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MICROBIAL LEACHING OF SOME VALUABLE ELEMENTS FROM EGYPTIAN PHOSPHATE ROCK

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ABSTRACT

Four phosphate rock samples representing different phosphate mineralization modes in Egypt were selected from Abu Tartur, Nile valley and Red sea areas. Factors affecting the phosphate rock solubilization and some of the contained valuable elements by *Aspergillus niger*, *Penicillium sp.* and *Pseudomonas fluorescens*, were studied with especial orientation towards the completion of phosphate rock samples solubilization especially the low grade one. Effect of nitrogen source type on leaching efficiency by *Aspergillus niger* when two nitrogen sources on the phosphate bioleaching efficiency, it is clear that the ammonium chloride is more favorable as nitrogen source than sodium nitrate in the bioleaching of phosphate rocks. When *Aspergillus niger* was applied under the following conditions: 50 g/l of sucrose as a carbon source, 0.1 N of ammonium chloride as a nitrogen source, 10 days incubation period, 0.5% solid: liquid ratio for P_2O_5 and 5% for U and REE and -270 mesh of grain size. The optimum leaching of P_2O_5 , U and REE from phosphate rock samples reached (23.27%, 17.4%, 11.4%, respectively), while at -60 mesh they reached to 16.58%, 28.9%, 30.2% respectively. The optimum conditions for the maximal leaching efficiencies of P_2O_5 , U and REE when applying the *Penicillium sp.* from the phosphate rock samples were: 100 g/l of sucrose as a carbon source for P_2O_5 and U and 10 g/l for REE, 7, 15 and 10 days incubation period for P_2O_5 , U and REE, respectively, 0.5% solid: liquid ratio for P_2O_5 and 5% for U and REE. Finally, the application of phosphate rock samples grinded to -270 mesh of grain size for P_2O_5 and (-60 to -140) for U and REE. The studied leaching efficiency of P_2O_5 , U and REE gave at -270 mesh 33.66%, 24.3%, 15.9% respectively, while at -60 mesh they gave 33.76%, 26.7%, 17.8% and at -140 mesh gave 31.32%, 27.9%, 17.6%, respectively. The optimum conditions for the P_2O_5 leaching efficiency when applying the *Pseudomonas fluorescens* were: 10 g/l of beef extract, 10 days incubation period, 0.5% solid: liquid ratio and -270 mesh of grain size reaching 79.35%. The same behavior was traced for both U and REE leaching efficiencies thus they reached 57.4% and 37.6%, respectively. While the attained results showed that the non sterilized rock is more favorable and the addition of phosphate rock after the incubation of organism for 4 days gave the higher efficiency than the addition of rock at the beginning of experiment.

INTRODUCTION

Nuclear energy shares nowadays with about 20% in the total world energy production even if exposing to a lot of criticisms from

the green parties all over the world. Uranium has become a widely used source for nuclear energy and is considered the main fuel, starting with exploration, mining of uranium ore

rocks, and milling the uranium ore materials to reproduce the base material for the uranium fuel cycle (Abd El-Latif, 1998). Uranium resources in Egypt can be classified into two main classes namely: the conventional (mined and milled basically as the main product for uranium) and the non-conventional (uranium production as a by-product). The Nuclear Materials Authority (NMA) has actually discovered seven conventional uranium resources in various Egyptian territories in the Eastern Desert and Sinai Peninsula. The Egyptian phosphate reserves are estimated by about 1.3 billion tons while the geological reserves reach 3000 million tons (Mahdy, 2009). The average assay of uranium in the Egyptian phosphate ores is 60 ppm, consequently, the phosphate assured reserves are estimated to contain about 40,000 tons uranium at least (NMA Internal report, 1992). Leaching of phosphate rock means mainly the dissolution of some strategic and economic rare metals such as fluorine, iron and phosphorus. The later is used in nearly 50% of the known industries. A new trend for solubilizing phosphate ores (especially the low grade ones) by microorganisms such as fungi and bacteria is developing. This trend is actually encouraged due to environmental and economical concerns. Microbial bioleaching of low-grade deposits makes the industrial application of these ores more economic. This occurs by two means: the first when microorganisms are able to change the redox state of the contained elements rendering them to be more soluble whereas the second when microorganisms attack the ore and release solubility reagents such as organic and inorganic acids that can solubilize these interested economic elements. Vassilev and Vassileva (2003), studied the biotechnological techniques of rock phosphate solubilization processes involving agro-industrial residues. The authors compared between the advantages of composing solid-state fermentation and liquid submerged fermentation employing free and immobilized microorganisms that produce organic acids and simultaneously solubilize the phosphate rock. They stated also that when introducing the fi-

nal fermented products into soil, plant systems promote the growth as well as phosphorous acquisition. Over 50% of the dissolution efficiency of the phosphate ores is achieved by phosphate dissolving microorganisms such as *Asperigillus niger*; *Penicillium sp.*, *Thiobacillus ferrooxidans*, *Thiobacillus thiooxidans* and *Rhizobium sacharomyces*. A highly significant correlation was found between the numbers of total phosphate-solubilizing fungi and the total phosphorous levels in cultivated and virgin Alberta soils (Kucey, 1983). The solubilization of phosphate from a phosphate containing ore was achieved by Rogers et al., (1993) through treatment with the bacterium *Pseudomonas cepacia* and the fungi: *Aspergillus niger*; *Aspergillus phenicis*, *Penicillium sp.* and *Chrysosporium sp.* which allow phosphorous from an aqueous mix of phosphate ore to be recovered.

