding such as monodentate, bi-dentate chelates or bridging ligand to form polymeric species with metal centers (Oldaham, 1987). Structural and other physico-chemical studies of monocarboxylate metal complexes are well known. Thus, Suresh(2009) has been interested in the structural chemistry of Cu(II) and Co(II) ternary coordination polymers by utilizing the versatile coordination modes of carboxylate ligand with metal center and various N-donor ligands such as bipyridyl, imidazole, methyl imidazole etc. Typically, adipic acid [α ,- ω -dicarboxylate aliphatic acid $(CH_2)_4(COOH)_2$] could react with copper to form Cu (II) adipate: $Cu(CH_2CH_2COO)_2$. The latter has previously been prepared and reported by Burken (1950).

From the industrial perspective, adipic acid is indeed the most important dicarboxylic acid. About 2.5 billion kilograms of this white crystalline powder are annually produced, mainly as a precursor for the production of nylon. Adipic acid is a valuable raw material used in the production of fibers, lubricants, plasticizers, and food additives as well as in the production of intermediates for pharmaceuticals, insecticides, and bactericides. Conventionally, it is manufactured by oxidation of cyclohexanone / cyclohexanol, by hydrogenation of phenol, or more commonly, by oxidation of cyclohexane (Davis et al., 1991 and Castellan et al., 1991).

On the other hand, uranium recovery in this work is studied through bioleaching technique which depends on adopting the organic acids producing from the microorganisms through proper bioleaching process. The latter is actually based on the ability of the produced microorganisms (bacteria and fungi) to transform several compounds to soluble and extractable elements, which can be recovered (Saeed et al., 2002). Recently, several works as Ibrahim, 2007 and Amin, 2008 have been made to utilize acidophilic heterotrophs (bac-

teria and fungi) for metals extraction from ores which contain calcite ($CaCO_3$) and dolomite [$CaMg(CO_3)_2$] as gangue minerals. *Aspergillus niger* has actually been found to produce several organic acids as citric and oxalic that can serve as leaching agents for the solubilization of metals.

Bioleaching has actually been widely used in the commercial extraction of uranium, copper and gold from their ores beside being exploited in the extraction of other base and rare noble metals as zinc, cobalt, nickel, molybdenum, gallium, germanium etc. In some cases, these processes have attained the phase of pilot scale experiments (Ehrlich and Brierley, 1990). Metal dissolution is achieved through a series of reactions including acidolysis, complex and chelate formation (Brandle et al., 2001).

MINERALOGICAL CHARACTERISTICS

The Carboniferous rock sequence of Abu Thor area (Figs.1 & 2) is actually represented by two Formations namely: a lower Um Bogma Formation and an upper Abu Thora Formation. The lower Um Bogma Formation (ab. 27 m thick) is classified into two members; viz a lower Mn ore member of karstified shallow marine carbonate facies hosting Mn ore together with Fe, Cu and U minerals and an upper dolostone-shale member (El Sharkawi et al., 1990). At Abu Thor area uranium and copper mineralizations are recorded within intra-Carboniferous paleokarst profile of Um Bogma Formation. The origin of copper and uranium mineralizations of Um Bogma Formation was discussed by many authors including Hilmy and Mohsen (1965), El Reedy et al. (1988), Dabbour and Mahdy (1988), El-Sharkawi et al. (1990), Hussein et al. (1992), Aita (1996) and Abd El Moneim et al. (1997). Recent studies by Mira and Aita (2009) postulated that the Carboniferous stratabound Cu and U mineralizations in the form of copper carbonate, chloride, silicate, sulphate and phosphate minerals are of supergene origin and have been concentrated by pedogenic processes and latosol formation.

