Amenability of heap leaching technology on uranium extraction from Gattar and El Missikat area, Eastern Desert, Egypt: A kinetic approach

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Abstract.

Studies of uranium heap leaching from different uranium mineralization situated in Eastern Desert of Egypt was investigated via batch experiments, followed by its optimum condition application on column percolation tests. The optimum process operating parameters were implemented on large column scale in order to make more condition control and evaluate the time and reagents needed in the large scale. The results show that leaching efficiency of GII attained about 78.3% with 34kg/ton acid consumption in a 44 days period, while leaching efficiency of El-Missikat attained about 86.6% with 28kg/ton acid consumption in a 40 days period. Kinetics reaction models of column tests have been investigated to optimize the column leaching behavior. Based on the leaching results of two mineralized samples, the rate of the uranium metal dissolution is controlled by the chemical reaction and the diffusion reaction but diffusion reaction control was more predominate than a chemical reaction control.

Key words: El-Missikat; Gattar; heap leaching; column test; kinetic reaction models

Introduction

Heap leaching is an industrial mining process used to extract precious metals, copper, uranium, and other compounds from ore using a series of chemical reactions that adsorption specific minerals and re-separate them after their division from other earth materials. In heap leach mining, the uranium mineralization places on a liner heap pad, then adds the chemicals reagents via drip irrigation systems to the ore[1].

Heap leach mining works well for large volumes of low grade ores, as reduced metallurgical treatment of the ore is required in order to extract an equivalent amount of minerals when

compared to milling. The significantly reduced processing costs are offset by the reduced yield of usually approximately 60-70%. The amount of overall environmental impact caused by heap leaching is often lower than more traditional techniques [2].

Heap leaching studies could be investigated laboratory via batch experiments followed by column leaching application. Which, unlike batch leaching, no agitation of the column occurs and the system is open and more closely resembles subsurface conditions in many natural environments. Although the procedures tend to be more expensive, time-consuming, and labor intensive than batch leaching, column leaching methods have the advantages of allowing observers to study longer term chemical interactions between solid samples and leachates, to note changes in the permeability of solid samples with time, and to evaluate how chemical reactions may change once more soluble compounds are flushed out of the solids [3].

Several promising uranium occurrences have been discovered in the Eastern Desert of Egypt as, Gable Gattar, El-Missikat, Abu Rushed and El-Sela areas. Gabal Gatta rare allies in the northern part of the Eastern Desert of Egypt at the intersection of coordinate 27°06'N and 33°16'E, at a distance of 95b Km from Hurgada City, at the Red Sea Coast. According to Mahmoud (2000), petrographical examination of GII fresh granite has revealed that it is mainly composed of orthoclase perthite (with subordinate microcline perthite), quartz and plagioclase beside minor amounts of biotite and muscovite Fig. 1. On the other hand, the accessory minerals are represented by zircon, fluorite, apatite and sphene[4].
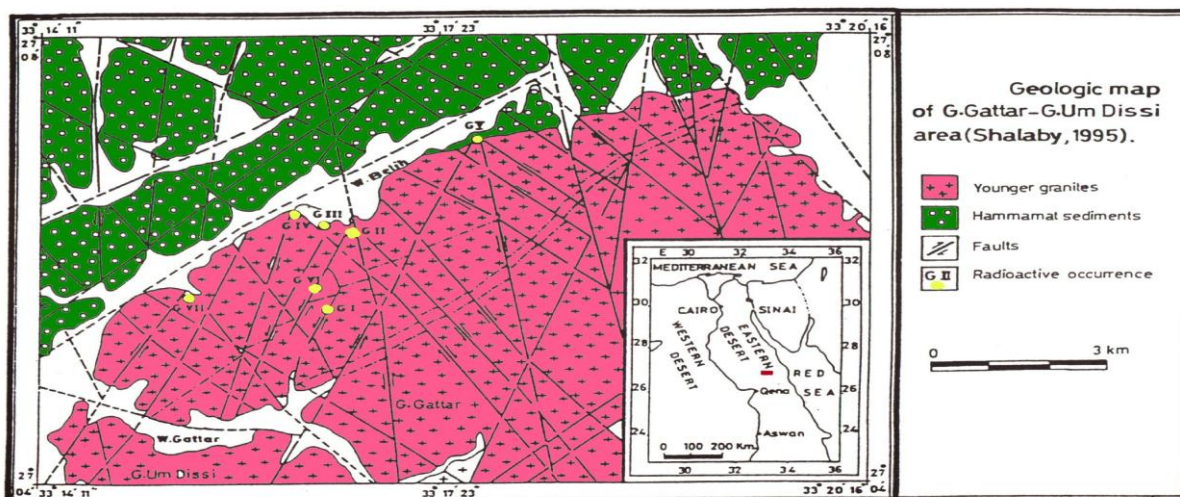

Figure 1: Geological map of G-Gattar

El-Missikat uranium prospect area lies at about 3 km, midway between Safaga, on the red Sea coast and Qena in the Nile Valley. It is roughly bound by longitudes $33^o15`$ - $33^o28`$ E and latitudes $26^o24`$ - $26^o30`$ N where the mineralogical studies revealed the presence of uranium minerals such as uranophane, uraninite, soddyite and renadite[5]. Gabal El-Missikat consists of rocks are essentially compound of quartz, potash feldspars, sodic plagioclase and biotitic. The main accessory minerals are sulfides, magnetite, zircon, apatite, fluorite, titanite, monazite, xenotime, uranothorite, rutile and uraninite. Hematite, epidote, muscovite and chlorite are present as secondary minerals [6, 7].
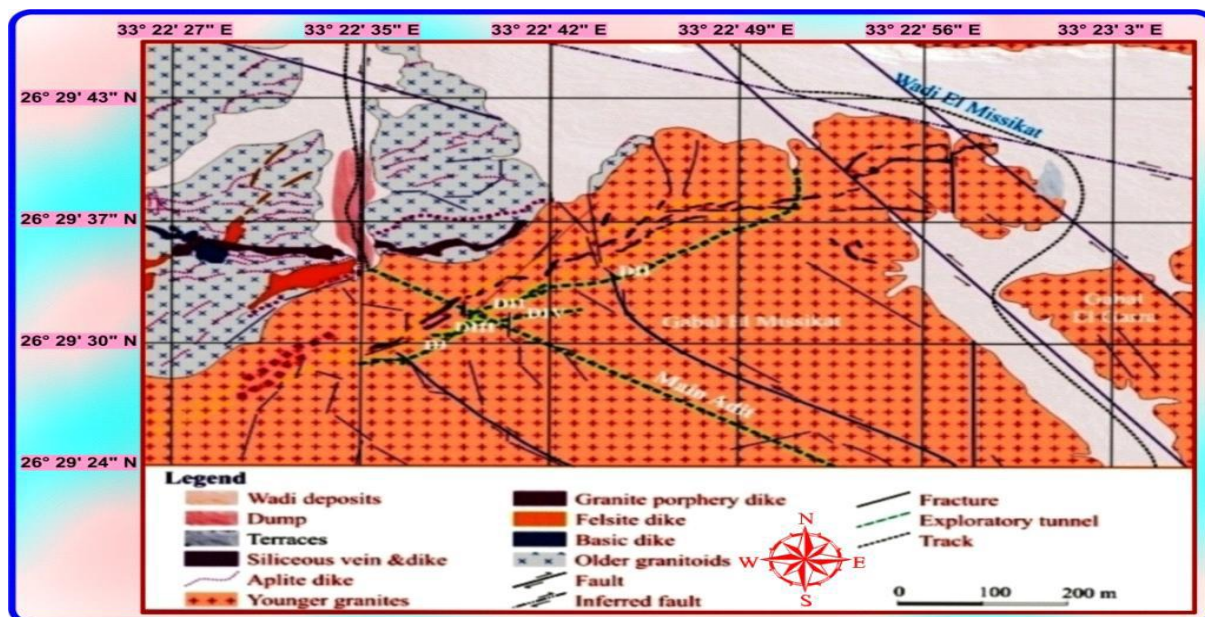
Figure 2: Geological map of El-Missikat area

