Leaching Characteristics of Wadi Belih Uraniferous Hammamat Sediments, Eastern Desert, Egypt.

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خلاصة

تناول هذا العمل مواصفات المعالجة المباشرة لخامات اليورانيوم بمنطقة وادي بليغ بالصحراء الشرقية-مصر. بإستخدام تقنية الإذابة بالتقليب. وهذا الخام يتواجد في الصخور الغرينية التي تنتمي الي رواسب الحمامات الواقعة في الجزء الشمالي للصحراء الشرقية حيث تتواجد معادن اليورانيوم علي هيئة معدن اليورانوفين (سليكات)، التيامونايت (فانادات)، وبدرجة أقل معدن الشروكنجرايت (كبريتات). وقد طبقت في هذه الدراسة كلا من الإذابة الحامضية بحامض الكبريتيك والإذابة القلوية بإستخدام خليط الكربونات وبيكربونات الصوديوم علاوة علي تطبيق تقنية الإذابة بالأملاح بإستخدام كل من كلوريدات الصوديوم والحديد. وتبدو تقنية الإذابة بالأملاح واعدة حيث أنه يتعين إزالة الراديوم علاوة علي إستخلاص اليورانيوم وهو أمر ذو أهمية خاصة بالنسبة للإهتمامات البيئية.

هذا وقد تم إستخلاص اليورانيوم بكفاءة 95٪ بالنسبة بإذابة الحامضية بإستخدام 25 جم/لتر حامض الكبريتيك لمدة 4 ساعات عند درجة 50مº وذلكعند إستخدام نسبة 2:1 مواد صلبة الي السوائل المذيبة وقد بلغ متوسط إستهلاك الجامض حوالي 37 كجم/طن خام. أما في درجة الحرارة العادية وهتد درجة 40مº وبإستخدام زمن قدره 6 ساعات للإذابة فقد وصلت كفاءة إستخلاص اليورانيوم الي 77٪، 85٪ علي الترتيب. وبتمديد زمن الإذابة الى 8 ساعات عند درجة الحرارة العادية فقد وصلت كفاءة إستخلاص اليورانيوم إلى 95٪.

في حالة الإذابة القلوية أوضحت الدراسة أهمية كل من الوقت ودرجة الحرارة. وبتطبيق تقنية الإذابة القلوية وصلت كفاءة الإستخلاص الي 85٪ عند إستخدام الظروف الآتية 100 جم/لتر بيكربونات الصوديوم عند درجة حرارة 90مº وكان زمن الإذابة 4 ساعات، وعند تمديد زمن الإذابة الي 24 ساعة تحسنت كفاءة إستخلاص اليورانيوم ووصلت الى 91٪.

أما في حالة تطبيق تقنية الإذابة بالأملاح فعند إستخدام كلوريد الصوديوم أثبت وجود حامض الهيدروكلوريك المخفف جداً أهمية قصوي للحصول علي كفاءة عالية لإستخلاص اليورانيوم، أما في حالة كلوريد الحديديك فإن كفاءة الإستخلاص وصلت الي 88٪ في غياب حامض الهيدروكلوريك وبإستخدام تركيز قدره 50 جم/لتر ح كل 3 .

Abstract

This work deals with the direct chemical treatment of Wadi Belih uraniferous ore material using the agitation leaching technique. The study ore is mainly localized in siltstones belonging to the Hammamat Sediments situated in the northern part of the Eastern Desert. The uranium minerals in the ore are mainly represented by the silicate mineral uranophane, the vanadate mineral tuyuamunite and to a lesser extent the sulphate mineral shroekingerite. Both acid (sulphuric acid), alkaline (sodium carbonate and bicarbonate) leaching methods have been applied beside sodium and ferric chlorides. The latter leaching reagents are greatly beneficial in removing radium together with uranium; a matter which is greatly important for environmental concerns.

Acid leaching has indicated that 95% of uranium could be dissolved by 25 g/L H_2SO_4 for 4 hrs at 50°C and using an ore/liquid ratio of 1/2. Acid consumption was found to average 37 kg/ton indicating a low content of basic constituents. Acid leaching at room temperature and 40°C for 6 hrs resulted in 77% and 85% leaching efficiency respectively. Extending the leaching time to 8 hrs at room temperature gave 95% leaching efficiency.

In alkaline leaching the importance of leaching time and temperature has been clearly evident. Maximum leaching efficiency obtained at 90°C for 4 hrs was 85% by 100g/L $NaHCO_3$ which increased to 91% by extending the leaching time to 24 hrs.