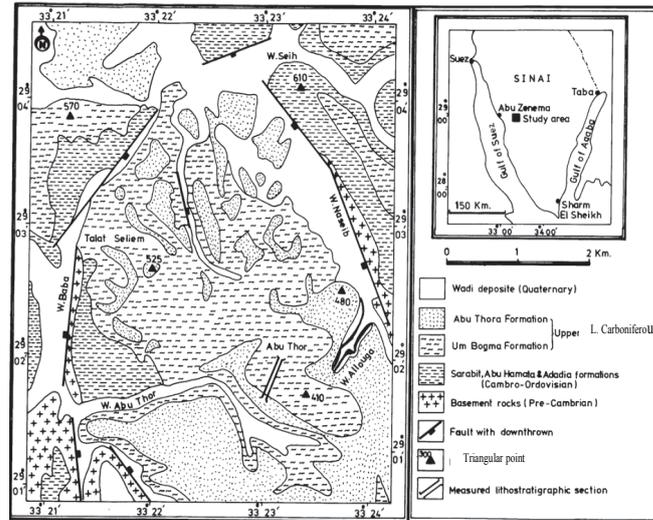


Fig. 1: The modified geologic Map , Abu Thor Locality (After Mira and Aita, 2009)

Mira and Aita (Op cit.) subdivided the paleokarst profile in Abu Thor locality into three main deep weathering soil horizons namely: a lower parent carbonate horizon, a middle subsoil horizon and an upper latosol horizon. The latosol horizon is classified into a lower laminated siltstone subhorizon and an upper organic-rich mudstone subhorizon containing the Cu and U mineralizations and from which the present technological sample is collected. Generally, the identified Cu- and U-bearing minerals in the studied area include: atacamite, paratacamite, rosasite, zircon, monazite and zippeite (Mira and Aita, 2009). The associated minerals in the host carbonate rocks include essentially malachite $4[\text{Cu}_2(\text{OH})_2\text{CO}_3]$, calcite, dolomite, quartz, hematite besides variable amounts of rutile, jarosite, goethite, crednerite, gypsum, ankerite, kaolinite, alunite, gibbsite, hausmanite, pyrolusite, phosphosiderite, and lawrencite (Aita, 1996).

EXPERIMENTAL

Material

The collected technological sample weighing about 5 kg is found to include visible green and bright colored Cu and U mineralizations (Fig.2). In the field , the recorded copper and uranium minerals appear in different forms such as lenticular masses (up to 40 cm long and 10 cm thick), discrete pockets (up to 20 cm in diameter), nodules, veinlets and spots. The host rock of these minerals consists mainly of alternating multicolored layers of kaolinitic green mudstone and altered shaly marl intermixed with organic-rich earthy soil materials.



Fig.2: Green copper and uranium mineralizations of the carbonate-rich latosol horizon, Abu Thor locality

Leaching Procedures

Adipic acid leaching of copper

Several leaching experiments for copper have actually been performed using adipic acid to optimize the relevant leaching factors. In these experiments, a 30 g of the working Cu / U ore ground to -200 mesh size is mixed with a suitable volume of adipic acid of various concentrations. The slurry is then agitated for a fixed time at a certain temperature after which the treated slurry is filtered and the residue left behind is thoroughly washed with distilled water and both filtrate and washings were made up to volume before analysis.

Microbiological leaching of uranium

For this purpose, a strain of *Aspergillus niger* isolated from the ferruginous siltstone ore in Allouga area, southwestern Sinai was properly prepared using a culture medium composed of Dox liquid medium of the following concentration (g/l): NaNO_3 , 2; KH_2PO_4 , 1; $\text{MgSO}_4 \cdot 7 \text{H}_2\text{O}$, 0.5; KCl , 0.5; $\text{FeSO}_4 \cdot 5 \text{H}_2\text{O}$: trace and sucrose: 30. The pH value of the medium is adjusted at 6.5 before autoclaving at 1.5 atm. for 20 min.

The bioleaching experiment was carried out in one liter Erlenmyer flask containing 600 ml of the prepared *A. niger* metabolite. The latter was analyzed for organic acids in culture filtrate by Gas Chromatography at the Regional Center for Mycology and Biotechnology, Al Azhar Univ., Cairo, Egypt. The initial pH of the used metabolite ranges from 2.5-3 and to which 300g of sample the Cu-leached ore residue after adipic leaching was added. The flask was incubated on a mechanical shaker at 100 rpm for 24 hours and the obtained filtrate was subjected to uranium determination.