The main target of this study is the applying microorganisms (fungi and bacteria) which considered as one of the most important and promising nowadays trends for the bioleaching and upgrading of low grade ores such as phosphate ores which have a confirmed reserve in Egypt. Many factors have been studied to achieve nearly complete dissolution of the valuable and strategic elements such as uranium, P_2O_5 and REEs.

EXPRIMENTAL

Material and Methods

Ore samples

The ore samples were collected from three Egyptian phosphorite occurrences namely, Nile valley (El Sebaiya locality), Red Sea (Safaga locality) and Western Desert (Abu-Tartur locality) representing the three different commercial phosphate belts present in Egypt.

Chemical composition of the studied phosphate samples

Chemical analyses of the major oxides of phosphate rock samples were carried out in

the laboratories of the Egyptian Nuclear Materials Authority (N.M.A.) according to the method described by Shapiro and Brannock (1962). The major oxides include SiO_2 , Al_2O_3 , CaO , MgO , Na_2O , K_2O , MnO , TiO and Fe_2O_3 . Trace elements were determined by the X-Ray Fluorescence technique on fused pellets using a Philip X Unique II instrument model PW 1510 and by Flame Atomic Absorption Spectrometry Unicam 969 produced by Unicam Company-England.

Microbial isolates

The two fungal isolates are used in the dissolution of phosphate rock samples were obtained from the oxidized Abu-Tartur phosphate ore by serial dilution method, in addition to one isolate from the root of wheat plant from El Meniufiya governorate. Bacterial isolate (*Pseudomonas fluorescens*) was isolated from two locations in Sinai (Abu Thour and Allouga).

Phosphate ore processing

Phosphate bioleaching experiments were performed by shaking 100 ml of sterilized C'zapeks-dox Broth medium in 250 Erlenmeyer flasks inoculated with 5 ml of stock spore suspension and incubated for 4 days then 0.5 g of sterilized phosphate rock was added (0.5% w/v) and incubated for another 6 days except otherwise mentioning. After filtration of the bioleaching solution, the soluble P_2O_5 was analyzed by the previously mentioned methods.

Application of pyramidal method for phosphate bioleaching

The target of applying the pyramidal system in the bioleaching of phosphate rocks by microorganisms was to enrich the leach liquor to the maximum concentration extent as well as to exhaust the treated phosphate rock to the minimal P_2O_5 , U and REE concentrations. The promotion of the leach liquor concentration was performed by adding new phosphate rock sample to the leach liquor obtained from the previous experiment. However, the exhaus-

tion of the P_2O_5 , U and REE in the treated phosphate rock sample was achieved by the addition of new media (without any organisms) to the leached phosphate rock sample. The leaching experiments were conducted using the obtained optimum conditions while the used fungus was the *A. niger*. After completing the bioleaching experiments, the pulps were filtered and the leached solutions were analyzed for their P_2O_5 , U and REE. The used technique was previously applied by El Hazek and Mahdy (1993), in the liquid-liquid extraction of uranium and in the elution of uranyl carbonate from a strong base anion exchange resin. The pyramidal batch-contact method shown in (Fig. 1) uses a phosphate rock-solution- transfer technique similar to Treybal's counter current contact technique for liquid-liquid batch shake-out experiment.

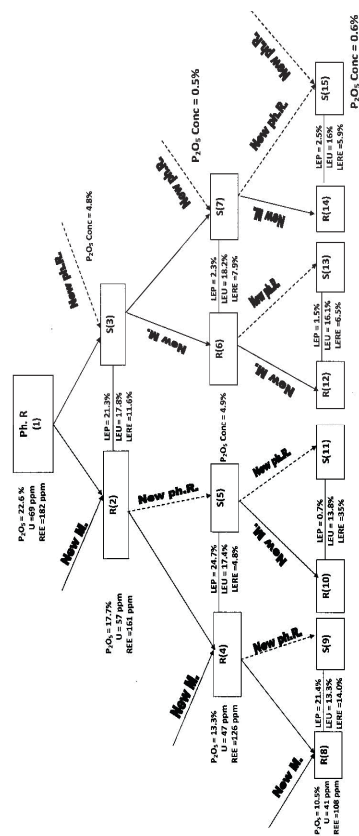


Fig. 1 : Bioleaching of phosphate rock samples using *Aspergillus niger* by applying the leaching pyramidal system

Ph.R.=Phosphate rocks, R=Residue, S=Solution, Conc.=Concentration, M.=Media, LEP=Leaching efficiency of P_2O_5 , LEU=Leaching efficiency of uranium, LERE= Leaching efficiency of rare earth elements (REEs)