In case of sodium chloride, presence of hydrochloric acid is greatly important while ferric chloride could leach uranium in the absence of hydrochloric acid. Thus 50 g/L $FeCl_3$ was able to leach about 88% uranium.

Introduction

Wadi Belih is situated in the northern part of the Eastern Desert at about 35 km to the west of Hurghada city. It is a major Wadi in the area that runs in an ENE-WSW direction and separates the southern flanks of Gebel Mokhan which are known as Gebel Umm Tawat to the north and Gebel Gattar to the south. Gebel Dokhan is indeed of a major interest since historic times because of the existence of the famous purple imperial porphyry used for ornamental purposes and which was therefore extensively quarried by the Romans. Also, the presence of green breccias in the southern foothills of Gebel Dokhan represents another point of interest in the area. These green breccias have been correlated with those of

Wadi Hammamat which were quarried by the Ancient Egyptians. More recently, the discovery of molybdenum ores in Gebel Gattar and Gebel Abu Harba, which is situated to the north of Gebel Dokhan, adds to the importance of the area.

In view of the presence of molybdenum ores in Gebel Gattar younger pink granites beside the fact that many of these rocks in Egypt are reported to host promising uranium occurrences, the Nuclear Materials Authority has undertaken in 1984 a field radiometric survey in the area around Gebel Gattar. Five Uranium occurrences have thus been discovered of which four occurrences are located along shear zones in the main body of the pink granite forming Gebel Gattar while the fifth uranium occurrence (G-V) is situated within the Hammamat sediments of Wadi Belih at the northern peripheries of Gebel Gattar. These sediments are of molasse type and are generally of dark green to greenish black in color. They are essentially composed of slates and siltstones and their microscopic investigation show angular to sub-angular quartz crystals embedded in a clayey matrix. The mineralized parts of the sediment are kaolinized and show actually intense reddish brown color due to strong hematitization, however, silicification has been moderate. Deep purple fluorite is indeed usually observed accompanying the uranium mineralization which is manifested in visible yellowish secondary uranium minerals. This suggests that uranium might have possibly been transported as a fluoride complex.

The present work deals mainly with the extraction of uranium from Wadi Belih Hammamat sediments. The host rock of the ore is a siltstone composed mainly of about 56.5% Kaolinite, about 27% of detrital quartz grains, about 8% of iron oxides beside about 5% alkali and alkaline earth elements as represented by CaO, MgO, Na_2O, K_2O in particular [1]. The uranium minerals are of the secondary oxidized type and are mainly represented by the silicate mineral uranophane, the vanadate mineral tyuyamunite beside lesser amounts of the sulphate mineral schroeckingerite [2].

The chemical treatment of Wadi Belih ore material has been performed in the present work by the agitation method due to relatively high uranium content using sulphuric acid, sodium carbonate and/or bicarbonate beside sodium and ferric chlorides.

Sulphuric acid is the most common acidic reagent used in uranium leaching because of its availability and low cost. It could also be manufactured on the same mill site from sulphur or SO_2 off-gas smelting of sulphide concentrates. In addition, sulphuric acid may be generated autogenously by treating uranium ores that contain sulphide minerals by air or oxygen under pressure or by bacterial action. Nitric and hydrochloric acids are both effective in uranium dissolution but they dissolve also many undesirable impurities from the ore.

$$UO_3 + 2H^+ \rightarrow UO_+^{2+} + H_2O$$

$$UO_2^{2+} + 3\,SO_4^{2-} \rightarrow [UO_2(SO_4)_3]^{4-}$$

$$UO_2^{2+} + 2\,SO_4^{2-} \rightarrow [UO_2(So_4)_2]^{2-}$$

Alkaline leaching could also be used for uranium leaching of ores containing appreciable carbonate gangue minerals which would consume excessive amounts of the acid. In such cases, sodium carbonate/sodium bicarbonate mixture would be used where stable complexes with the carbonate ion would be formed; viz.,

$$UO_3 + 3\,CO_3^{2-} + H_2O \rightarrow [UO_2CO_3)_3]^{4-} + 2\,OH^-$$

$$UO_3 + 2\,CO_3^{2-} + H_2O \rightarrow [UO_2(CO_3)_3]^{2-} + 2\,OH^-$$

$$UO_3 + 8\,HCO_3^- \rightarrow [UO_2CO_3)_3]^{4-} + 4H_2O + 2\,CO_3^{2-} + 3\,CO_2$$

On the other hand, uranium leaching by salts such as sodium and ferric chlorides seams promising due to its higher leaching efficiency. In addition these leachants are greatly beneficial in removing radium, a matter which is greatly important for environmental concerns.