Analytical Procedures

Proper quartering of the technological sample was performed after its grinding to less than 200 mesh size to obtain a representative sample being subjected to complete chemical analysis of both major and trace elements

content. For the former the conventional wet chemical technique was applied (Shapiro and Brannock, 1962). Whereas SiO_2 , Al_2O_3 , TiO_2 and P_2O_5 were determined using relevant spectrophotometric methods, the contents of Na and K were determined by a flame photometric technique. Total Fe as Fe_2O_3 , MgO and CaO were determined by titration methods. The loss on ignition (L.O.I) was determined gravimetrically. The estimated error for major constituents is not more or less than 1 %.

The trace elements V, Cr, Ni, Zn, Ga, Rb, Sr, Y, Zr, Nb, Pb and Cu, Ba were analyzed at the laboratories of the Nuclear Materials Authority by the X-ray fluorescence technique (XRF) using Philips Unique II unit with automatic sample changer PW 1510 (30 position), connected to a computer system using X-40 program for spectrometry. The detection limit of the measured elements by XRF technique was estimated to be 5 ppm.

To follow the leaching and recovery efficiencies, the different stream solutions were subjected to Cu and U analysis. For the former, an atomic absorption spectrophotometer (AAS) Unicam 969, England was used while for uranium the oxidimetric titration method against ammonium metavanadate was used after its reduction. Finally, the obtained products have been qualitatively analyzed using ESEM-EDX analysis.

RESULTS AND DISCUSSIONS

Chemical Composition of the Working Technological Sample

The complete chemical analysis of the working technological Abu Thor ore sample is given in Table (1) including its CuO content. From the latter, it is obviously evident that besides the high level of the loss on ignition, it contains a high content of both Ca and Cu metal which exist as carbonate minerals reflecting a high carbonate content.

Table 1 : The chemical analysis of the working Abu Thor technological ore sample

Component	wt.%	Component	wt.%
SiO ₂	14.50	K ₂ O	0.35
TiO ₂	0.17	P ₂ O ₅	0.01
Al ₂ O ₃	5.36	L.O.I (550 ^o C)	5.60
Fe ₂ O ₃	1.93	L.O.I. (550-1000 ^o C)	29.10
MnO	3.25	SO ₄	2.00
MgO	3.03	CuO	12.50
CaO	23.50	Cl	0.60
Na ₂ O	0.01	Total	101.9

Table 2: XRF analytical results of the interesting trace elements in the working Abu Thor technological ore sample

Trace element	ppm	Trace element	ppm
Ba	1282	Pb	160
V	880	Cr	182
Ni	88	Sr	740
Nb	43	Ga	27
Zn	317	Zr	310
Rb	83	U	875
Y	101		

The principal possible mineralogical composition has been calculated in the light of the chemical composition and has shown the presence of about 67% of carbonate minerals. These include 13.8 % dolomite, 33.6% calcite and 19.4% malachite. The latter is calculated according to the analysis of CuO content and its equivalent of CO₂. As a matter of fact, the presence of such high carbonate content has been behind the choice of adipic acid leaching of copper and the bioleaching of uranium in order to avoid the excessive consumption of sulfuric acid in classical leaching procedures.

On the other hand, another part of the technological sample was subjected to X-ray fluorescence for the analysis of some trace elements (Table 2). The latter shows that U attains 875 ppm while V assays 880 ppm besides interesting values of Zn, Cr, Ni and Ga ; namely 317, 182, 88 and 27 ppm, respectively.

Results of Chemical Processing

Copper recovery

Adipic acid leaching

Effect of adipic acid concentration: The effect of adipic acid concentration was studied between 0.1 and 0.9 mole , while the other leaching factors were fixed at -200 mesh ore

size, half an hour agitation time, 50°C leaching temperature and 1/3 solid-liquid (S/L) ratio. The leaching efficiencies of both uranium and copper given in Table (3) indicate that the best conc. of adipic acid is 0.5 mole for copper leaching. Under these conditions, the leaching efficiency of copper has attained up to 95.3% with which uranium dissolution was about 6.5%. Higher concentrations of adipic acid did not markedly affect the copper leaching efficiency, however uranium leaching increased where at 0.9 mole, it attained 13% .These results indicate that uranium solubility in adipic acid is greatly limited ; a matter which would enable its selective separation from copper during leaching. The obtained data are actually in agreement with the results obtained by Bassi et al. (1988) who have reported that solid-solid reactions of basic copper carbonate with adipic acids gave the corresponding copper (II) carboxylate chelates . Formation of Cu adipate can be represented by the following successive equations (Fessenden and Fessenden, 1982; Bassi and Kalsi, 1977):