RESULTS AND DISCUSSIONS

Chemical Characteristics of Phosphate Sample

Table (1) shows the chemical composition of the phosphate samples obtained from the Nile

Table 1 : Major oxides (%) of the phosphate rock samples

Sample	El Sebaiya			Safaga (Red Sea)			Abu-Tartur		
	1	2	3	1	2	3	Non-Oxidized	Oxidized	
P ₂ O ₅	22.50	24.88	26.90	19.30	19.35	25.30	21.36	27.32	23.40
CaO	44.90	43.52	44.60	46.09	43.94	43.70	43.83	40.17	43.02
Fe ₂ O ₃	2.72	2.27	3.00	1.40	1.20	1.40	3.06*	2.93	3.10
SiO ₂	16.30	12.18	17.80	14.90	3.71	8.70	9.00	6.13	6.80
Al ₂ O ₃	1.28	1.83	—	1.53	2.21	—	0.53	1.70	—
Na ₂ O	1.22	1.62	—	1.40	1.73	—	1.33	0.72	—
K ₂ O	0.11	0.12	—	0.11	0.16	—	0.17	0.13	—
MgO	1.15	1.52	0.36	1.26	5.30	1.37	1.33	1.26	2.83
Cl	0.26	0.55	0.20	0.53	0.45	0.60	0.27	0.17	1.20
CO ₂	2.26	8.66	—	4.22	17.02	—	7.20	7.25	—
SO ₃	3.80	3.73	0.90	8.98	1.35	3.10	7.90	8.75	3.80
F	2.63	1.16	2.90	0.02	1.21	3.10	3.40	3.00	3.10
H ₂ O	0.1	—	—	—	—	—	0.5	—	—
Total	99.23	101.54	94.66	100.04	97.63	87.27	99.87	87.43	99.75

(1): present work
(2): Salih, 2006
(3): Dabbous, 1981

(—): Not analyzed
(H₂O): at 110 °C for 2 hours
(*)Fe total

Valley (El Sebaiya), the Red Sea (Safaga) and from the New Valley (Abu Tartur). The trace elements analysis data of the studied phosphate samples are shown in Table (2).

Table 2: Trace elements analysis data (ppm) of phosphate rock samples

Sample	Elements	El Sebaiya	Safaga (Red Sea)	Abu-Tartur	
				Non-oxidized	Oxidized
U		69	46	23	32
Th		14	10	12	11
V		368	123	204	277
Cd		5	19	11	9
Pb		10	20	2	13
Cu		11	24	25	21
Cr		141	14	72	86
Co		4	6	8	11
Zn		133	142	67	71
Sr		681	377	40	34
Rb		24	35	118	66
Y		35	38	78	51
Zr		37	30	72	63
Ni		13	4	15	22
REE	HREE	61	54	482	313
	LREE	121	119	884	423
	Σ	182	173	1366	736

Application of Fungal and Bacterial Isolates for Phosphate Samples Bioleaching

Bioleaching technique has been applied in this study to dissolve the P₂O₅, U and REE from phosphate rocks through performing the previously mentioned experiments. Explaining some of the phenomena took place during studying different factors can be briefly presented as follow where the following factors were studied upon *Aspergillus niger*, *Penicillium sp.* and *Pseudomonas fluorescens*. The obtained results from each organism along the studied factors are summarized in Table (3).

Table 3: Factors affecting phosphate bioleaching efficiencies by micro-organisms

Factor Range	<i>Aspergillus niger</i>			<i>Penicillium sp.</i>			<i>Pseudomonas fluo.</i>		
	P ₂ O ₅ %	U%	REE%	P ₂ O ₅ %	U%	REE%	P ₂ O ₅ %	U%	REE%
Sugar or nutrient conc. (g/l)	1	---	---	---	---	---	73.8	35.5	24.8
	3	---	---	---	---	---	77.35	42.06	27.7
	5	---	---	---	---	---	76.6	56.08	34.7
	10	8.15	6	27.5	28.24	6.96	79.35	83.2	62.5
	30	15.3	12	18.2	28.43	15.31	---	---	---
	50	23.9	17.4	11.4	33.42	30.62	8.36	---	---
	100	18.6	29.05	2.8	33.66	36.19	0.05	---	---
	1	20.9	21.2	7.8	26.24	40.71	8.06	70.1	12.8
	3	---	---	---	27.57	36.7	10.4	71.1	19.2
	4	23.04	18.6	9.1	---	---	---	---	---
Contact time (day)	5	23.9	17.4	11.4	---	---	---	---	---
	7	---	---	---	33.66	36.19	18.6	79.35	25.6
	8	19.5	17.3	9.6	---	---	---	---	---
	10	30.42	17.1	18.2	39.1	33.01	82.35	82.35	43.6
	15	36.18	16.1	27.3	18.25	38.2	76.29	76.29	14.8
	0.5	46.8	29.9	34.2	33.66	20.9	34.2	79.35	58.8
	1	23.27	17.4	11.4	18.65	35.8	38.16	34.68	48.5
	1.5	18.5	9.5	9.5	10.15	36.5	34.5	24.02	40.8
	2	7.52	8.9	7.5	5.68	47	35.2	18.02	40.6
	5	1.23	2.7	7.8	2.00	55.3	42.5	7.57	38.3
Solid/liquid ratio (0.5 w/v)	-60	16.58	28.9	30.2	33.76	26.7	17.8	72.24	68.8
	-140	21.5	25.7	9.4	31.32	27.9	17.6	72.38	89.5
	-230	22.6	20.3	6.5	31.92	26.4	14.4	76.22	92.1
	-270	23.27	17.4	11.4	33.66	24.3	15.9	79.35	57.4
	-270	23.27	17.4	11.4	33.66	24.3	15.9	79.35	57.4

