

Beneficiation of Akashat Phosphate Rocks by Flotation Process

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ABSTRACT

In this work, reverse froth flotation technique has been adopted to upgrade the Iraqi phosphate ore from Akashat deposit as an alternative method to the existing calcination method. Prior to flotation experiments, a feed flotation was prepared by washing and desliming operations on 300 and 75 μm ASTM sieve opening to eliminate fine materials. In flotation experiments, the effect of the parameters, collector (oleic acid) quantity, phosphate depressor (sodium sulfate) quantity, solid%, pH value of the pulp (using H_2SO_4) and flotation time were investigated. The experimental results obtained showed that the flotation method applied has managed to beneficiate Akashat phosphate ore to the acceptable level for commercial utilization. The phosphate concentrate obtained under the optimum conditions (1kg/t of oleic acid ,10kg/t of sodium sulfate, 30% solid concentration, 6.5 pH and 3 minutes for flotation time) containing 32% P_2O_5 , 0.5% MgO and CaO/ P_2O_5 ratio less than of 1.6% with a recovery of 93%.

Keywords: Akashat phosphate rock, reverse flotation, carbonate impurities.

تركيز صخور فوسفات عكاشات بطريقة التعويم

يتناول هذا البحث دراسة إمكانية تركيز خام الفوسفات العراقي من منجم عكاشات في الصحراء الغربية في محافظة الانبار باستخدام طريقة التعويم الرغوي العكسي كطريقة بديلة عن الطريقة الحرارية (Calcination) المستخدمة حالياً. تمت عمليات الغسل والغربلة الرطبة للخام قبل اجراء تجارب التعويم للحصول على غذاء تعويم ذو مدى حجمي (75+300-) مايكرون وخالي من الدقائق الناعمة. في تجارب التعويم تم دراسة تأثير بعض

المتغيرات المهمة على رتبة P_2O_5 ونسبة الأسترجاع (Recovery) وهي كمية حامض الاولييك (Oleic Acid) كمجمع للكاسايت , كمية كبريتات الصوديوم (Sodium Sulfate) كمغطس للفوسفات , كثافة اللباب , قيم درجة الحموضة (pH) وزمن التعويم. أظهرت النتائج التجريبية التي تم الحصول عليها على إمكانية التعويم الرغوي العكسي في رفع تركيز معدن الفوسفات في خام عكاشات الى المستوى المقبول للأستخدام التجاري حيث تم الحصول على ركاز يحتوي ($1.57\% P_2O_5, 0.5\% MgO, CaO$) ونسبة إسترجاع 93% في الظروف المثلى للتعويم وهي: (كمية المجمع 1kg/t , كمية المغطس 10Kg/t , كثافة اللباب 30% , درجة الحموضة (pH) 6.5 وزمن التعويم 3 دقائق)

INTRODUCTION

Phosphate rock is naturally occurring mineral assemblages containing high concentration of phosphate minerals, which can be commercially exploited, either directly or after processing. About 95% of the world phosphate rock production is consumed for manufacturing of phosphate fertilizer that are necessary for the cultivation of world's crops [1]. The phosphorus content or grade of diverse phosphate rocks origins is commonly reported as phosphorus pentoxide (P_2O_5) and marketable phosphate rock must contain $\geq 30\% P_2O_5$ [2].

Like all ores and minerals in the earth, the quality of phosphate deposit will vary from area to area and from country to country. The deposit may contain variety of mineral impurities, which vary considerably in the type and quality. The common impurities in the phosphate deposit are carbonates (calcite and dolomite), silicates, feldspar, mica, and clays[3]. Therefore, phosphate ore requires processing to upgrade the phosphate content (P_2O_5) by removing these gangue minerals to meet the requirements of the phosphate industry : $\geq 30\% P_2O_5$, CaO/ P_2O_5 ratio < 1.6 , MgO content $< 1\%$ and Fe_2O_3 and Al_2O_3 content maximum 2.5% [4]. Determination of ore deposit type, mineral composition, texture and mineral impurities associated with the phosphate mineral are necessary in selecting the upgrading process and the appropriate technique to treat it. Simple or complex combinations processes may be used such as crushing, grinding, screening, scrubbing ,washing, calcination, acid leaching and flotation [5].