Experimental

In a trial to test possible physical concentration of uranium, a granulometric sieve analysis test of a crushed and coarsely ground ore sample was performed, it did not show any concentration. Therefore, it was decided to chemically treat the bulk ore material directly. A technological sample of the ore material assaying 1.38% uranium has been prepared for most of the present experimental work. Several acid and alkaline leaching experiments using the agitation technique were performed. Leaching experiments were carried out in 250 ml glass rounded-bottom flasks fitted with three openings.

Table (1) represents the experimental conditions that were performed during the leaching studies.

Filtration of the slurry was carried out through buchner funnels using small laboratory vacuum pump. The obtained filtrate was analyzed for both uranium and remaining free acidity while the spent cake was washed, dried and analyzed for any residual unleached uranium content.

Table (1) : Leaching Conditions Performed for Acid, Alkaline and Salt Leaching Experiments upon Wadi Belih Uraniferous Hammamat Sediments

Factor	Experiment	Fixed leaching conditions
A-Acid leaching: 1- Effect of sulphuric acid concentration (g/L)	10,15,25,50,75, 100	60°C, 4 hrs 1/2 S/L ratio - 100 mesh
2- Effect of leaching temperature (°C)	25,40,60	25 g/L, 6 hrs 1/2 S/L ratio - 100 mesh
3- Effect of leaching time (hr)	4,6,8, 24	25 g/L, 25°C 1/2 S/L ratio - 100 mesh
4- Effect of ore grain size (mesh)	20,40,60, 100, 200	25 g/L, 25°C 1/2 S/L ratio 4 hrs
5- Effect of solid/liquid ratio	1/1,1/2, 1/3,1/4	25 g/L, 25°C 4 hrs - 100 mesh
6- Effect of oxidant, $KClO_3$ (g/50g ore)	0.25,0.50,1	25 g/L, 25°C -100 mesh 1/2 S/L ratio, 4 hrs
B-Alkaline leaching: 1- Effect of reagent conc., (g/L)	100 Na_2CO_3 25,50,75, 100 $NaHCO_3$ 25 CO_3+75HCO_3 50CO_3+50HCO_3 75CO_3+25HCO_3	4 hrs 90°C - 100 mesh 1/2 S/L ratio
2- Effect of leaching time, (hr)	4,8,24,48	100 g/L Na_2CO_3 & 100 g/L $NaHCO_3$ 90°C, -100 mesh 1/2 S/L ratio
3- Effect of leaching temperature, (°C)	25,50,70,90	100 g/L Na_2CO_3 & 100 g/L $NaHCO_3$ (8 hrs,& 4 hrs) -100 mesh 1/2 S/L ratio

Table (1) : Cong.

Factor	Experiment		Fixed leaching conditions
	NaCl g/L	FeCl3 g/L	
C- Salt leaching - HCl		50,100,200	4 hrs 25°C
5 HCl	0,25,50,75	0,25,50,75	-100 mesh
15 HCl	0,25,50,75	0,25,50,75	1/2 S/L ratio

Results and Discussions

In the present work, the chemical composition of three technological samples are represented in Table (2,3).

Due to the relatively high uranium content in the study ore, it was decided to adopt the agitation leaching technique. An average technological sample was prepared by properly mixing equal weights of the three analyzed samples. For the sake of comparative studies, both sulphuric acid and alkaline leaching agents were used. The relevant factors affecting the uranium leaching efficiency by both reagent types have been studied and discussed. In addition, some experiments have been performed using chloride leaching and in particular $FeCl_3$. This is due to the fact that chloride is an efficient leachant for radium while radium sulphate and carbonate are not highly soluble. This trend of chloride leaching has become nowadays more important due to exceedingly environmental concerns.

It is worthy mentioning the major features of the leaching characteristics of Wadi Belih ore material have been previously studied [2]. In that study, it was concluded that the optimum agitation acid leaching conditions for complete uranium dissolution at room temperature include 100 g/L sulphuric acid for 4hrs agitation time in a solid/liquid ratio of 1/2 using an ore sample ground to - 100 mesh grain size and without using any oxidant. In the meantime, the mentioned study has indicated that only about

50% of uranium could be leached by alkaline leaching using Na_2CO_3 and/or $NaHCO_3$.