Several studies have been achieved to leach U and associated elements from G-Gattar. The leaching of uranium and molybdenum from G-Gattar mineralization using acid and alkaline agitation leaching was studied. Acid leaching has indicated that complete leaching of U/MO by using 50g/l H_2SO_4 and solid/liquid ratio of 1/2 at room temperature for an agitation time of 12 hr. About 95.1% of uranium leaching efficiency was obtained at 60 ^{o}C for 8 hr by using 50g/l Na_2CO_3 or $NaHCO_3$ in case of alkaline leaching [8.9.10].

Uranium percolation leaching from both Gattar-II and Gattar-V mineralized samples was studied. From the results obtained, they notice that the particle size has a significant impact on the leaching efficiency. Regarding GII, the leaching efficiency (based on the solution) of –10 mm sample is 76.9%, but the leaching efficiency of –40 mm sample is 47.4%[11].

The leaching studies achieved on El-Missikat attained the efficiency reached to 91% after 8 hr of agitation [12]. In the same path, the contained REE leaching is studied with uranium recovery, which achieved leaching efficiency of about 95%.[13,14].Agitation and column percolation leaching techniques applied upon the uranium rich mineralization (El Missikat) showed that these techniques succeeded in providing considerable results [15].

Uraniferous iron grains from Gabal Gattar and El Missikat are similar in petrographic characteristics. Their grains are mainly composed of uranophane and β-uranophane coated and stained with limonite. They occur in fracture and cavity and usually attain an orange color due to staining with reddish brown limonite. These grains are closely associated with opaque minerals. Some of the uraniferous iron grains occur interstitially between quartz and perthite. Some other grains occur in the form of aggregates of needle-like crystals[16.17].

Due to the relatively low uranium assay and limited extension of the discovered occurrences, it was decided to investigate the possibility of applying the heap leaching technique for uranium dissolution from such small occurrences.

This research concerned with the amenability of heap leaching application via study the optimum conditions for uranium leaching from the two previous uranium mineralization ores, prior by application of column test as a laboratory view of heap leaching. Kinetics reaction models of column tests have been investigated to optimize the column leaching behavior.

2. Experimental

2.1. Characteristics of the study mineralized sample

The representative composite sample used in this study was obtained from Gabal Gattar and El Missikat mineralized by Nuclear Material Authority (NMA), Egypt having the chemical composition as shown in Table1.

Table 1: Chemical composition of GII and El-Missicat representative sample

Oxide	GII	El-Missikat	Trace Elements	GII	El-Messicat
	%	%		ppm	ppm
SiO$_2$	75.30	87.97	Mo	49	4
TiO$_2$	0.28	0.11	Co	5	5
Al$_2$O$_3$	10.30	3.4	Zn	220	400
Fe$_2$O$_3$	2.10	4.4	Ba	71	200
FeO	0.53	0.58	U	1300	1850
MnO	0.02	0.1	REEs$\sum$	85	130
MgO	0.50	1.16	Zr	30	200
CaO	1.69	0.55	Cu	16	100
Na$_2$O	3.50	0.078	Th	29	20.5
K$_2$O	3.40	0.068	Nb	88	87.5
P$_2$O$_5$	0.50	0.75	Sr	<2	201
L.O.I	1.60	1.7	Cr	4	Nil
Total	99.72	100.7	Ni	5	80
			Pb	87	417

As shown in Table 1, it is obvious the similarity in major oxides composed. Expect of containing the high silica in El-Missikat and more economic elements such as REEs, Ba, Cu and Sr , than GII sample they are the same.

All leaching testes were carried out in tap water using commercial grade H$_2$SO$_4$ (Merk) as the lixivant solution and A.R grade of other reagent used. The hydrogen ion concentration of the different solutions was measured accurately using the pH- meter model (HAANA pH-mV-temp).

2. 2. Uranium leaching procedures

2.2.1. Granulometric analysis

This type of analysis was performed upon 1.0 Kg of the study sample where it was subjected to crushing and sieving along with a range of sizes from - 1.25 to - 0.25 mm. After that, all fractions of grain size were analyzed to uranium determination.

2.2.2 Batch test conditions (agitation leaching)

To study and determine the optimizing factors affecting the acid agitation leaching of uranium, different series of agitation leaching experiments were performed after selecting the appropriate. Certain weight of the uranium mineralization, ground to appropriate size, was mixed well with a suitable volume of different sulfuric acid concentrations. The studied factors are, grain size, uranium distribution, agitation time, and sulphuric acid concentration.

% l eacheability = U concn in sample –Uconcn in residue×100

U concn in sample

2.2.3. Column test application

Leaching experiments were conducted using PVC columns (5 cm ×100 cm high) in case of column tests and (20*300cm height) in case of application test. To avoid the "side wall effect", the inner wall was polished with sandpaper in advance to increase the roughness. The top of the leaching column was opened; the bottom was reserved for the outlet of the duct to collect the leachate and was covered with 5cm layer of the 5-mm-thick quartz sand particles.

Table 3 summary and comparison of the column leach tests conditions.

2.2.4 Uranium control analysis

Uranium was analyzed in the corresponding low concentration of aqueous phases using ArsenazoIII reagent under different conditions[18].In high concentration ($\geq$ 10ppm) uranium was determined in the pregnant 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 [19].

3. Results and Discussion

3.1. Chemical composition of GII and El-Missikat uranium occurrence

As shown in pervious Table 1, Iron is present in a relativity high percent (2.1 and 4.4% as ferric oxide and 0.53 and 0.58 % as ferrous oxide in GII and El-Missikat respectively) and therefore require controlled leaching conditions to minimize its dissolution in order not to interfere with uranium during its recovery. So that, sulfuric acid is excellent reagent used to dissolve uranium. Since most uranium

minerals can be leached only when they have been oxidized, oxidizing conditions are maintained by ferric ions, which are generated by the oxidation of the ferrous ions present in solution[20] Oxidation effect could be achieved by pyrolusite (MnO) which exist as a major oxide in two operated samples (0.02 and 0.01%) respectively.