Currently, Iraqi phosphates(Akashat mine) are upgraded by calcination process at Al-Qaim complex, but the high capital costs of the plant and higher amounts of thermal energy required to achieve the necessary degree of beneficiation are the major drawbacks of this process. Moreover, calcination is considered as non-environmentally friendly method[4].Therefore, attention should be given to study the possibility of using an alternative upgrading methods. Flotation is one of the promising upgrading methods for phosphate beneficiation, more than half of the world's marketable phosphate is upgraded by flotation. It has great commercial benefits owing to its high separation efficiency and low costs [6,7,8]. The calcareous type of phosphate ore (Akashat phosphate) is extremely difficult to concentrate by flotation, due to the similar physicochemical characteristics of surfaces of the main constituents, carbonates and phosphates which show identical responses to collectors and depressants, this makes their separation by flotation a challenging problem and this is a problem of this work [9].

Nevertheless, many efforts have been spent on implementing flotation technique for separating carbonates from phosphate ores, including thermodynamic analysis, modification of the technique, controlling the pulp environment, and finding new reagents that can specifically differentiate between carbonates and phosphates [10]. However, reverse flotation, in particular, showed promising results with calcareous phosphate ores all over the world. It depends on depressing phosphate and floating carbonate minerals at acidic pH.

Abdel Khalek (2000) studied the removal of carbonate from phosphate ore using single stage flotation for carbonates by using different types of phosphate depressant (Aluminum sulfate, phosphoric acid and sulfuric acid) at special conditions of pH and collector dosage. The results of this stage show that phosphoric acid gives better grade and recovery of P_2O_5 than the other depressants. He indicated that a single stage for flotation of carbonate is not enough to produce high-grade concentrate. Therefore, he suggested another flotation stage for either phosphate or silica to achieve concentrate with P_2O_5 above 30 % [11].

Mohammadkhani et al (2011) applied double reverse flotation to recover phosphate from very low grade sedimentary phosphate rock (Kohe-lar phosphate) in Iran, rich in carbonate and silicate, using different reagents of collectors, depressants and frothers. Anionic-cationic double reverse flotation was found to be an efficient method to separate phosphate from carbonates. The grade and recovery of the P_2O_5 in the final concentrate reached 21.67 and 65.5% respectively, but the consumption of depressant was high, which makes the reagents undesirable for treating very low grade sedimentary phosphate ($P_2O_5 < 10\%$) in industry because of economic issues[3].

Recently, Al-Fariss et al (2012) conducted reverse flotation technique to Al-Jalamid phosphate ore in Saudi Arabia, using oleic acid and tall oil as collectors, sulfuric acid as a pH regulator to keep the pH of the pulp at 6.5 and sodium sulfate as a phosphate depressor. At optimum conditions it succeeded to separate the carbonate minerals and increase the P_2O_5 content from 26.6% to 36.7% with separation efficiency and recovery of 33.7% and 92.1% respectively [7].

The aim of this work is an attempt of using reverse flotation route to beneficiation of Akashat Iraqi phosphate to decrease the content of carbonate impurities and produce marketable phosphate ($P_2O_5 > 30\%$) as an alternative route for the calcination process that is currently used.

EXPRMINTEAL WORK

Materials

Phosphate ore sample: The sample is used in this research is from Akashat mine in Anbar Governorate, western Iraq. The sample was brought from the feed preparation section prior to calcination process in Al-Qaim complex.

Chemical reagents: Oleic acid ($C_{18}H_{34}O_2$) was used as collector in flotation process, sodium sulfate (Na_2SO_4) used as a phosphate depressant, sulfuric acid (H_2SO_4) as a pH regulator after dilution to 10% by distilled water and pine oil used as frother in flotation process.

Methods**Sample Preparation**

The phosphate ore sample of 20 kg received from Akashat mine, was crushed to pass on 1000 μm sieve in a laboratory jaw crusher then, after ore homogenization, identical sample of 300gm was separated for size distribution analysis using Jons Riffle sampler. Furthermore, a representative specimen was withdrawn for chemical and qualitative mineralogical analysis.

Chemical and Mineralogical Analysis

The chemical and qualitative mineralogical analysis of the representative sample of the phosphate ore gained from the ore preparation step was conducted in Chemical Analysis Section/Central Laboratories of Iraq Geological Survey. The chemical analysis was carried out by using X-ray fluorescence (XRF) type (Shimadzu 1800), while the mineralogical analysis was done by using X-ray diffraction (XRD) type (Shimadzu XRD-7000). The X-ray diffraction was recorded at 40 kV and 30 mA for a Cu-target tube.