Effect of nitrogen source type on leaching efficiency by *Aspergillus niger* Fig. (2):

It shows the effect of two nitrogen sources on the phosphate bioleaching efficiency. From the obtained results, it is clear that the ammonium chloride is more favorable as nitrogen source than sodium nitrate in the bioleaching of phosphate rocks. Higher acid production and phosphate solubilization from ammonium assimilation has also been reported for the solubilization of fluoroapatite by *Aspergillus niger* (Cerezine et al., 1988). It was found that the U and REE bioleaching from the phosphate rock samples using *Aspergillus niger* had the same trends of the P₂O₅ dissolution

and thus the same interpretations are also applicable here.

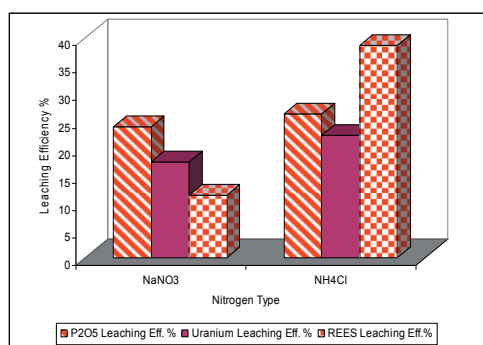


Fig. 2: Effect of nitrogen-source type on leaching efficiency By *Aspergillus niger*

Effect of carbon source concentration on phosphate leaching efficiency by *Aspergillus niger* (Fig. 3)

Through studying the effect of carbon source concentration on phosphate leaching efficiency by *Aspergillus niger*, the solubilization of uranium is attributed to the production of organic acids such as citric acid by the *Aspergillus niger* fungus. Moreover, the formed weak citric acid plays another important effect. It solubilizes the carbonates of the phosphate rock sample and the latter also increase the dissolution of uranium of the phosphate sample. This organic acid form insoluble salts with solubilized REE.

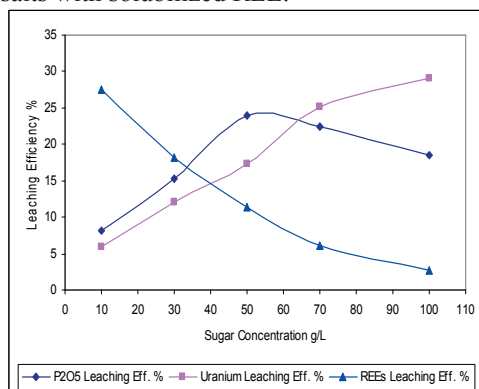


Fig. 3 : Effect of carbon source concentration on leaching efficiency By *Aspergillus niger*

Effect of carbon source concentration on phosphate leaching efficiency by *Penicillium sp.* (Fig.4)

It is clear that the phosphate leaching efficiency started with nearly constant leaching value when using 10 and 30 g/l sucrose (28.24% and 28.43%, respectively). After increasing the sucrose up to 50 and 100 g/l, the leaching efficiency of the phosphate rock samples was increased to 33.42% and 33.66%, respectively. This increase in the leaching efficiency is actually due to the assimilation of growth rate and further increase in the production of organic acids which decrease the media pH and thus increasing the solubilization rate of the phosphate rock samples.

When studying the effect of carbon source concentration on phosphate leaching efficiency by *Penicillium spinulosum*:

- The increase in the U leaching efficiency is in harmony with the increase of the P_2O_5 leaching efficiency due to the incorporation and/or substitution of U in apatite phosphate.
- The formed organic acids (especially the oxalic acid) by the action of the microorganism may form REE oxalates precipitates (Mahdy, 1989), thus the soluble REE in leach liquor decreases.

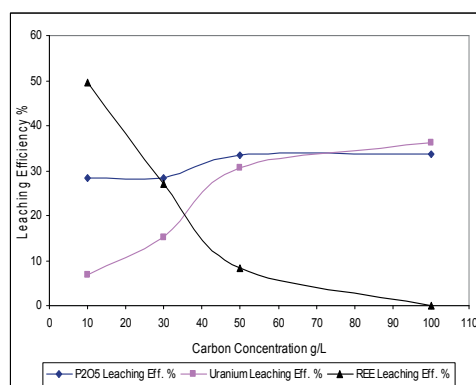


Fig. 4 : Effect of carbon source concentration on Leaching efficiency (using *Penicillium Sp.*)

Effect of contact time on leaching efficiency by *Aspergillus niger* (Fig. 5)

It was clear that the P_2O_5 leaching efficiency increased with increasing the incubation time till 5 days reaching 23.9%, the P_2O_5 leaching efficiency started to decrease again rapidly till 19.5% however, another increase (reaching to the optimum P_2O_5 leaching efficiency) was recorded at 15 days 36.18%.