On the other hand, El-Missikat sample contains some deleterious elements such as Ti, Mo, Th, Pb and Zr at relatively higher to trace level than GII ore sample, and might cause either chemical poisoning and/or physical fouling in case of uranium extraction by ion exchange resin or else might accompany uranium during its purification by organic solvent extraction.[21] So that, the leaching solution concentration should be lower than 100g/l to avoid their dissolution. As Fe^{+3}/Fe^{+2} ratio greater than 2, it's needn't to adding oxidant to achieve uranium dissolution reaction[21,22].

Silicate and iron oxide gangue minerals consume sulfuric acid during initial reactions. Silicate minerals consume acid by breakdown to a wide range of soluble solution products. K-feldspar, Na-feldspar, Ca-plagioclase and Biotite breakdown to Ortho-silicic acid, H_4SiO_4, and various metal cations such as Na^+, K^+, Ca^{2+}, Fe^{2+}, and Fe^{3+}.

The ferric iron concentration in leach liquor is controlled by adjusting the redox potential by the addition of oxidant. For typical leaching conditions the relationship between the redox potential and their on concentrations is given by the Nernste quation[23]:

$$Ec = 397 + 0.19847 T \log([Fe^{3+}]/[Fe^{2+}]) \quad (1)$$

WhereEcisthesolutionpotentialrelativetothesaturatedcalomelelectrodeat 35°C(mV),[] is the molar concentration and T is the temperature(K). Equation(1) shows that at an oxidation potential of 400MV about 50% of their on is in the ferric state, while at 500mV only 2% remains as ferrousion.[22]

The presence of P_2O_5 might be harmful if the pH of leaching medium exceeds 2 where uranyl phosphate would precipitate. In the meantime, although such elements as V, Zr, Cr, Co and Ni are present in quite low levels in the ore, they might build up in the leach liquor if recycled several times , and cause several problems during uranium elution and precipitation of the final product. GII working ore material contains some valuable elements that might be considered for recovery to improve the economy of the ore processing although existing in low amounts e.g. Th, Nb, and REEs. On the contrary, El-Missikat, significantly contain moderate amount of REEs to reach to be economic.

Heap leaching technique produce a huge amounts of pregnant leach solution which get difficulty to pretreatment before loading, so that require low H_2SO_4 concentrate to keep the resulting leache at pH not exceed 1.5.In addition to decrease the solubility of other associated elements[24]. The rare earth mineral smonazite, xenotime, bastnaesite and florencite are all quite insoluble above a pH value of1.0at55°C [25]. However, synchisite (a fluorocarbonate containing calcium) and churchite(an yttrium phosphate) will dissolve under mild (pH value of 1.5) leaching conditions. Yttrium and the heavy rare earths are of ten

incorporated into of finite and, to a lesser extent, uraninite and brannerite. It is the dissolution of these minerals that contributes to the rare earth content of uranium ml each liquors[26].

3.2. Granulometric analysis of ore sample

Uranium distribution was investigated in the study sample for each grain size faction, Table 2 for determining the most suitable size to achieve the aim of the study.

Table 2: Granulometric analysis and uranium distribution in the sample

Size (mm)	GII			El_Missikat		
	Fraction weight, (g.)	Size distribution wt.%	Assay of Uranium, ppm	Fraction weight, (g.)	Size distribution wt.%	Assay of Uranium, ppm
+1.25	140	14.0	70	140	14.0	41
-1.25 to +0.5	437	43.7	122	437	43.7	33
-0.5 to +0.25	180	18.0	149	180	18.0	9.4
-0.25	245	24.5	350	245	24.5	17
Total	1002	100.2	172	1002	100.2	100.4

3.3. Relevant factors of uranium acid leaching from Gattar and El Missikat uranium mineralization

The experiments were designed to study the effects of several variables on uranium recovery, acid consumption, solid\liquid ratio, grain size, contact time, and PLS pH.
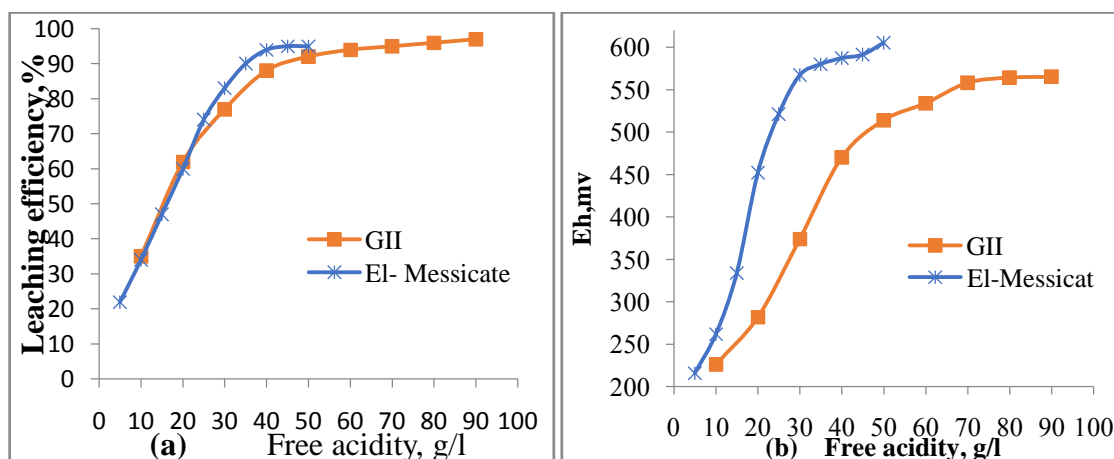
3.3.1. Free acidity effect

Figure 3: Effect of (a)free acidity b) Eh on leaching of uranium

From the obtained data shown in Figure 3, it is clear that, the uranium leaching efficiency increases as periodically from 35 to 92 %, as the acid concentration of leach solution increases from 10 to 50 g/l , then tends to stability after that. On other hand, behavior shows considerably increase in uranium leaching efficiency (17 to 94) with lower increase in acidity (5 to40g/l).

From these data, it is concluded that the iron content in the ore sample play important role in the leaching efficiency, which accelerate the uranium dissolution with lower acid need.

Figure 3b can show more data which verify the above conclusion. Since, the redox potential increases in leaching process more rapid in El-Missikat than GII ore sample. From these data, it is concluded that an economically 40 and 50g/l acid concentration is the best one for El-Missikat and GII respectively.