Wet Size Analysis and P_2O_5 Distribution

Since the flotation technique used to beneficiate the phosphate ore is a wet process, the size analysis was conducted on a wet base by mixing 300 gm of slurry phosphate ore sample having particle size more than 500 μm with water for 10 minutes at solid to liquid ratio 1:3 and then allowed to pass through a set of ASTM sieves of 500, 300, 150, 75, 53 and 45 μm sieve opening using sieve shaker. The amount of the phosphate ore retained of each size fraction was dried, weighted and a sample is taken for MgO, CaO, and P_2O_5 determination. The slurry that passed through 45 micron sieve was collected in a container, filtered, dried, weighted and a sample is taken for analysis too. The drying was carried out in a laboratory oven at 100 $^\circ\text{C}$ for two hours. The results obtained were then used to calculate the size distribution and distribution of P_2O_5 in each size fraction.

Flotation Experiments

The flotation experiments were conducted in a Denver-type, model D-12. The desired amount of water was added to the 1 liter flotation cell, then 300 gm of phosphate ore having particle size in the range of -300+75 μm assaying 29 % P_2O_5 was introduced. The pulp was mixed for 2 minutes by machine impeller itself at 1200 r.p.m with the air valve closed. This speed was maintained constant for all experiments. The pH of pulp was measured and the necessary amount of sulfuric acid was added to reach the desired pH in 2 minutes conditioning time. Then the required amount of depressor was added. After 2 minutes as conditioning time, a measured amount of collector was added and the pH was adjusted again. After other two minutes, some drops of frother were added. When the conditioning time finished, the air valve is opened. Phosphate concentrate was filtered, dried, weighted and analyzed for P_2O_5 . Then, the recovery of P_2O_5 was calculated. In the course of the flotation experiments, the effect of (collector and depressor quantities, solid concentration, pulp pH value and flotation time) on the grade and recovery of P_2O_5 % of the concentrated phosphate were studied.

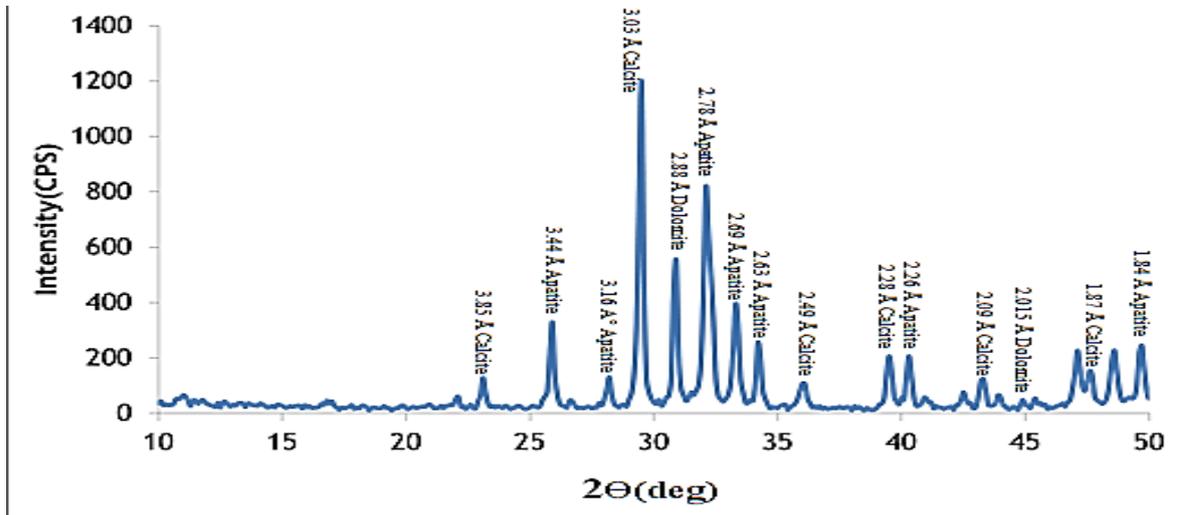
Results and Discussion

Chemical and Mineralogical analysis

The results of the chemical composition of phosphate raw material used in this work are shown in Table 1. It can be seen that the phosphate ore is an intermediate P₂O₅ content 22.9% and high in CaO and MgO%. From the data in Table 1 the CaO:P₂O₅ weight ratio was calculated and found to be above 2.1. This given value and that of P₂O₅% and MgO (1.49%) are beyond the requirements (P₂O₅ ≥ 30%, CaO/P₂O₅ ≤ 1.6 and MgO < 1%) of the phosphate grade for industrial uses [4]. On other hand, the chemical analysis results showed that the phosphate ore sample contains low amounts of SiO₂, Fe₂O₃, Al₂O₃ and SO₃. The results of X-ray diffraction analysis of the phosphate ore sample is shown in Figure 1. This Figure indicates that apatite (Ca₁₀(PO₄,CO₃)₆(F,OH)₂) is the predominant phosphate mineral, whereas calcite (CaCO₃) is the main carbonate gangue mineral associating the ore with some dolomite Ca Mg(CO₃)₂ mineral too. This could explain the high CaO/P₂O₅ value of the ore.