However, due to the variability in both the nature and grade of Wadi Belih uranium ore as well as to properly evaluate the feasibility of this ore, it was decided to undertake a detailed leaching study of Wadi Belih ore material.

A) Acid Leaching Results of Wadi Belih Ore Material

Sulphuric acid leaching has been chosen to study the acid leaching conditions of Wadi Belih ore material by the agitation method. This choice is actually justified due to the absence of carbonate mineral constituents Table (2). The leaching factors studied include the effects of the acid concentration, temperature, time and the grain size of the ore material.

Table (2) : Chemical Analysis of the Major Elements on Elemts of Wadi Belkh Uraniferous Hammamat Sedoment (wt. %)

Sample No. Ingredient	1	2	3	Average
SiO_2	67.54	64.95	69.00	67.16
Al_2O_3	16.19	16.83	15.42	16.15
Fe_2O_3	7.43	9.51	7.23	8.06
FeO	0.08	0.08	0.09	0.08
MnO	0.03	0.06	0.04	0.04
MgO	0.73	1.04	1.04	0.94
CaO	1.01	0.72	0.72	0.82
Na_2O	0.30	0.17	0.27	0.25
K_2O	3.06	3.00	3.03	3.03
TiO_2	0.80	0.86	0.76	0.81
P_2O_5	0.26	0.26	0.25	0.26
H_2O*	0.54	0.85	0.07	0.70
H_2O**	1.56	1.12	1.06	1.25
CO_2	0.02	0.09	0.05	0.05
Cl^-	0.15	0.17	0.12	0.15
Total	99.70	99.71	99.78	99.75

* Humidity ** Water of crystalization

Table (3) : Analytical Results of Trace Elements of Wadi Blih Uraniferous Hammamat Sediment (ppm)

Sample No. / Ingredient	1	2	3	Average
Ba	320	331	357	336
Cu	16	18	17	17
Nb	6	5	7	6
Rb	103	111	98	104
Sr	62	65	65	64
Pb	15	14	17	15
Zn	6	5	7	6
Zr	88	91	79	86
U	11500	14000	16000	13800
ΣREEs	110	100	91	100

The results obtained from the study of sulphuric acid concentration effect are plotted in Fig (1). From these data, it is clearly evident that Wadi Belih ore material is easily amenable to sulphuric acid leaching. Thus, about 60% uranium leaching efficiency has been obtained at only 15 g/L acid concentration. However the acid input was completely consumed. Using 25 g/L acid concentration the leaching efficiency was increased to 95% while the remaining free acid content assayed 6.4 g/L. Increasing the acid input thereafter to 50, 75 and 100 g/L improved only slightly the leaching efficiency. In the maintained leaching experiments, the consumed acid averaged only 18.5 g/L which equal to 1.85 g/50 g ore (37 kg/t ore) reflecting the relatively low basic constituents in the study ore material.

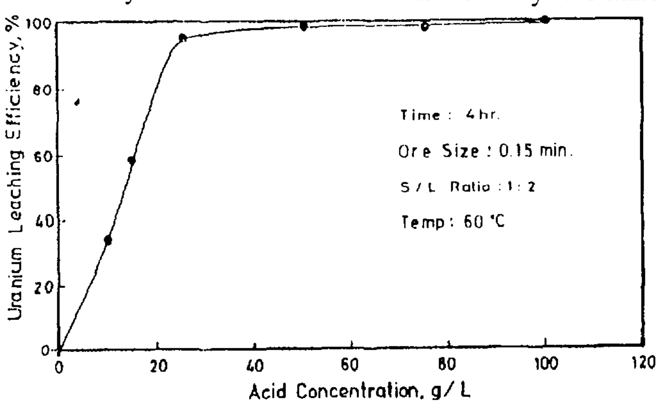

Figure (1) : Effect of Sulphuric Acid Concn. on Uranium Leaching Efficiency of Wadi Belih Ore Material

Therefore, it can be mentioned that 25 g/L acid concentration in a S/L ratio of 1:2 would be considered adequate for uranium leaching from Wadi Belih ore material at the given conditions. This result is strongly competent to that of Mahdy et al. [2] who used 100 g/L H_2SO_4 at room temperature and got the same leaching efficiency.