3.3.2. Effect of agitation time

Leaching experiments were performed over a range from 30 up to 200 min. Other variables were fixed at the leaching conditions of 40 g/l sulfuric acid, 1/2 solid /liquid ratio, at 25 ^{O}C temperature and grain size of -0.25 mm. The obtained data show that uranium leaching efficiencies increase with increasing contact time achieving its maximum after 120min. Increasing time over 120 min was found to be ineffective as shown in Figure 4.
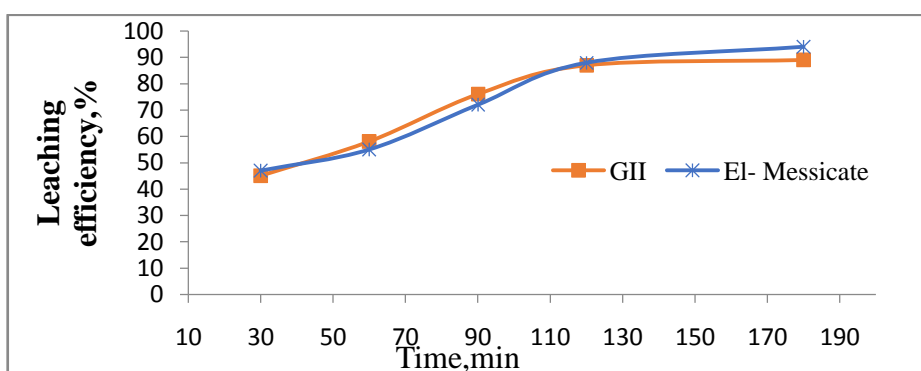

Figure 4:Effect of contact time on leaching of uranium

3.3.3. Solid/liquid ratio

The effect of solid/liquid ratio on the dissolution of uranium was studied using 1:1, 1:2, 1:3,1:4 and 1:5 solid/liquid ratios, while the other testing parameters comprised at 40g/l sulfuric acid conc., 180 min. agitation time, 25°C temperature, and 150 r.p.m. agitation speed. The results are shown in Figure 5.
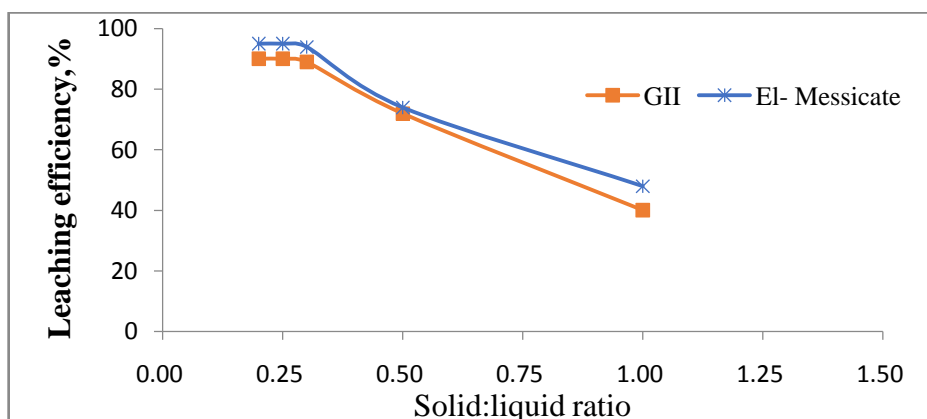

Figure 5: Effect of solid: liquid ratio on leaching of uranium

The amount of solid was kept constant, and the liquid volume was changed to obtain the desired solid/liquid ratios. From these data, it was found that beyond 1/3 S/L ratio, only slight

steady increase in the leaching efficiencies of uranium has been achieved. Accordingly, a solid ratio of 1/3 would be considered as optimal ratio at which the uranium leaching efficiency of attained 89 and 92 % for El-Missicat and GII, respectively.

3.3.4. Effect of Grain size

The effect of the grain size on the uranium leaching efficiency is achieved by studying the grain size of mineralized samples ranged from + 1.25 to − 0.25 mm. Other leaching conditions were fixed at 40 g/l acid concentration, 1/3 solid/liquid ratio for 120min agitation time at room temperature. The results obtained are shown in Figure 6, as shown uranium leaching efficiency has increased from 48 to 89% and 52 to94% for El-Missicat and GII, respectively with decreasing the crashed size from +1.25 to -0.25 mm. This can be explained by the fact that by decreasing the grain size, the surface area exposed to the reaction increases and hence the percentage of extraction also increases.
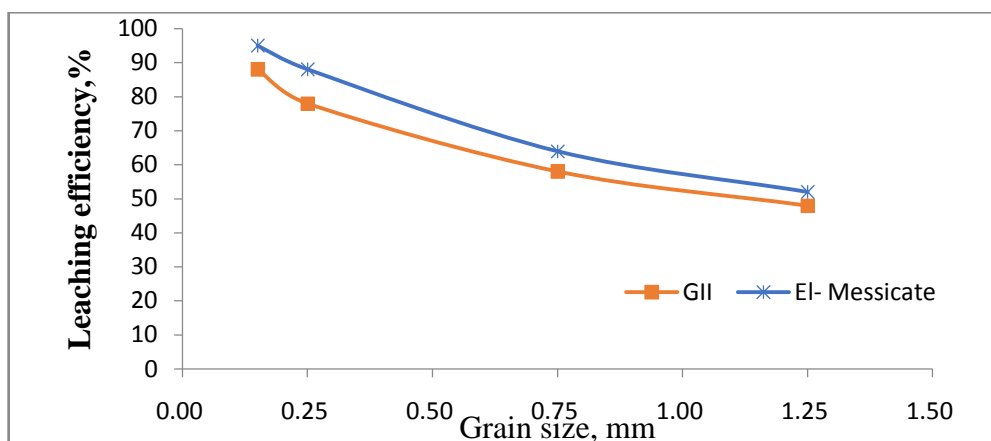

Figure6: Effect of grain size of ore sample on leaching of uranium

3.4. Column percolation leaching

Column leaching (5.0cm diameter and 100cm high) experimental was performed to study the effect of the following parameters on uranium dissolution and acid consumption: ore particle size, application rate, Iixiviant acid concentration, ore height, and ore grade. The experiment was expected to generate a reduction in acid consumption without affecting uranium dissolution.

3.4.1. Free acidity effect

The effect of the H_2SO_4 concentration was studied from 20 to 50g/l on the uranium leaching efficiency on column during 25day at room temperature with -0.25mm.The derived plotted figures7(a,b) shows that the same result that obtained on the batch experiment. Since, the uranium increase with free acidity increase and tend to be stable as free acidity increase from 40 to 50g/l.
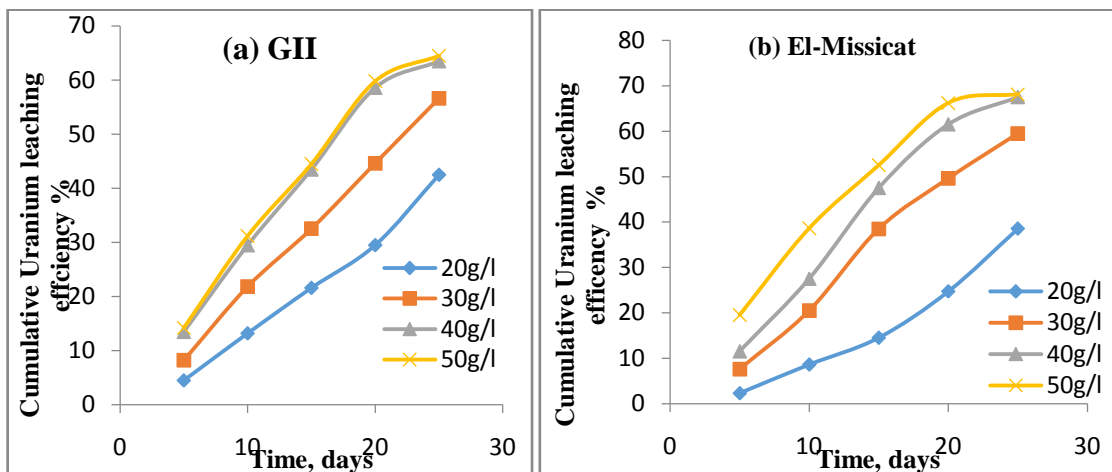
Figure 7: Effect of free acidity on uranium leaching during column leaching of GII and El-Missicat