Table (1) :Chemical composition of Akashat phosphate ore

Element composition	P ₂ O ₅	CaO	MgO	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	SO ₃	Cl	L.O.I
Concentration wt%	22.9	50.45	1.49	2.93	0.6	0.32	1.26	0.05	19.2



Figure(1):XRD pattern of phosphate raw material

Wet Size Analysis

The results of size analysis of P₂O₅% and its distribution in each size fraction are given in Table 2 . From this Table (column 2 and 5), it can be seen that about 90.5% of the ore having particle size of less than 500 micron and about 30% of the ore having particle size of less than 75 micron, which could have a detrimental effect on the flotation operation, particularly in reagents consumption. Therefore the removal of this size fraction from the ore would be beneficial. Obviously the rejection of this fraction -75 μm will result in a loss of about 17% P₂O₅ from the bulk of the ore (Table 2,column 10) which has only 13 % P₂O₅ (column 8). Basically, most of the P₂O₅ in the ore is concentrated in the ore particle size range -300+75μm, which constitutes about 74% of the total P₂O₅ in the ore, as can be seen clearly in (Table 2, column 9). But CaO% is increased somewhat about its content in phosphate raw material in this range of particle size as shown in Table 2 (column 7) due to increasing the content of apatite where calcite is existing basically in chemical structure of apatite. In any case, it is suggested to prepare the ore feed to the flotation cell in a way having -300+75μm particle size range.

Table (2):Wet size distribution

1	2	3	4	5	6	7	8	9	10
Size(μm)	Particle size	Wt (gm)	Wt %	Cumulative pass%	MgO %	CaO %	P ₂ O ₅ %	Distributed P ₂ O ₅ %	Cumulative under size %
+500	500	26	9.6	90.38	1.2	52.5	16.2	6.78	95.49
-500 +300	300	10	3.7	86.69	0.93	53.8	25.6	4.12	91.47
-300 +150	150	88	32.4	54.22	0.74	54.4	30.6	43.38	48.18
-150+75	75	66	24.3	29.87	0.82	54	29	30.8	17.38
-75 +53	53	13	4.8	25.08	2.52	50.8	19.6	4.09	13.38
-53 +45	45	7	2.5	22.50	5.38	46.8	14.6	1.64	11.88
-45	Pass	61	22.5	-----	2.76	46	12.1	11.88	-----
Total		271							

Effect of Collector Quantity

To study the effect of the collector (oleic acid) quantity on the flotation separation of calcite from the phosphate ore sample and then on P₂O₅ grade of the concentrate and its recovery, different quantities of oleic acid were studied (0.5, 0.75, 1, 1.25, 1.5 kg/t). These experiments, were carried out under the conditions (depressor quantity 15 kg/t, 30% solid concentration, pulp pH 5.5 and 5 minutes flotation time). These conditions are chosen according previous works in this field [3,7,10,11].

The experimental results of the P₂O₅ content and its recovery of phosphate concentrate (sank materials) are shown in Figure 2. From this figure, it is obvious that there are no significant changes in% P₂O₅ of the concentrate from that of the feed value 29 % P₂O₅. The values of P₂O₅ obtained at 0.5 and 0.75 kg/t collector quantity were 28.8% and 29% respectively. This can be attributed to the insufficient quantity of the collector that is needed for the flotation of calcite. The % recovery of P₂O₅ at these collector values was 88% and 91% respectively. Whereas, when the collector quantity increases to 1 kg /t, the % P₂O₅ of concentrate reaches a maximum value of 30.3% P₂O₅ with a recovery of 93.8% and beyond this collector quantity, has no significant changes in the P₂O₅ content of the concentrate. The values of P₂O₅ obtained at 1.25 and 1.5 kg/t collector quantity are 30.1% and 30% respectively. On other hand, the recovery slightly decreases (Fig 2) from that obtained at 1 kg /t collector quantity. The results obtained, however, are satisfactory , it indicates that calcite can be floated from the phosphate material. However, according to the experimental results a collector quantity of 1kg/ t where by a maximum P₂O₅ 30.3% of the concentrate was obtained can be considered as optimum.