Three experiments have been performed in a trial to achieve the obtained leaching efficiency of 95% at lower temperature. In these experiments, the acid concentration was fixed at 25 g/L and the other leaching conditions mentioned above were used while the leaching time was extended to 6 hrs. Thus at room temperature, the leached uranium amounted to 77% while at 40°C, it increased to 85% and at 60°C, 97% of uranium was leached.

Although, these results indicate the amenability and ease of leaching of Wadi Belih ore material even at room temperature when applying prolonged leaching time. It is generally advisable to only use temperatures higher than ambient after careful consideration of initial and operating costs of heating against other relatively inexpensive variables. In addition, the increase in temperature has the disadvantage of excessive dissolution of impurities that are essentially insoluble at lower temperatures.

Fig. (2) clarifies that 8 hrs. leaching time under the mentioned conditions would bring about 97% uranium leaching efficiency. Referring to Mahdyís et al. work [2], there could be two alternatives:

a. Using 25 g/L acid concentration and 8 hrs. agitation time.

b. Using 100 g/L acid concentration and 4hrs. leaching time.

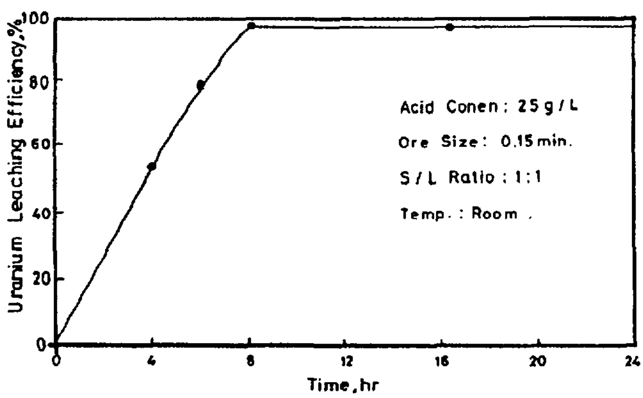

Figure (2) : Effect of Time uon Uranium Leaching Efficiency of Wadi Belih Ore Material

Concerning the effect of time on leaching experiment using acid agitation leaching the obtained leaching efficiencies were comparable Fig.(2). This is actually due to the nature of uranium minerals which mainly occur in the form of surface coatings.

It is worthy mentioning, in a leaching operation, the grain size of the input ore reflects its effective surface area in contact with the leaching agent. On the contrary, operating costs would increase by increasing the ore fineness due to excessive energy consumption on one hand and to eventual filtration difficulties. Five experiments have been performed on ore ground to pass 20, 40, 60, 100 mesh size using 25 g/L acid. The obtained efficiencies were comparable.

As the solid/liquid ratio in the leaching slurry would control its viscosity and hence efficient mixing, its effect was therefore studied using 1/1,1/2,1/3 and 1/4 solid/liquid ratios. Fixed leaching conditions involved 25 g/L acid, 4 hrs agitation time at 60°C and using ore fineness of - 100 mesh. The obtained leaching results were indeed comparable.

Although uranium minerals in the study ore are of the secondary type in which uranium exists in its hexavalent state, some oxidizing leaching experiments were performed. In the latter $KClo_3$ was used in the range of 5 to 20 kg/t while using 50 g/L acid at 60°C for 4 hrs in a S/L ratio of 1:2 on the ore ground to - 100 mesh. No improvement in uranium leaching efficiency was obtained confirming the previously attained results [2].

b) Alkaline Leaching Results of Wadi Belih Ore Material

The results of the alkali reagent concentration effect upon uranium leaching efficiency from Wadi Belih ore are plotted in Fig. (3 & 4). In this study, the other leaching conditions were fixed at a S/L ratio of 1:2, a leaching time of 4 hrs at 90°C and an ore fineness of - 100 mesh without applying any oxidant.

Investigation of these results indicated the importance of $NaHCO_3$ in uranium leaching efficiency. Thus while 25 g/L $NaHCO_3$ resulted in a uranium leaching efficiency of about 47%, a concentration of up to 100 g/L Na_2CO_3 resulted in only about 34% uranium leaching. Using 75 g/L $NaHCO_3$ gave a leaching efficiency of about 83% in presence or absence of 25 g/L Na_2CO_3. The maximum leaching efficiency of 85.3% was obtained when using 100 g/L $NaHCO_3$.

To study the effect of time upon uranium leaching efficiency from Wadi Belih ore, two leaching experiments series were performed using 100 g/L Na_2CO_3 and $NaHCO_3$ in the range of 4-48 hrs. Other leaching conditions were fixed at a S/L ratio of 1:2, 90°C leaching temperature and an ore fineness of -100 mesh without applying any oxidant.