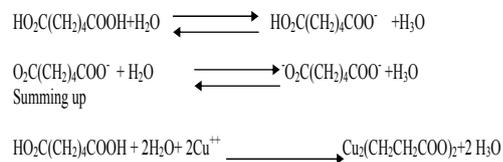


Table 3: Effect of adipic acid concentration on copper and uranium leaching efficiencies from Abu Thor technological ore sample

Adipic acid concentration, mole	Leaching efficiency, %	
	Copper	Uranium
0.1	63.3	4.21
0.2	75.9	5.17
0.3	83.2	5.92
0.4	90.8	6.33
0.5	95.3	6.49
0.6	98.2	7.45
0.7	98.3	8.20
0.8	98.3	10.00
0.9	98.3	13.00

Effect of agitation time: The effect of leaching time upon Cu and U leaching efficiencies is studied in the range from 10 to 60 minutes, while the other leaching conditions are fixed at 0.5 mole adipic acid concentration, -200 mesh size ore material, a leaching temperature of 50 °C and using a solid / liquid ratio of 1/3. The obtained data shown in Table (4) reveal that a high copper leaching efficiency exceeding 95% occurs within the first 30 min. associated with about 6.5% uranium leaching efficiency. Therefore, it can be concluded that thirty minutes are adequate to almost complete Cu leaching using 0.5 mole adipic acid concentration.

Table 4: Effect of leaching time upon copper and uranium leaching efficiencies from Abu Thor technological ore sample

Time/minutes	Leaching efficiency, %	
	Copper	Uranium
10	33.18	1.30
20	71.90	4.20
30	95.30	6.49
45	96.70	7.43
60	96.98	8.25

Effect of temperature : Four adipic acid leaching experiments have been performed to investigate the effect of leaching temperature in the range from room (about 25 °C) up to 100 °C. In these experiments, the other leaching conditions are fixed at -200 mesh size ore material, 0.5 mole adipic acid concentration for 30 min. agitation time and using a 1/3 S/L ratio. The obtained data are shown in Table (5) and reveal actually the importance of temperature to obtain a high leaching efficiency of copper. Working at room temperature under the mentioned conditions did not leach more than 10% of Cu while that of uranium amounted to only 0.5%. Increasing the leaching temperature to 50°C has increased the leaching efficiency of copper to 95.3% and its further increase to 70°C increased the Cu leaching efficiency to 97.18% , while that of uranium increased to 7.31% and after which there has been only a slight increase in the leaching efficiencies. It can thus be mentioned that the optimum leaching temperature of Cu using 0.5 mole of adipic acid under the above mentioned conditions would be 50°C.

Table 5: Effect of leaching temperature upon copper and uranium leaching efficiencies from Abu Thor technological ore sample

Temperature, °C	Leaching efficiency, %	
	Copper	Uranium
25	10.00	0.5%
50	95.30	6.49
70	97.18	7.31
100	97.30	8.1

Effect of the solid/liquid ratio : The effect of the solid/liquid ratio upon copper and uranium leaching efficiencies was studied between 1/3 and 1/5. In these experiments, the fixed leaching conditions involved -200 mesh size ore material, 0.5 mole adipic acid concentration for 30 min. agitation time at 50 °C as leaching temperature.. From the obtained leaching efficiencies given in Table (6), it is found that beyond 1/3 S/L ratio, only a slight steady increase in the leaching efficiencies of

both copper and uranium has been achieved. Accordingly, a solid/liquid ratio of 1/3 would be considered as optimum at which the leaching efficiency of copper and uranium attained 95.3 and 7.31%, respectively.