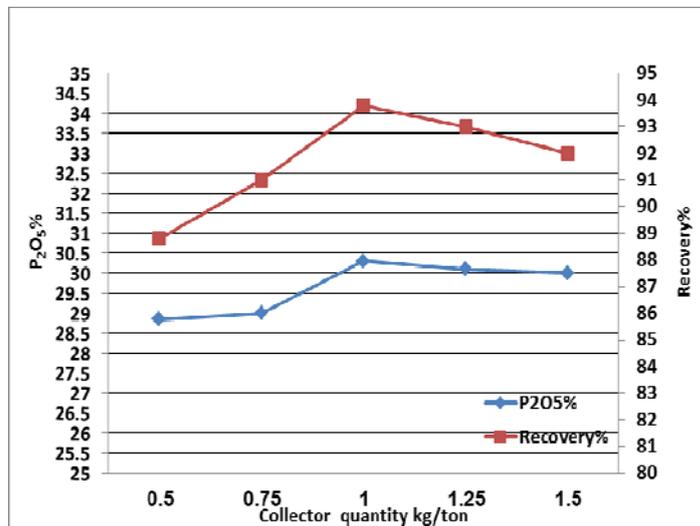


Figure (2): The effect of collector quantity on flotation

Effect of Depressor Quantity

Depressants play a vital role in phosphate flotation by preventing the flotation of unwanted minerals in direct flotation or of phosphate minerals in reverse flotation which is the case in the work. Therefore, the effect of sodium sulfate (Na₂SO₄) addition on apatite (phosphate mineral) depression and its effect on P₂O₅ content and recovery of the concentrate (sank material) studied thereupon. The tests were conducted at the conditions (1 kg/t oleic acid , 30% solid concentration, pH of the pulp 5.5 and 5 minutes flotation time) using different quantities (5,10,15,20,25 kg/t) of the depressor reagent.

The results obtained are shown in Figure 3, which clearly shown that the %P₂O₅ increases from 29% in feed to 31.5% in the concentrate at a depressor quantity of 5kg/t and, it reaches a highest value in these experiments (32.3%) P₂O₅ with recovery of 94.5% at a depressor quantity of 10 kg/t. Further increase in the depressor quantity to 15, 20 and 25kg /t, resulted in a successive reduction in P₂O₅ and recovery. The P₂O₅ grade obtained is of 31.7%, 31.2% and 30.7% respectively. It has been demonstrated [7,12] that the phosphate minerals (such as apatite) is depressed in acidic medium (pH 5.5 -6.5) due to the adsorption (or formation) of aqueous CaHPO₄ on its surface, and hence allow the carbonate to float. However, it was stated Elgillani and Abouzeid (1993) [12] and Somasundaran and Zhang (2000) [13] that the content of dissolved Ca²⁺ (free Ca²⁺) in apatite/ calcite/water system play a decisive role in the formation of aqueous CaHPO₄. Increasing the free Ca²⁺ ions in the system (free dissolved Ca²⁺ in the pulp due to presence of carbonate minerals in acidic medium) reduce the concentration of aqueous CaHPO₄.Consequently, free Ca²⁺ should be minimized to enhance the selective flotation of carbonate from phosphate minerals. That is why it has been suggested to use sodium sulfate (Na₂SO₄) as a controlling agent for dissolved free Ca²⁺ in the pulp. When sodium sulfate (high soluble salt)is added to the pulp most of the dissolved Ca²⁺ will precipitated as calcium sulfate as in equation below:



So if sulfate ions (SO₄²⁻) is not added ,dissolved Ca²⁺ (basically from carbonates) in the pulp will stabilize the apatite mineral (reducing CaHPO₄ formation) causing it depression to be extremely difficult [10].On other hand, the formed gypsum (CaSO₄.2H₂O) will precipitated on calcite surface and enhance its floatability. Addition of excess sodium sulfate, however, leads to the precipitation of gypsum (CaSO₄. 2H₂O) onto apatite which increases its floatability and hence reduces the selectivity of calcite flotation [7].The results of experimental work as in Figure 3 are in agreement with the above discussion.

However, from the experimental results shown in Figure 3, it can be stated that using 10 kg/t of sodium sulfate, resulted in a phosphate concentrate having P₂O₅ grade of (32.3%) and recovery(94.5%), thus this depressor quantity (10 kg/t) is considered optimum value.

Effect of Solid Concentration

To study the effect of this parameter on P₂O₅% and recovery of phosphate concentrate, different solid concentrations (15,20,25,30,35%) were tested. The experiments were carried out

using 1Kg/t oleic acid ,10Kg/t sodium sulfate, 5.5 pulp pH and 5 minutes flotation time. The results obtained are shown in Figure 4. It can be seen that the % P₂O₅ content of the phosphate concentrate increases as the the pulp solid concentration increases to 30% and it decreases with the rise in solid concentration to 35% while the %recovery was found directly proportional to the solid concentration.