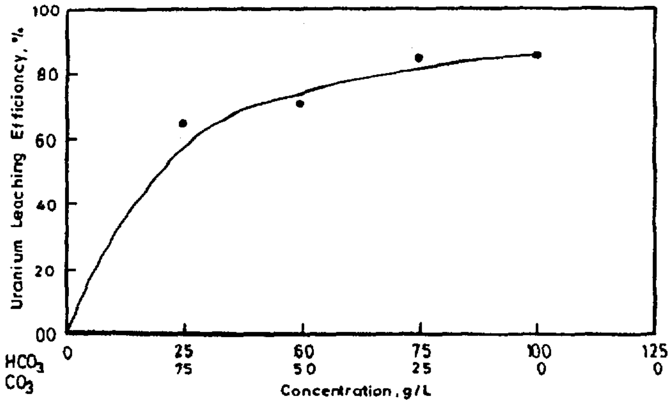

Figure (3) : Effect of Carbonat / Bicarbonate Concn. on Uranium Leaching Effeciency of Wadi Belih Ore Materal

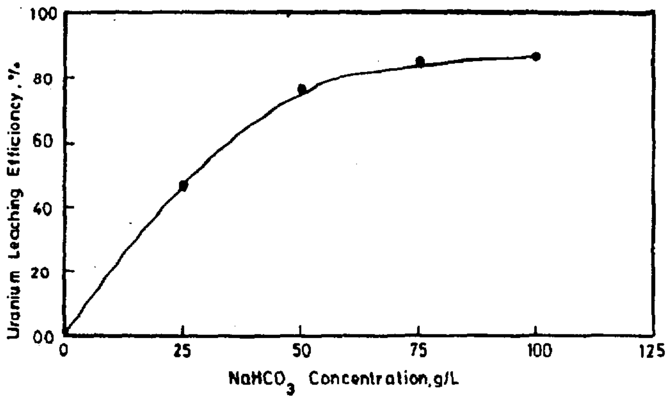

Figure (4) : Effect of Carbonat Concn. on Uranium Leaching Effeciency of Wadi Belih Ore Materal

The obtained results plotted in Fig. (5), clearly indicate that time is quite important in uranium leaching efficiency specially when using Na_2CO_3 as the leaching reagent. Thus uranium leaching was increased from about 34-79.8 and 84% when the leaching time was increased from 4 to 8, 24 and 48 hrs respectively. However, in case of $NaHCO_3$ leaching, improvement in uranium leaching efficiency by increasing the leaching time was reported to be 85-99.5%.

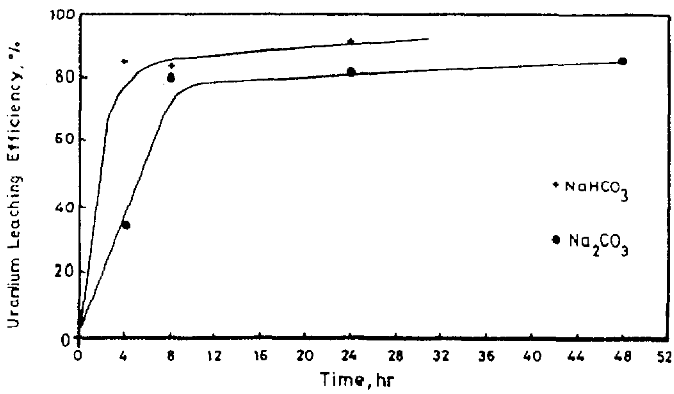

Figure (5) : Effect of Alkaline Leaching Time on Uranium Leaching Effeciency of Wadi Belih Ore Materal

To study the temperature effect upon uranium leaching efficiency, two series of leaching experiments were performed using 100 g/L Na_2CO_3 and $NaHCO_3$ in the range of 25-90°C. In the Na_2CO_3 leaching experiments, the leaching time was fixed at 8 hrs while those of $NaHCO_3$, the leaching time was fixed at only 4 hrs. The obtained results are plotted in Fig. (6) and the leaching conditions were fixed at a S/L ratio of 1:2 and an ore fineness of - 100 mesh without using any oxidant.