Table 6: Effect of solid/liquid ratio upon copper and uranium leaching efficiencies from Abu Thor technological ore sample

Solid/liquid ratio	Leaching efficiency%	
	Copper	Uranium
1/3	95.30	6.49
1/4	97.38	7.39
1/5	97.90	8.95

From the above studied leaching factors of Abu Thor technological ore sample, it can be concluded that the optimum leaching conditions for dissolving about 95% of copper associated with about 6.5% U would be summarized as follows:

- Grain size : -200 mesh.
- Acid concentration : 0.5 mole
- Leaching time : 30 minute
- Leaching temperature : 50 °C.
- Solid/liquid ratio : 1/3

Preparation of copper product

For studying the recovery procedures of copper from the working sample, a proper 3 liter adipate leach liquor was prepared from 1 Kg of the working ore sample using the above mentioned determined optimum leaching conditions. Chemical analysis of CuO and U in this liquor is found to attain 39.7 g/l and only 21.3 mg/l respectively. From this liquor, blue copper adipate crystals have been obtained by its proper cooling for half an hour. The obtained crystals (Fig. 3) have been subjected to infrared analysis to confirm their structure.

Accordingly, the obtained IR spectra (Fig. 4) of the blue crystals show a broad peak at 3,430 cm⁻¹ which is attributed to the characteristic stretching vibration of hydroxylate O-H. The broad band ranging from 500 to 900 cm⁻¹ can be attributed to the disordered distribution of

vacancies and the continuous distribution of bond length in an amorphous material (Shek et al,1997). These results reveal that abundant surface hydroxyl groups exist in the prepared copper adipate crystals. On other hand ,to prepare a marketable Cu product, the obtained copper adipate was easily converted to hydroxide or oxide by dissolution in one mole sulfuric acid followed by precipitation of Cu(OH)₂ using ammonia solution at pH 5.5. The obtained hydroxide product has been subjected to proper analysis using the ESEM-EDX technique (Fig. 5) where Cu assays about 97% indicating its almost high purity .



Fig.3: Prepared copper-adipate crystals

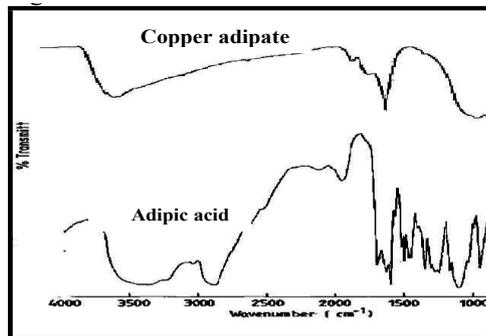


Fig. 4: Infrared spectra of copper-adipate crystals

Uranium recovery

Microbiological leaching

The main part of U left behind in the ore residue after adipic acid leaching of Cu was then directed to bio-leaching using *Aspergillus niger*. However before leaching, the prepared *Aspergillus niger* metabolites was first

subjected to proper chromatographic analysis (Fig. 6) indicating that it secretes in the growth media some organic acids including formic (about 40%), citric (about 35%) beside acetic and oxalic acids.

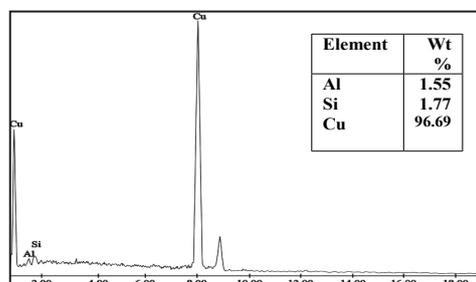


Fig. 5: ESEM with EDX analysis of the prepared copper hydroxide product

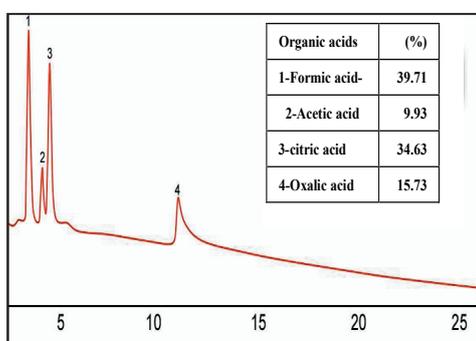


Fig.6: Typical organic acids chromatograph of *A.niger* grown on Dox liquid medium