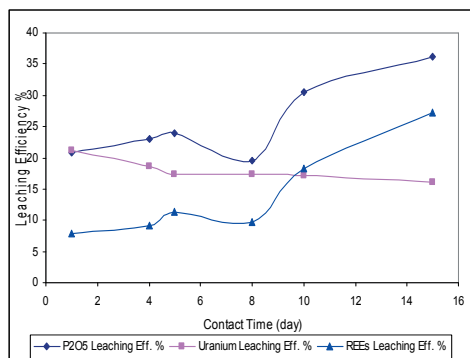


Fig. 5 : Effect of contact time on leaching efficiency by *Aspergillus niger*

Concerning the bioleaching efficiency of REE from the phosphate rock samples, it follows exactly the P_2O_5 leaching however with lower figures. On the other hand, the U bioleaching efficiency from the phosphate rock samples when applying the *Aspergillus niger* shows almost constant values regardless the incubation time. In other words when increasing the incubation time from one day till 10 days, the leaching efficiency was ranged from 16.1 to 21.2 % only.

Effect of contact time on leaching efficiency by *Penicillium sp.* (Fig. 6)

It is clear that the phosphate leaching efficiency increased from 26.24% to 39.1% when increasing the incubation time from 1 to 10 days. The phosphate leaching efficiency returns to decrease again at 15 days to 18.25%. This may be due to the organism consumption of the nutrients needed for its survival and growth and consequently to the production of more organic acids, the latter may reach the lag

phase of its life cycle. Moreover, the already solubilized salts increase the media pH and so reduce the phosphate leaching efficiency.

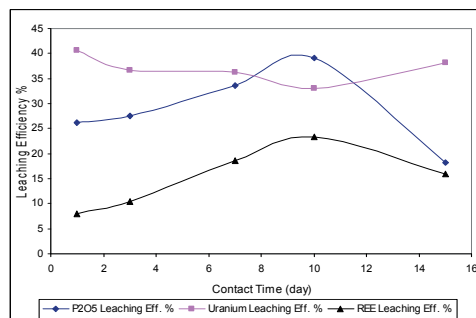


Fig. 6: Effect of contact time on leaching efficiency (using *Penicillium Sp.*)

The behavior of both U and REE follows the phosphate solubilization trend due to their existence in the crystal lattice of apatite. Or else, the formed organic acids leads to the dissolution of the carbonate constituents of the phosphate rock samples and thus provides more Ca^{++} to the media to form the insoluble dicalcium phosphate $Ca(HPO_4)$ which latter incorporate the U and REE.

Effect of grain size on leaching efficiency by *Aspergillus niger* (Fig. 7)

It is clear that the smaller particle size is more convenient to bioleaching of the phosphate rock samples due to the increase of their surface area. Thus, it can be seen that the leaching efficiency was slightly constant trend with decreasing the grain size.

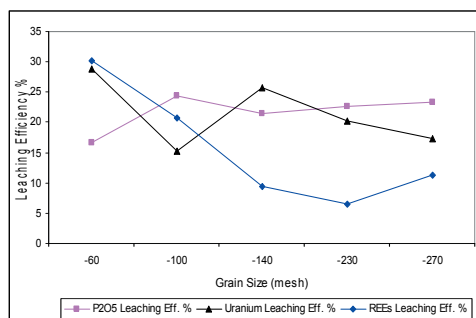


Fig. 7 : Effect of grain size on leaching efficiency By *Aspergillus niger*

Effect of solid/liquid ratio on leaching efficiency by *Aspergillus niger* (Fig. 8)

The leaching efficiency was inversely proportional to the solid/liquid ratio and reached its maximum value at 46.8% for 0.5% (solid/liquid ratio) then decreased gradually till 1.23% at 5% of the ores.

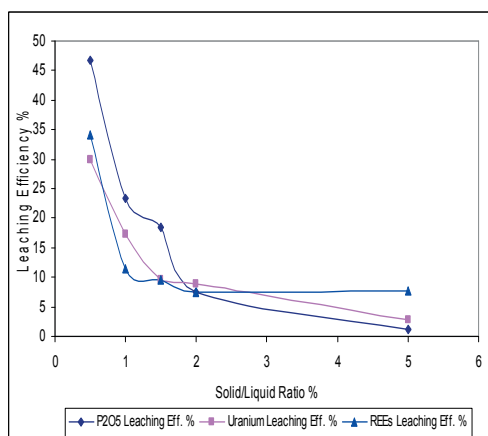


Fig. 8 : Effect of solid/liquid ratio on leaching efficiency by *Aspergillus niger*

Concerning the bioleaching efficiency of U and REE from phosphate rock samples when applying the *Aspergillus niger*. It is clear that both U and REE leaching efficiencies followed the same trend of the phosphate solubilization efficiency due to the existence of the U and REE in the lattice of the phosphate mineral. It is worthy to mention here in that, the amount of the solubilized uranium from its sedimentary ores decrease with increasing the solid/liquid ratio (ore/liquid media ratio) starting from 1% to 8% when applying *Aspergillus terreus* and *Penicillium spinulosum* (Hefnawy et. al., 2002). The authors attribute the uranium solubilization to following two reasons:

- Raising the final media pH which perhaps decreases the solubilization efficiency.
- The high binding capacity of the fungal mycelium at higher concentrations of the ore.