However, The decrease in P₂O₅ % of the concentrate (sank materials) as the solid concentration increase to 35% may be due to the consistency of the pulp which becomes dense, so that inadequate supply of collector occur which hinder the efficiencies of calcite flotation (i.e. the collector present in the pulp is not enough to cover the surface almost of all calcite particles needed to float them). Furthermore the inefficiency of flotation at high pulp solid concentration may also be due to the obstruction encountered the free flowing of the air bubbles due to increase attrition among the solid particles. Henceforth retardation in the flotation of calcite was occur [8]. This in turn interpreted the reason of the gradual increase in % recovery with increasing pulp solid concentration. However, the maximum P₂O₅ value obtained was of (32.2%) at solid concentration of 30% and the recovery was of 95.5%.Therefore, this solid % can be considered as optimum value.

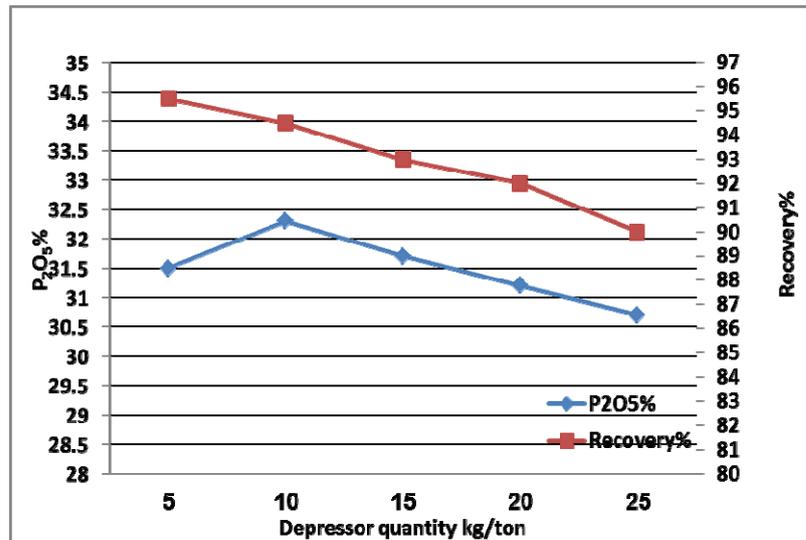


Figure (3): The effect of depressor quantity on flotation.

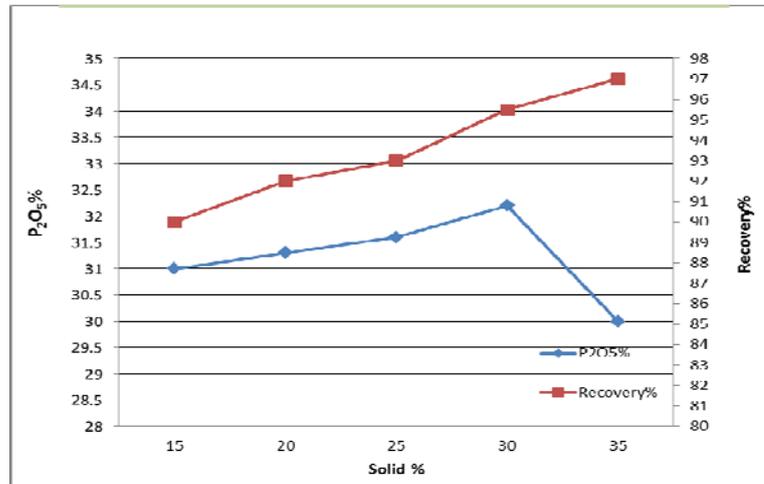


Figure (4) : The effect of solid % on flotation

Effect of pH Value

The pH of the pulp is a key factor in phosphate reverse flotation in acidic media. It controls the stability/instability of calcite surface due to the release of calcium ions (Ca²⁺) as well as formation of CaHPO₄ on phosphate surface. Therefore, the effect of pH on flotation performance of Akashat phosphate ore was next studied. Several experiments were conducted at different pH values (4,4.5 ,5.5,6.5) using sulfuric acid (H₂SO₄) as a pH regulator . It was claimed [7,11,12] that flotation of carbonates from phosphate should be carried out at acidic media with pH range of 4 - 6.5. Accordingly the above pH range was chosen. The experiments were carried out under the optimum conditions obtained from previous experiments (1 kg/t oleic acid,10 kg/t sodium sulfate, 30% solid concentration, whereas the flotation time kept constant at 5 minutes).