According to Hefnawy et al. (2002 & 2003), the bioleaching process could be achieved using a solid/*A. niger* metabolite ratio of 1:2 and adjusting the pH of the solution at 2.5-3. for an incubation time of 24 hours at 100 rpm. It is interesting to mention herein that the uranium content in 300 g of the copper-leached residual ore sample attains about 250 mg besides about 1814 mg of copper. The obtained bioleach liquor solution (600 ml) was subjected to proper analysis and was found to assay about 335 ppm for uranium beside 60 ppm copper indicating leaching efficiencies of 81.83 and 1.98%, respectively.

Preparation of uranium product

As a matter of fact, uranium would precipitate from the obtained bioleach liquor after arising its pH to 7.5 using 10% NaOH and the obtained product has then been subjected to proper analysis using the ESEM-EDX. From the latter shown on Fig. (7), it is found that U assay in the product amounted to only 32.93% U and being associated with several impurity elements; namely Al, Fe and P and some Na. It is significant to mention herein that Cu is not present in this precipitate reflecting its low content in the working bioleach liquor as is previously mentioned.

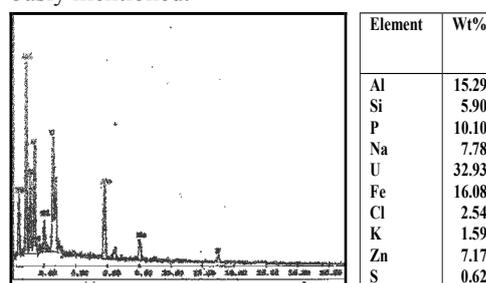


Fig.7: ESEM-EDX analysis of uranium concentrate, sodium diuranate product directly precipitated from the bioleach liquor at pH 7.5

In order to improve the quality of the obtained impure uranium concentrate, the latter (0.674g) is dissolved in 1 molar sulfuric acid and the obtained solution is subjected to proper concentration and purification using anion exchange resin which is quite selective for uranium recovery from the obtained sulfate leach liquor. In the latter solution, the competing anions include mainly SO_4^{2-} and HSO_4^- and therefore uranium would be better adsorbed at pH value exceeding 1.8 while below this value, HSO_4^- would be strongly adsorbed. (Merritt, 1971; Preuss and Kurrin, 1965).

In this work, 2.5ml of wet settled resin (wsr) Amberlite IRA- 400 anion exchanger was packed in a suitable Pyrex glass column (0.5 cm diameter) over a glass wool plug. The prepared uranium sulfate solution was firstly treated with 5% of NaOH to adjust its pH to 1.8 followed by its passing through the prepared resin column using a contact time of 3 min. (0.33 ml/min.). The loaded uranium

is then eluted from the resin using 1N NaCl acidified with 0.1M sulfuric acid. An eluate volume of 200 ml is collected at the end of the elution process and is found to assay 1000 ppm resulting to an elution efficiency 90%. From the obtained eluate, uranium is precipitated by NH₄OH as ammonium diuranate at pH 5.5 and the product is subjected to analysis using ESEM-EDX (Fig. 8) from which U assay increased up to about 87%.

CONCLUSION

Proper processing has been achieved for the Cu / U mineralization hosted in carbonate-rich latosol horizon of the Carboniferous Um Bogma Formation at southwestern Sinai. Thus, to avoid excessive sulfuric acid consumption in the classical leaching procedure, an almost selective Cu leaching has first been performed using adipic acid followed by bio-leaching of uranium. In both techniques, the optimum working conditions have been determined using an ore ground to-200 mesh size. Accordingly for Cu leaching, 0.5 mole adipic acid was used at 50 °C for 30 min. in a S/I ratio of 1/3 resulting in leaching efficiency ex-