3.4.3. Effect of Grain size

In this type of leaching the columns were packed with differing the particle size from +0.25 to -0.25 with fixing the other conditions, 30g/l H_2SO_4 and 1/3 solid liquid ratio were achieved during 25 day. Their plotted Figures 8 (a,b) shows the directly increase in uranium leaching with decrease in the particle size which owing to the increase in the particle surface area at which the reaction takes place.
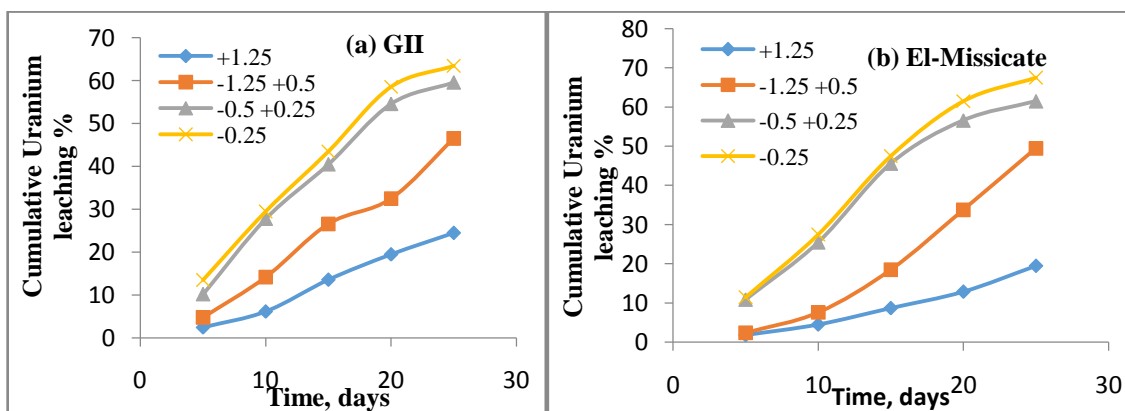

Figure 8:Effect of grain size on leaching of uranium during column leaching of GII and El-Missicat

3.5. Column kinetic reactions

As shown in pervious figures there are evident that the mechanism of leaching of the short-time (batch experiment) is different from that of the long-time (column experiment). Since the slopes for the curves at these periods (120min for batch and 25 day for column) are noticeably different.

The dissolution kinetics of uranium was studied to understand the rate-controlling step and to optimize the leaching process. As uranium leaching is heterogeneous reaction including

more than one phase, specifically fluid and solid phase, shrinking core model (SCM) for spherical particles of unchanging size can be used to study the kinetics.

With respect to the study of the liquid–solid reaction kinetics, many different mathematical models of kinetic reactions, such as the unreacted core shrinking model, and the particle model, have been proposed. One of the most important models is the unreacted core model, which has been successfully and extensively used.

Based on the research results of Z. Ekinci, the uranium ore leaching fractal dynamics can be studied with the unreacted core model and the reaction is shown as follows[27] :

A$_{(fluid)}$ + B$_{(solid)}$Products $\longrightarrow$
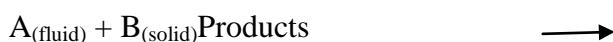
If the action is controlled by a chemical reaction, the reaction kinetics is given as follows:

$$1-(1-X)^{1/3}=K_1t \quad (3.1)$$

Where X is the ratio of the accumulated amount of the leached uranium to the total content of uranium in the ores, and K is the uranium dissolution rate (g d^{-1}).

If the action is controlled by diffusion through a metal-ore surface, the reaction kinetics equation can be written as follows:

$$1-3(1-X)^{2/3}+2(1-X)=K_2t \quad (3.2)$$

Applying a regression analysis to the tested data by using these equations, it is found that the rate of the uranium metal dissolution is controlled by the chemical reaction and the diffusion reaction. Based on the leaching results of two mineralized samples, the integrated rate values of the leaching for every tested sample are described by equations (3.1) and (3.2) and shown in derived figures.

3.5.1. Effect of free acidity

Figures 9$_a$ (GII and El-Missikat) derived from pervious column tested results, shows that 30g/l H$_2$SO$_4$ is the excellent concentration for applying the column leaching in two mineralized samples on basis of chemical reaction model.

On basing the diffusion model as shown in Figures9$_b$(GII and El-Missikat), the situation differ than in chemical model. Since, the 40 and 50g/l are preferred concentration for GII and El-Missikat mineralized samples respectively. Thus, the speed of the uranium dissolution reaction increases, and the chemical reaction control occurs much earlier than the diffusion reaction control in the leaching experiment.

In order to obtain the reaction order for the total H$_2$SO$_4$ concentration, log-log plots of the rate constants versus the total H$_2$SO$_4$concentration are plotted and given in Figure 10.The reaction