The results obtained are illustrated in Figure 5. From this figure, it is clearly seen that the P₂O₅ grade of the phosphate concentrate increase with the increase in pH value from 4 to 6.5, while the recovery decreases from 94.5% to 90% at pH 4 and pH 6.5 respectively. The reason of obtaining a concentrate of P₂O₅ grade at the decrease of pH value (4 and 4.5) less than of that at the increase of pH (5.5 and 6.5) and the reverse in the % recovery was suggested to that increase H⁺ in the pulp will tend to increase the dissolution rate of both apatite and calcite. The increase in the dissolution rate of calcite will be less than that of apatite, because the calcite surface will be covered with gypsum(CaSO₄.2H₂O) more readily than that of apatite. Thus, the increase of Ca²⁺ concentration around apatite surface will reduce the adsorption of aqueous CaHPO₄ on apatite surface and this leads to stabilize apatite mineral and causing to decrease its depression. The net result being that the precipitation of CaSO₄.2H₂O on both calcite and apatite. This means that the apatite surface becomes resembles that of calcite and the separation between them retreat [7,11]. However, as there is no significant difference of P₂O₅ value at pH 5.5 (32.1%) and that at pH 6.5 (32.3%) and as far as the acid consumption is taken in consideration. It is suggested to consider the pH of 6.5 as an optimum value.

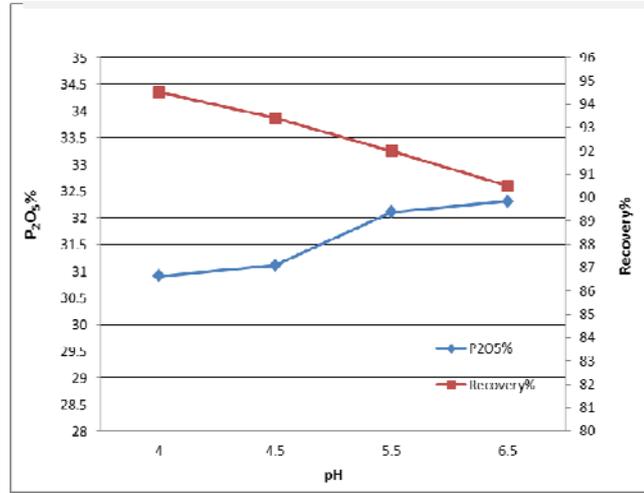


Figure (5): The effect of pH value on flotation

Effect of Flotation Time

Flotation time is another important factor affecting the beneficiation of the phosphate ore. Figure 6 shows the experimental results which were obtained at three different times of flotation while keeping other optimum conditions of the previous experiments constant (1 kg/t oleic acid, 10 kg/t sodium sulfate, 30% solid concentration and pH 6.5).

From Figure 6, it can be seen that increasing flotation time from 2 to 5 minutes, has a slightly effect on P₂O₅%. The results showed that the P₂O₅ of the phosphate concentrate obtained at 2, 3 and 5 minutes are 31.8, 32.1 and 32.2 % respectively.