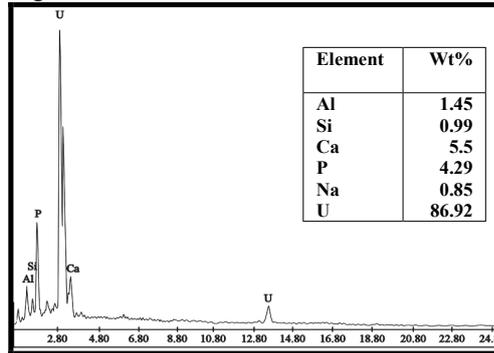


Fig. 8: ESEM-EDX analysis of ammonium diuranate precipitated from Amberlite IRA- 400 resin eluat at pH 5.5

ceeding 95% and only about 6.5 % U. In the succeeding bioleaching step, U was leached using *A. niger* metabolites in a S/I ratio 1/2 for 24 hours. Under these conditions, a U leaching efficiency of about 82% has been realized. Proper, marketable pure Cu and U products have been prepared as Cu(OH)₂ via Cu adipate crystallite and (NH₄)₂U₂O₇ via anion exchanger resin. From all the obtained results, it has been possible to formulate the tentative flow-sheet on Fig.(9).

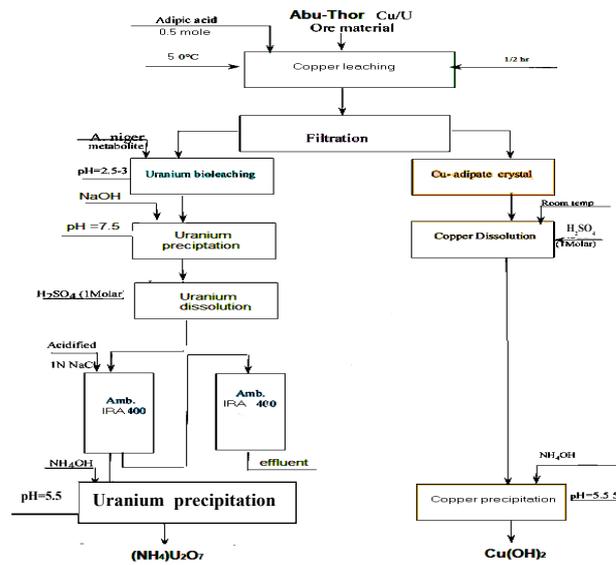


Fig.9: A tentative flowsheet for the recovery of U and Cu from Abu Thor technological sample hosted in the carbonate –rich latosol horizon of Um-Bogma Formation

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الاسترجاع المتتالي لكل من النحاس واليورانيوم من التربة اللاتراتية الغنية بالكربونات منطقة ام بوجمه موقع أبو ثور – جنوب غرب سيناء- مصر

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تمت معالجه عينه تكنولوجية لخام النحاس و اليورانيوم من التربة اللاتراتية الغنية بالكربونات في تكوين ام بوجمه في موقع ابو ثور – جنوب غرب سيناء-مصر . تحتوى هذه العينه على ١٢,٥٪ من اكسيد النحاس و ٨٧٥ جزء في المليون من اليورانيوم . عولجت العينه سابقه الذكر بحمض الاديبيك اولا لاستخلاص النحاس ومن ثم طريقه الاستخلاص الحيوي لإذابة اليورانيوم و ذلك لتفادي الاستهلاك المفرط لحمض الكبريتيك في أساليب التقنيه التقليديه . وقد وصلت كفاءة الاستخلاص إلى حوالي ٩٥٪ من النحاس في المرحلة الأولى للمعالجه و حوالي ٨٢٪ لليورانيوم في المرحلة اللاحقه . تم إعداد المنتجات التسويقيه بالطرق الكيميائيه المتعارف عليها حيث تم تحضير بلورات أدبيات النحاس أولاً ثم أدبيت في حمض الكبريتيك ومن ثم تلي ذلك ترسيب النحاس على هيئه هيدرواكسيد باستعمال القلوبات و تحويلها الي أكسيد بالحرارة بينما في حاله اليورانيوم المستخرج من محلول الاذابه الحيويه تم تنقيته عن طريق التبادل الايوني لراتنج (IRA-Amberlite- 400) .