Effect of Solid \Liquid Ratio on leaching Efficiency using *Penicillium Sp.* (Fig. 9)

The decrease in the leaching efficiency of phosphate rock by increasing the solid/liquid ratio is due to the higher concentrations of the rock which may inhibit the growth rate of microorganisms and the further fast death of cells causing decrease in the production of organic acids which is the main topic for the bioleaching mechanism using the fungal isolates.

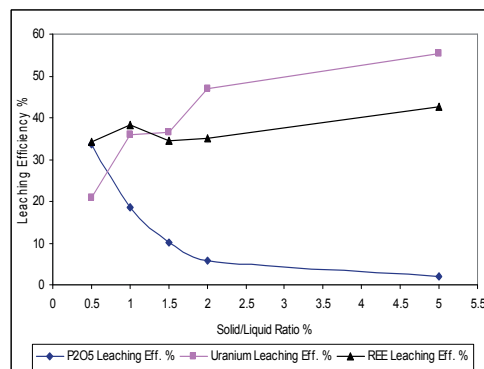


Fig. 9 : Effect of solid \liquid ratio on leaching efficiency (using *Penicillium Sp.*)

Regarding the effect of solid/liquid ratio on U and REE leaching efficiencies from phosphate rock by applying the *Penicillium sp.*, it is clear that by increasing the solid/liquid ratio from 0.5% to 5%, the U leaching efficiency increased also from 20.9 to 55.3% (curved line) while the REE leaching efficiency increased slightly from 34.2 to 42.5% (straight line).

The difference in the behavior of P₂O₅ leaching efficiency and both U and REE leaching efficiencies can be attributed to the existence of U and REE in other minerals such as iron oxides minerals and clay minerals in higher concentrations than existing in phosphate minerals. This phenomenon is shown here only due to the libration of these different minerals in different grain sizes.

Effect of mesh size on leaching efficiency using *Penicillium Sp.* (Fig. 10)

It is manifested that the grain size has no effect on the leaching efficiency of phosphate rock samples by *Penicillium sp.* Thus, it can be seen that the leaching efficiency was nearly constant ranging from 31.3 to 33.76%,

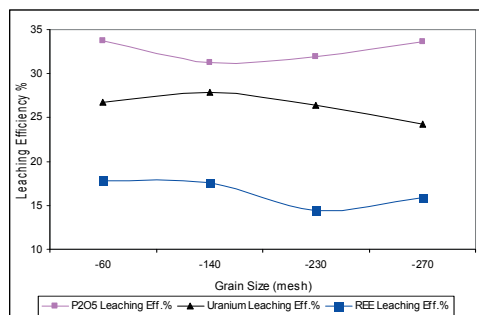


Fig. 10 : Effect of mesh size on leaching efficiency (using *Penicillium Sp.*)

Concerning the effect of grain size upon U and REE leaching efficiencies from phosphate rock samples by using the *Penicillium sp.*, it is clear that they follow more or less the same trend of the P₂O₅ leaching efficiency.

Effect of nutrient concentration (g/l) on leaching efficiency using *Pseudomonas fluorescens* (Fig. 11)

Effect of nutrient concentration on leaching efficiency by *Pseudomonas fluorescens* reveals that the leaching efficiency of the phosphate rock samples slightly increases with increasing the beef extract concentration from 1g/l to 10 g/l till it reaches maximum value at 79.35%. This increase may be due to increasing of growth rate and production of organic acids, thus decreasing pH value promotes the leaching efficiency. The same behavior can be traced for both U and REE leaching efficiencies at nutrient beef extract concentration of 10g/l. The U and REE leaching efficiencies reached 83.2 and 65.5% respectively. This is due to the incorporation of U and REE in the crystal lattice of the phosphate minerals or else substituting Ca in such minerals (Altschuler et. al., 1958).

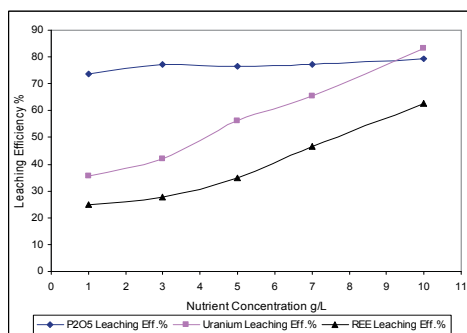


Fig. 11 : Effect of nutrient concentration (g/l) on leaching efficiency (using *Pseudomonas fluorescens*)

Effect of contact time on leaching efficiency using *Pseudomonas fluorescens* (Fig. 12)

It is clear that the leaching efficiency of P₂O₅, U and REE increased with increasing the period of incubation from 1 day to 10 days till reaching its optimum value at 10 days (82.35, 14.8 and 26.8% respectively). Then it decreased again at 15 days, this may be due to consumption of all the nutrients in the media after this period. Or else, the formed organic acids led to the dissolution of the carbonate constituents of the phosphate rock samples and thus providing more Ca⁺⁺ to the media to form the insoluble dicalcium phosphate Ca(HPO₄) then latter incorporate the U and REE.