order was determined to be about 0.920 and 0.983 for GII and El-Missikat mineralized samples respectively, which indicate strong dependence of the rate on H_2SO_4 concentration.
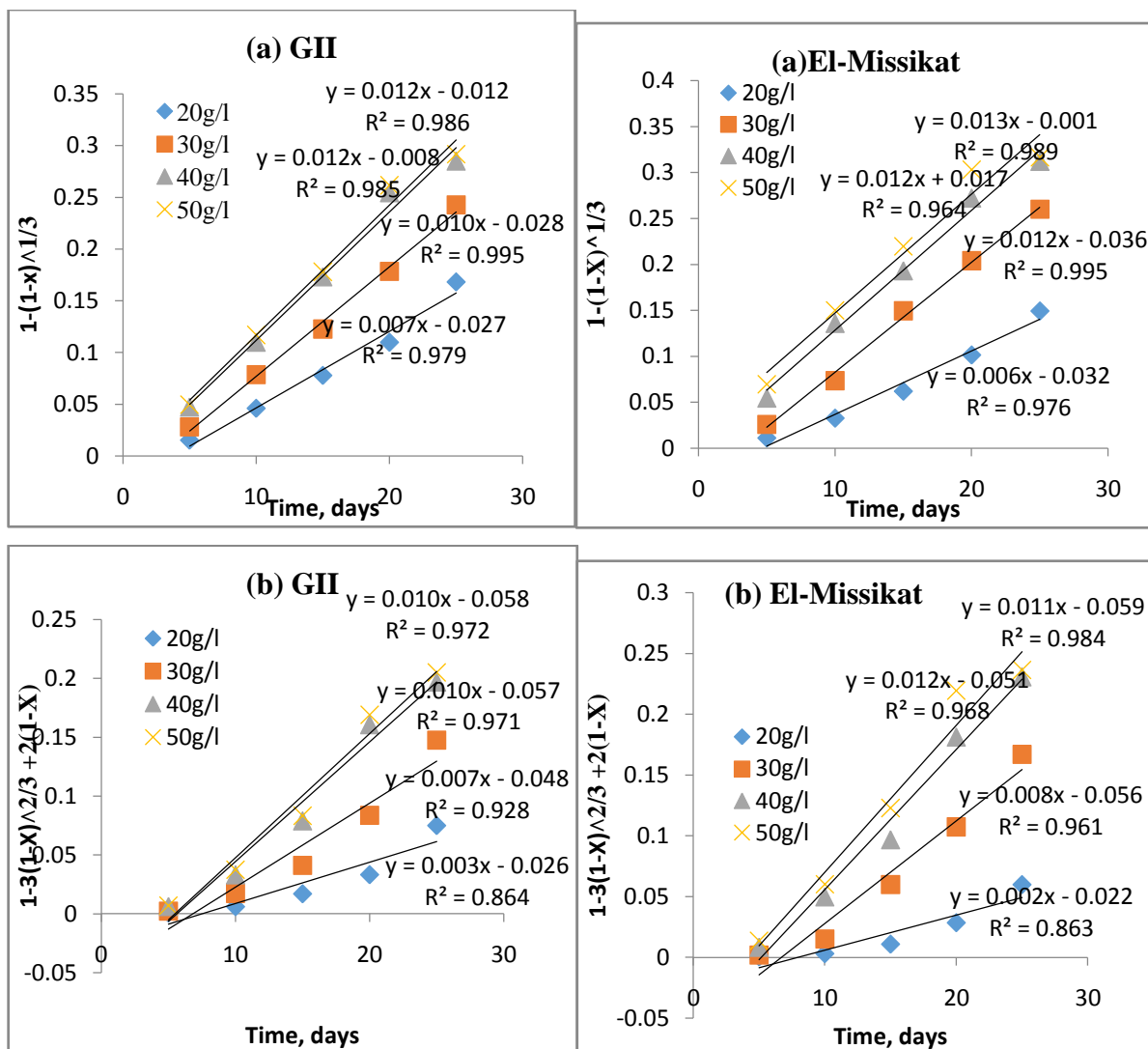

Figure 9: The kinetic curve of uranium leaching with different H_2SO_4 concentration based on different models. (a) Chemical reaction contro (b) Diffusion reaction control
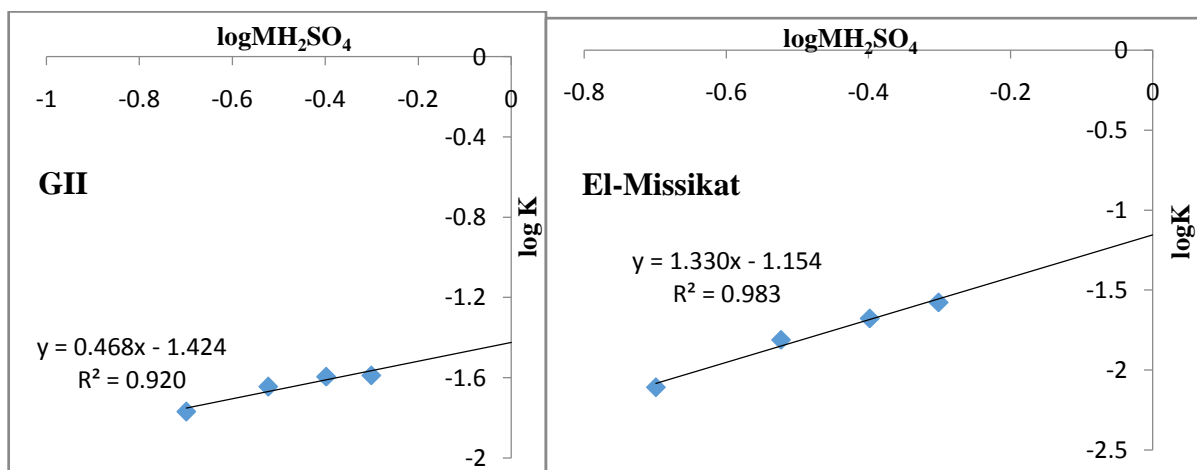

Figure 10: log-log plot of the rate constant versus H_2SO_4 concentration.

3.5.2. Effect of Grain size

Figures 11a, shows the integrated rate values of the leaching kinetic for the mineralized samples with different fractal dimension based on the chemical reaction control model. The reaction rate reaches a maximum value after 20day, where showed excellent result at(-0.5 to +0.25) and -0.25mm in case of GII and El Missicat mineralized samples respectively. Since give the higher slops 0.986 for two sizes of two mineralized samples.