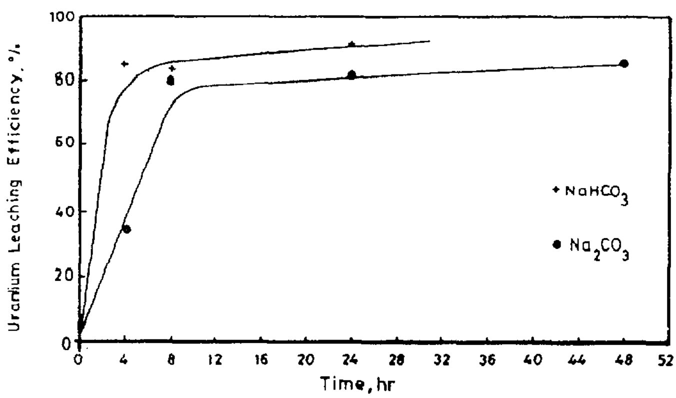

Figure (6) : Effect of Alkaline Leaching Temp. on Uranium Leaching Effeciency of Wadi Belih Ore Materal

The obtained results indicated the importance of the leaching temperature upon uranium leaching efficiency from Wadi Belih ore. The effect is actually more pronounced in case of $NaHCO_3$ which gave better results than those of Na_2CO_3 in spite of using only 4 hrs leaching time. This might be due to the hydrolysis effect that might have led to uranium reprecipitation in case of Na_2CO_3 leaching. The best obtained uranium leaching efficiency of about 85% has been obtained at 90°C in case of $NaHCO_3$ leaching.

It can thus be concluded that while acid leaching was successful at room temperature, the high temperature of up to 90(C was quite important in alkaline leaching. The previous alkaline leaching studies [2] did not result except in 50% leaching although using up to 200 g/L Na_2CO_3. The reason was due to reducing leaching time (4 hrs) and carrying out the leaching experiments at room temperature.

C) Chloride Leaching Results of Wadi Belih Ore Material

Environmental concern about radium removal from the tailings of uranium milling operation has been directed studied towards modifying the milling process itself. This is because of the different chemical properties of uranium and radium, such as the low solubilities of radium sulphate and carbonate in contrast to those of uranyl sulphate and carbonate. In other words, a good leachant of uranium is not necessarily a good leachant for radium.

In the present work, an approach has been directed to apply two inorganic salts namely NaCl and especially $FeCl_3$ whose effectiveness as leachants for many other minerals beside uranium and radium is well known and whose leaching involves an oxidation step. In the work of Nirdosh et al. [3], 1M $FeCl_3$ solution was reported to dissolve 67% of radium from Elliot Lake Ore, Ontario assaying 0.1% uranium present mainly as uraninite and brannerite with 5% pyrite. This was achieved for one hour at room temperature. It is actually understandable that the minimum condition for good radium removal from ores is good uranium removal. This is because radium is a daughter of uranium and therefore occurs at the same positions in the mineral lattice.

A scouting test upon the uraniferous Hammamat sediments using NaCl only as a leachant resulted in a very low uranium solubility. Alternatively, using 5 and 15 g/L HCl as a leachant resulted in 17.6 and 65% uranium leaching efficiency respectively, Fig. (7). Addition of NaCl in the range of 25 to 75 g/L to the 5 g/L HCl leachant did not improve the leaching efficiency. However, addition of 50 g NaCl/L to the 15 g/L HCl leachant improved the leaching efficiency to 95.1% . Moreover, the addition of 100 g/L NaCl to the 15 g/L HCl leachant resulted in almost complete leaching of uranium. In these experiments, the leaching conditions were fixed at a S/L ratio of 1:2 and an ore fineness of -100 mesh during 4 hrs agitation time at room temperature.

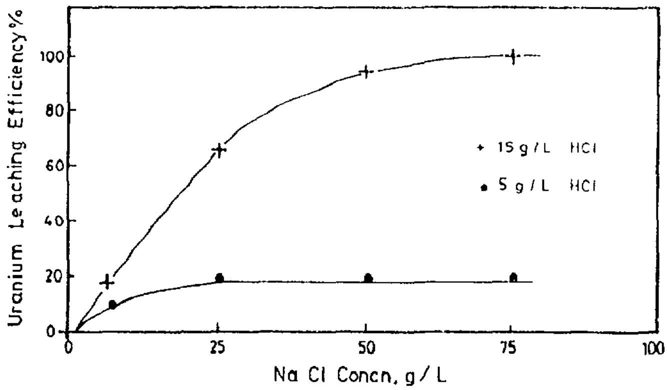

Figure (7) : Effect of Sodium Chloride Concn. on Uranium Leaching Effeciency of Wadi Belih Ore Materal