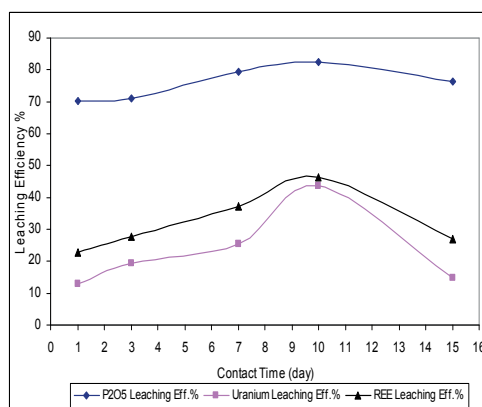


Fig. 12 : Effect of contact time on leaching efficiency (using *Pseudomonas fluorescens*)

Effect of solid/liquid ratio on leaching efficiency (using *Pseudomonas fluorescence*, Fig. 13)

It is clear that the leaching efficiency of phosphate rock samples is inversely proportional to the solid/liquid ratio reaching its maximum P_2O_5 higher value at 75.77% for 0.5% solid/liquid, then decreased gradually till its maximum P_2O_5 lower value at 7.57% for the higher solid/liquid ratio (5%).

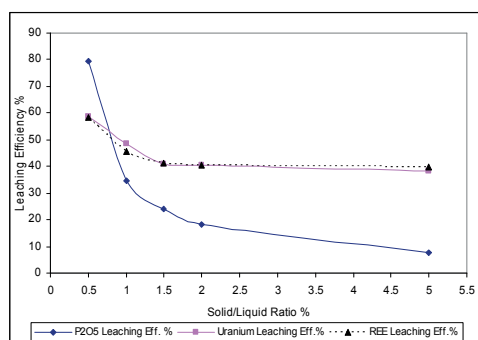


Fig. 13 : Effect of solid/liquid ratio on leaching efficiency (using *Pseudomonas fluorescence*)

Effect of grain size on leaching efficiency using *Pseudomonas fluorescence* (Fig. 14)

The obtained data show that the leaching efficiency of phosphate rock samples was increased from 72.27% to 79.35% with decreasing the grain size from -60 to -270 meshes. This may be explained according the fact that the decrease in grain size led to the increase in the surface area.

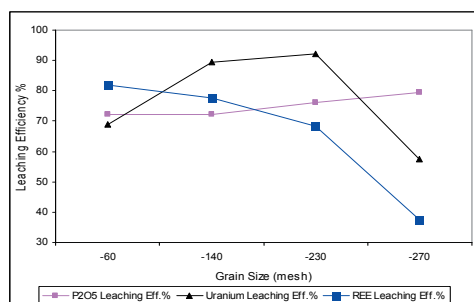


Fig. 14 : Effect of grain size on leaching efficiency (using *Pseudomonas fluorescence*)

The non-sterilized rock is more favorable than the sterilized one. This may be due to the fact that the addition of the phosphate rock inhibits the growth of the bacteria from the beginning and consequently affect the production of acids and the pH value of the media which is expressed by decrease of leaching efficiencies.

Application of pyramidal system in bioleaching of phosphate rock, the obtained results of applying this technique are shown in Table 4. The pyramidal system can be applied in the bioleaching of phosphate rock using *P. fluorescence* bacterial isolate and it is expected that complete P_2O_5 leaching could be obtained after applying two cycles.

CONCLUSIONS

The phosphate rock of Egypt solubilization and some of the contained valuable elements by *Aspergillus niger*, *Penicillium sp.* and *Pseudomonas fluorescence*, have been studied with especial orientation towards the completion of phosphate rock samples solubilization especially the low grade one.

When *Aspergillus niger* was applied, the optimum leaching of P_2O_5 , U and REE from phosphate rock samples reached (23.27%, 17.4%, 11.4%, respectively).

The optimum conditions for the maximal leaching efficiencies of P_2O_5 , U and REE when applying the *Penicillium sp.* from the phosphate rock samples were at -270 mesh 33.66%, 24.3%, 15.9% respectively, while at -60 mesh they gave 33.76%, 26.7%, 17.8% and at -140 mesh gave 31.32%, 27.9%, 17.6%, respectively.

The optimum conditions for the P_2O_5 leaching efficiency when applying the *Pseudomonas fluorescence* were: 10 g/l of beef extract, 10 days incubation period, 0.5% solid: liquid ratio and -270 mesh of grain size reaching 79.35%. The same behavior was traced for both U and REE leaching efficiencies thus

they reached 57.4% and 37.6%, respectively. While the attained results showed that the non sterilized rock is more favorable and the addition of phosphate rock after the incubation of organism for 4 days gave the higher efficiency than the addition of rock at the beginning of experiment.