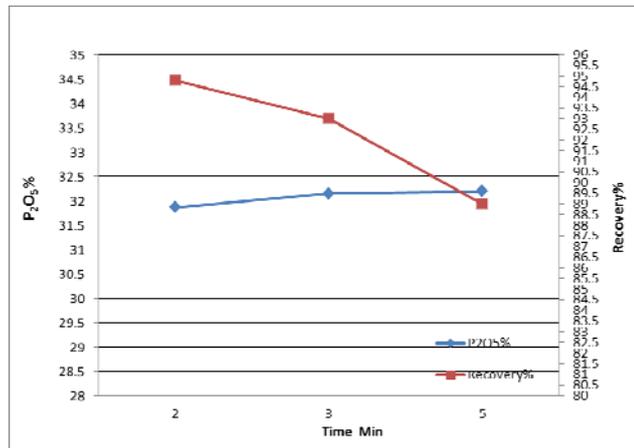


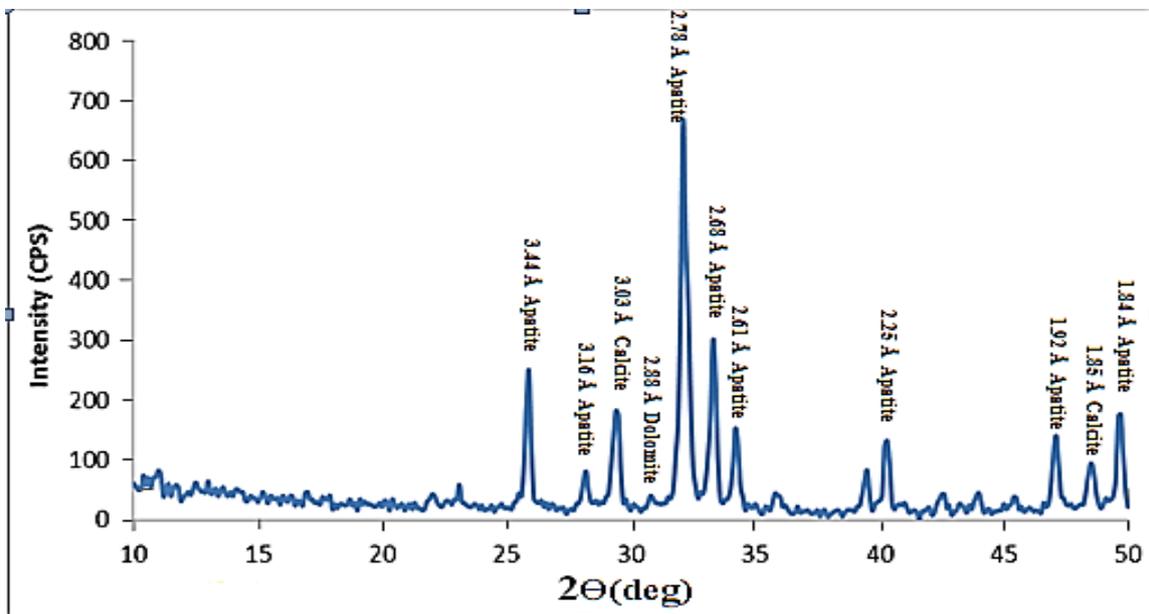
Figure (6) The effect of flotation time on flotation

Despite there is no significant change in P₂O₅ grade of the phosphate concentrate at 3 and that at 5 minutes, it was selected 3 minutes as an optimum value according to the observation during the experimental work which showed that this time was enough to float sufficient quantity of impurities while 5 minutes was a long time of flotation and the froth would be reduced before the end of this time. Moreover the recovery of P₂O₅ grade at 3 minutes (93%) was higher than that at 5 minutes (90%).

However the results of chemical analysis of the phosphate concentrate under optimum conditions (1 kg/t oleic acid , 10 kg/to sodium sulfate, 30% solid concentration, 6.5 pH and 3 minutes flotation time) are shown in Table 3. Comparing these results, with that of Table 1 of phosphate raw material , it can be seen, in addition to high P₂O₅ grade, decrease in MgO content and the weight ratio of CaO/P₂O₅ to an acceptable level for industrial requirements (P₂O₅ ≥30%, MgO <1%,CaO/P₂O₅ ratio < 1.6%). On other hand, the XRD result of phosphate concentrate after this test is shown in Figure 7. It can be seen that the diffraction peak intensities of calcite and dolomite are significantly reduced, while those of the apatite increase as compared with the XRD results of untreated ore sample which is shown in Figure1. This result confirms the success of reverse flotation process to upgrade Akashat phosphate ore and decrease the calcareous impurities from it.

Table (3): Chemical composition of phosphate concentrate after flotation

Element composition	P ₂ O ₅	CaO	MgO
Concentration wt%	32	50.5	0.5



Figure(7):XRD pattern of phosphate concentrate after flotation

CONCLUSIONS

Based on the test results of this work, the following conclusions can be drawn:

- 1- The phosphate ore under study is of an intermediate P_2O_5 grade 22.9% calcareous type with carbonates impurities mainly calcite, and from the size distribution analysis, it is noted that the P_2O_5 is mostly concentrated in the size fractions between -300 +75 μm .
- 2- Washing and desliming are a necessary step to achieve flotation feed assaying of 29% P_2O_5 and low content of 0.8% MgO by removing most of the gangue materials and some of the dolomite in the fine particles -75 μm .
- 3- From flotation experiments, it can be concluded that the separation of carbonates (mainly calcite) from phosphate mineral (apatite) attributed to use sodium sulfate (Na_2SO_4) as a controlling agent for dissolved free Ca^{2+} in the pulp by precipitating it as gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) on calcite surface and enhance its floatability. Furthermore the apatite depression is related to its instability in acidic media due to adsorption (or formation) of aqueous CaHPO_4 on apatite surface, thereby preventing its flotation by the action of the collector (oleic acid).
- 4- Under optimum conditions (1 kg/ton of oleic acid, 10kg/ton sodium sulfate, 30% solid %, 6.5 pH and 3 minutes flotation time), Akashat phosphate ore can be potentially upgraded and phosphate concentrate containing 32% P_2O_5 , 0.5% MgO and CaO/ P_2O_5 ratio of 1.57%, with a recovery of 93% can be achieved.

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