Performing the same experimental conditions mentioned above, however, using $Fe\,Cl_3$ in the range of only 25-50 g/L added to 5 g/L HCl leachant resulted in about 90-95% leaching efficiency. While using Fecl3 alone as a leachant in a concentration of 50g/L (about 0.3 M) gave a uranium leaching efficiency of about 88% Fig. (8). The possible reaction of $Fe\,Cl_3$ with uranophane can be represented as follows:

$$3\ FeCl_3 + Ca(UO_2)_2(SiO_3)_2(OH)_2 5H_2O \rightarrow 2\ UO_2Cl_2 + FeCl_2 + CaSiO_3 + Fe(OH)_2$$

It can thus be concluded that $Fe\,Cl_3$ which is effective in radium leaching is also effective in leaching uranium from Wadi Belih ore material.

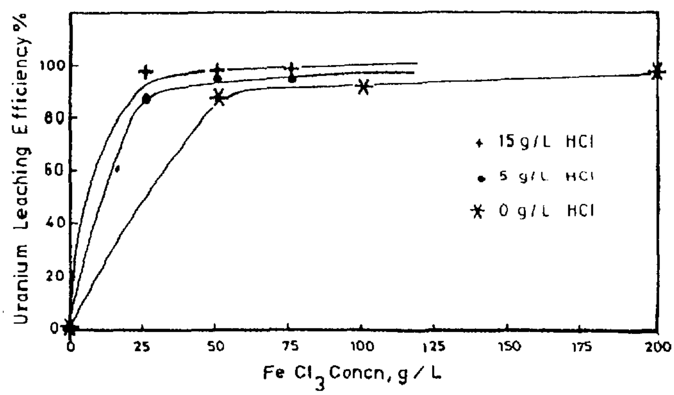

Figure (8) : Effect of Ferric Chloride Concn, on Uranium Leaching Effeciency of Wadi Belih Ore Materal

Conclusions

Study of the acid leaching factors indicated that a sulphuric acid concentration of 25 g/L for 4 hrs agitation time at 60°C in a solid/liquid ratio of 1:2 and using an ore fineness of -100 mesh without applying any oxidant resulted in 95% uranium leaching efficiency. It was also found that acid consumption is relatively low where the consumed acid average only 37 Kg/t ore. This indicates clearly the relatively low basic constituents in the study ore material. Leaching at room temperature and at 40°C for 6 hr. using H_2SO_4 concentration of 25 g/L gave a leaching efficiencies of 77% and 85% leaching efficiency respectively. Working at room temperature and extending the leaching time to 8 hrs has led to uranium leaching efficiency of 97%. On the other hand, it has been proved that an ore grain size of up to - 200 mesh size did not adversely affect the leaching efficiency. Similarly, neither the presence of oxidant nor the solid/liquid has any effect whatsoever upon the acid leaching efficiency of uranium.

In alkaline leaching study, the obtained results have indicated the importance of $NaHCO_3$ to the leaching efficiency. Thus, while 25 g/L of the latter resulted in a uranium leaching efficiency of up to about 47%, however a concentration of up to 100g/L Na_2CO_3 resulted in only about 34% leaching efficiency. Furthermore, 75 g/L $NaHCO_3$ gave a leaching efficiency of about 83% in presence or absence of 25 g/L Na_2CO_3. The maximum leaching efficiency of 85.33% was obtained when using 100g/L $NaHCO_3$. In these results, the other leaching conditions were fixed at a S/L ratio of 1:2 and a leaching time of 4 hrs at 90°C and an ore fineness of -100 mesh. As was expected, extending the leaching time to 24 hrs and using 100 g/L of Na_2CO_3 or of $NaHCO_3$ increased the leaching efficiency to 81 and 91% respectively.

Using NaCl in the range of 25 to 75 g/L in the presence of 5 g/L HCl did not result in a uranium leaching efficiency beyond about 19% while using 50 g NaCl and 15 g/L HCl improved uranium leaching efficiency up to 95.1%. On the other hand, $Fe\,Cl_3$ only has proved to be effective in uranium leaching where 50 g/L has resulted in about 88% leaching efficiency. In presence of 5 and 15% HCl, leaching efficiency of uranium has increased to 95 and 97% respectively.

Uranium recovery from the acid sulphate leach liquor can be performed with both anion exchange resin and/or solvent extraction while its recovery from the alkaline leach liquor can be achieved by anion exchange resins.

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