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الإذابة الميكروبية لبعض العناصر القيمة من صخر الفوسفات المصري

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في هذا العمل تم اختيار ٤ عينات لصخر الفوسفات ممثلة لأشكال مختلفة من الفوسفات المتمعدن في مصر من مناطق أبو طرطور عينتان ، وادى النيل ، البحر الأحمر . وقد تم دراسة العوامل المؤثرة في إذابة صخر الفوسفات وبعض العناصر الهامة باستخدام فطريات الأسبرجيلز نيجر والبنسلين وبكتريا السبودمونات فلورسنس . وقد أوضحت النتائج المتحصل عليها أن العوامل المثلى لعملية الإذابة البيولوجية للخامات الفوسفاتية بواسطة فطراسبرجلس نيجر للوصول إلى أعلى كفاءة استخلاص لكل من خامس أكسيد الفوسفور والعناصر الأرضية النادرة من عينات الخامات الفوسفاتية هي ٥٠ جرام / لتر من السكر و كمصدر كربوني ، ١. عيارى كلوريد الامونيوم كمصدر نيتروجيني ، ١٠ أيام فترة تحضين ، نسبة الصلب إلى السائل (صخر الفوسفات إلى البيئة السائلة للفطريات) ٥٠٪ ، على أن تكون حجم حبيبات الخامات الفوسفاتية - ٢٧٠ مش ، كانت أعلى نسبة إذابة لعنصر الفوسفور واليورانيوم والعناصر الأرضية النادرة هي ٢٧ و ٢٣ و ١٧ و ٤ ، ١١ و ١٪ على التوالي ، في حين عند حجم حبيبات - ٦٠ مش كانت نسبة الإذابة ١٦ و ٩ و ٢٨ و ٢ و ٣٠ و ٤ ، ١١ و ١٪ على التوالي. في حين أن الظروف المثلى لأعلى كفاءة إذابة لكل من خامس أكسيد الفوسفور واليورانيوم والعناصر الأرضية النادرة عند تطبيق فطر البنسلين لإذابة عينات الصخور الفوسفاتية هي: ١٠٠ جرام/لتر من المصدر الكربوني لكل من خامس أكسيد الفوسفور واليورانيوم أو ١٠ جرام/لتر للعناصر الأرضية النادرة في حين تستمر فترة الحضانه لمدة ٧ ، ١٥ ، ١٠ أيام لكل من خامس أكسيد الفوسفور واليورانيوم والعناصر الأرضية النادرة على الترتيب ، و أخيرا فان حجم حبيبات خام الفوسفات المطحون تصل إلى - ٢٧٠ مش لخامس أكسيد الفوسفور و من - ٦٠ إلى - ١٠٠ مش لعناصر اليورانيوم والأرضيات النادرة و ٥٠٪. نسبة العينة الصلبة إلى الوسط السائل لخامس أكسيد الفوسفور و ٥٠٪ لليورانيوم والعناصر الأرضية النادرة . أعلى نسبة إذابة لهذه العناصر كانت كالتالى : عند - ٢٧٠ مش حجم حبيبات ٦٦ و ٣٣ و ٢٤ و ٣ و ١٥ و ٩٪ لكل من خامس أكسيد الفوسفور واليورانيوم والعناصر الأرضية النادرة على الترتيب . وعند - ٦٠ مش ٧٦ و ٣٣ و ٢٦ و ٧ و ٨ و ١٧ و ٣ و ٣١ و ٢٧ و ٩ و ١٧ و ٦ و ١٪ لكل من خامس أكسيد الفوسفور واليورانيوم والعناصر الأرضية النادرة على الترتيب . أما فى حالة - ١٤٠ مش حجم ٣٢ و ٣١ و ٢٧ و ٩ و ١٧ و ٦ و ١٪ لكل من خامس أكسيد الفوسفور واليورانيوم والعناصر الأرضية النادرة على الترتيب . أما العوامل المثلى للوصول إلى كفاءة إذابة عالية من خامس أكسيد الفوسفور عند استخدام العزلة البكتيرية مع عينات خامات الفوسفات هي ١٠ جرام/لتر من مستخلص اللحم كمصدر تغذية رئيسي. ١٠ أيام فترة تحضين. ٥٠٪ من نسبة الصلب إلى السائل (خام الفوسفات إلى سائل التغذية للبكتيريا) و حجم الحبيبات يصل إلى - ٢٧٠ مش مع عدم تعقيم الصخر قبل الإذابة على أن يضاف الصخر الفوسفاتي بعد أربعة أيام من التحضين قد أعطى أعلى كفاءة إذابة أكثر من إضافة الصخر في بداية تجربة الإذابة وهي ٣٥ و ٧٩٪ . وقد سلك كل من اليورانيوم والعناصر الأرضية النادرة نفس السلوك فبلغت كفاءة الإذابة ٨٣ و ٢ و ٦٥ و ٦٠٪ على الترتيب .