Figures 11b, which based on the surface diffusion reaction control model shows lower slopes of dissolution rate curve than other of the chemical reaction control model. This can be attributed to the dependence of uranium dissolution rate on surface diffusion reaction control than chemical one. However, as the chemical reaction goes on, the heat of the chemical reaction has been accumulated and the movement of the molecular collision has been aggravated, then the leaching solution diffuses into the nucleus of the ores gradually; afterwards, the diffusion reaction rate also increases gradually.
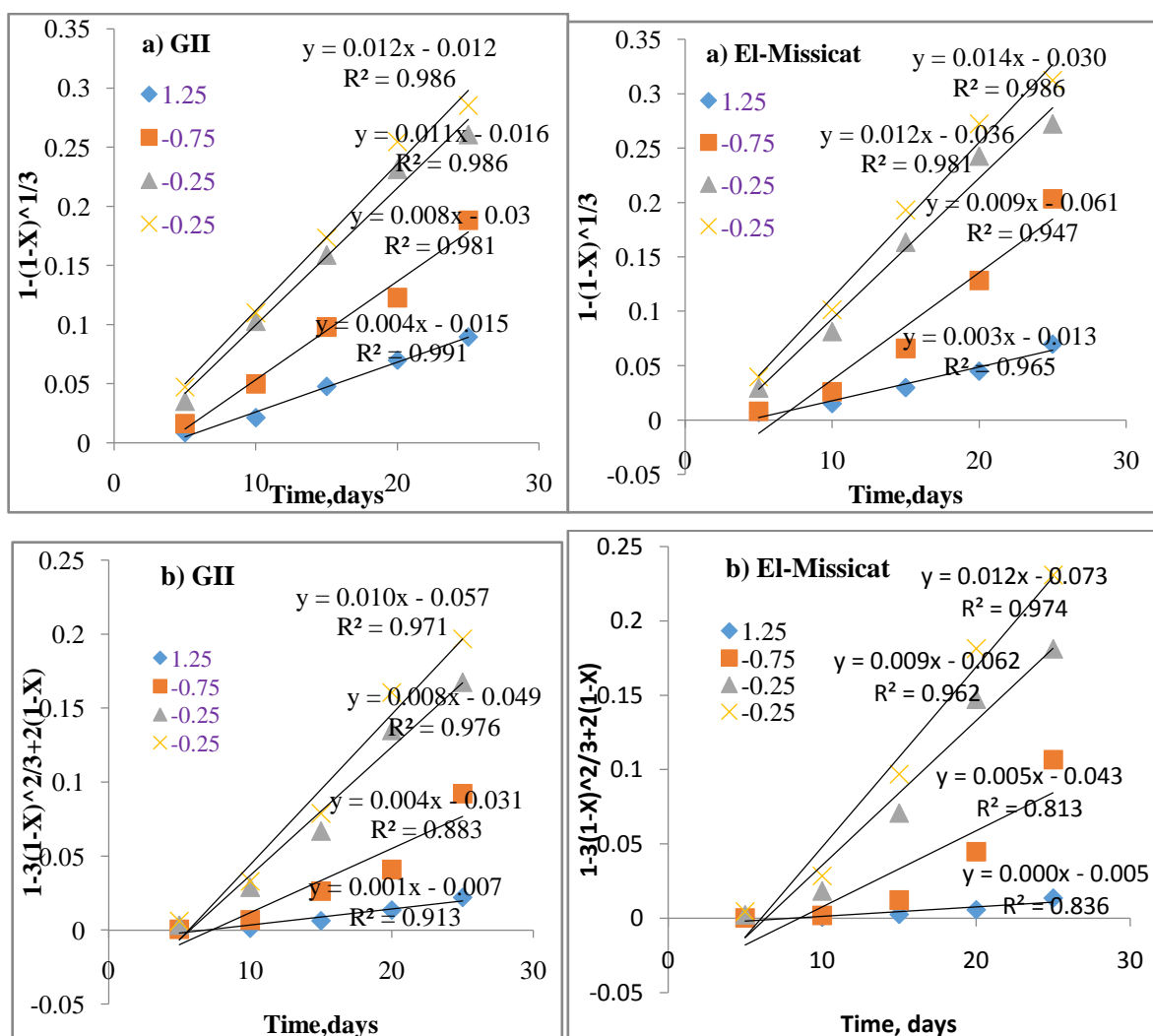

Figure 11: The kinetic curve of uranium leaching with different particle size based ondifferent models.
(a) Chemical reaction control; (b) diffusion reaction control

The apparent rate constant was determined and plotted versus the initial average particle size and the results are shown in Figure 12. The linear relationship between the rate constant K, and the particle size indicates that the ash layer diffusion reaction on the particle surface is the rate-limiting step of the dissolution process. As shown in Figure 12, GII ore samples gives higher slop than El-Missicat one, which indicate that GII ore samples gives higher dissolution rate with particle size decrease than El-Missikatone.
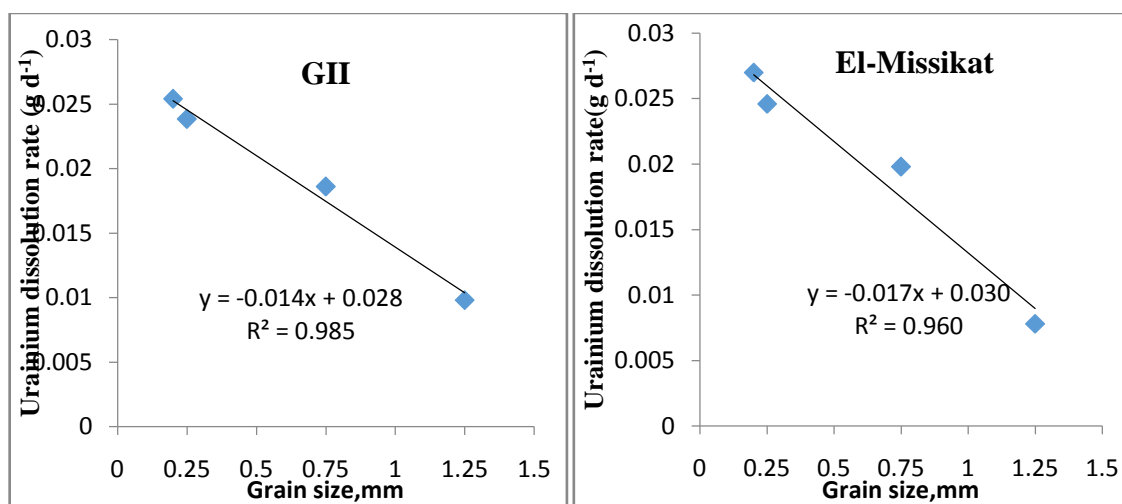

Figure 12: Plot of the Uranium dissolution rate constant versus the average of the particle size

3.5.3.Column leaching application

The conditions of application needed to be determined in order to prepare of pilot plant scale. Experiments were implemented on large column scalein order to make more condition control and evaluate the time and reagents needed in the large scale.Uranium leaching efficiency and consumed reagents would be calculated and plotted to each other to be illustrated.

Table 3: The results of column percolation leaching experiments as a guide for a future pilot plant scale

Items	G-II	El-Missicat
Ore weight, (Kg)	140	140
Average uranium, mg/Kg	1300	1850
Grain size, mm	-10	-10
Leaching acidity, g/l	40~20	60~20
Sprinkling intensity, $L/m^2/hr$	10	10
Leaching efficiency, %	78.3	86.6
Leaching period, d	44	40
Consumption of H_2SO_4 g	1360	1120
Consumption of H_2SO_4, g/kg	34	28
Accumulative L/S ratio	1.925	1.41
Total uranium, g	182	231
Total leached uranium, g	142.5	200

Figure 13$_a$, illustrate the uranium leaching efficiency versus time, since, the leaching efficiency reached maximum value at 78.3% after 44 dayfor GII uranium mineralization, while in El-Missicat samples 86.8 % leaching efficiency was reached after 40 day. Then leaching efficiency tends to be stable since the uranium dissolution rate will decrease incalculably. That could be attributed to limitedness the diffusion and chemical action at following days.

By measuring the pH and Eh along experiment and plotted versus time, as in figure 13$_b$, we could pursed the column behaviour.As shown, Eh increase with time owing to the increase in iron dissolution rate with uranium. Eh has been increased progressively in El-Missicat than GII leaching ,which can be attributed to iron abandantaly in El-Missikat.
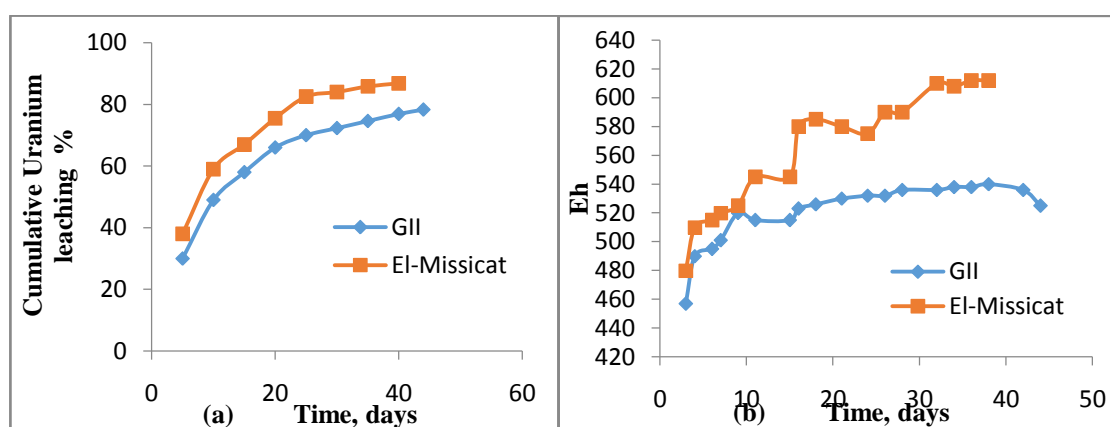

Figure 13: a) Uranium leacheabiltyandb) leach liquor Eh versus time

In general an increase in H_2SO_4 followed by pH decrease, which in turn makes it possible to dissolve Iron (III) required in uranium dissolution. Iron (III) leaching solutions are sensitive to pH changes. It is necessary to keep pH under 2 to prevent the Iron (III) to be precipitated as the hydroxide. So So that, the addition of sulfuric acid concentration on leach solution differs along the leaching time depending on the resulted leach liquor pH.
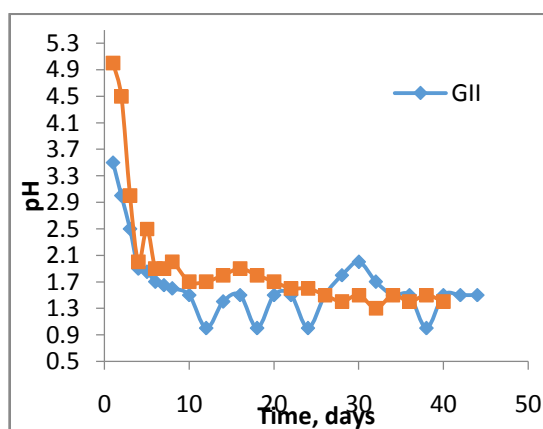

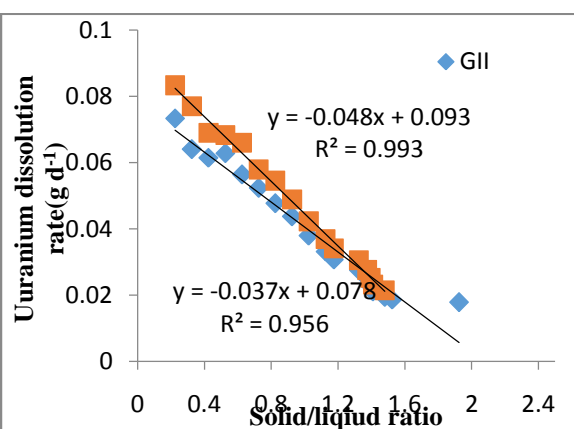**Figure 14:pH behavior during column test versus time accumulated**

Figure 15:Plot of uranium dissolution rate versus solid/liquid ratio

Figure 14, shows the change on pH with time on the uranium leaching treatment on column test, since being in high value then decrease to about 1.7~1.5 until the treatment finish. pH is kept between 1.7~1.5 to limits the desolation of other uranium associated elements.

For more verification of column leaching test to adjust the reagent amounts used, solid/liquid ratio is measured during leaching and plotted versus uranium dissolution rate as in Figure (15). Slops of two curves are 0.956 and 0.993 for GII and El-Missicat ore samples, which indicate that, suited of liquid/solid ratio used for uranium dissolution and the higher uranium dissolution rate in El-Missicat than GII.

To examine the uranium dissolution behavior in column test during leaching, the two controlling reaction model were applied and plotted as in figures (16$_{a,b}$).As shown, there are the preferably diffusion reaction model than chemical one and the higher slops of El-Missikat than GII ore samples. This can attribute to that weight abundance of uraniferous grains amounts to 17.50%, 21.00% for GII and El-Missikat respectively (16).Which reflected to the chemical reaction model slops 0.908, 0.916 for and El-Missicat respectively**.**
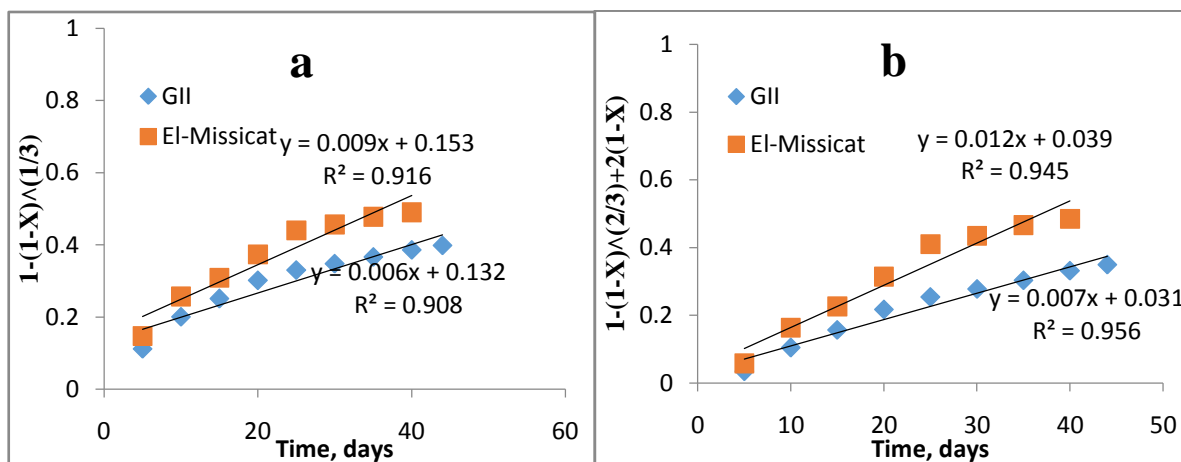

Figure (16): The kinetic curve of uranium leaching of GII andEl-Missicatore samples based on different .models. (a) Chemical reaction control; (b) diffusion reaction control

According to figure (14), the leaching trend changes during the experiment, confirming that there are at least two stages in the leaching of uranium ores. Uranium leaching require acidic solution with high concentration to adjust the pH &Eh of ore sample and resulted leach liquor in the first stage which obey the chemical reaction control and diffusion reaction control models . Second stage proceed with solutions of less free acidity to keep the pH value about 1.7~1.5 and uranium concentration in available value, which obey the diffusion reaction control.

4. Conclusion

The amenability of heap leaching of uranium from low grad ores of GII and EL-Missicat were investigated via batch and column tests. Kinetics models were applied on column leachingtests to understand the rate-controlling step and to optimize the leaching process. A diffusion reaction control was more predominate than a chemical reaction control. Finally, the obtained optimum conditions were applied on big column, and then the leaching behavior was analyzed and studied, besides verified by kinetic models in order to prepare of the pilot scale.

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