Development of flotation scheme for fine Jordanian phosphate: physical and chemical evaluation & Froth flotation.

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Abstract

Sieve analysis in general has been used for decades to monitor material quality based on particle size. The particle size distributions of a material can be important in understanding its physical and chemical properties. It affects the strength and load-bearing properties of rocks and soils. It affects the reactivity of solids participating in chemical reactions, and needs to be controlled in many industrial products.

The particle size distribution of phosphate is a list of values or a mathematical function that defines the relative amounts of particles present, sorted according to size.

The method used to determine the particle size distribution is called particle size analysis, and the apparatus a particle size analyzer.

The sample which used in this study collected from Jordan phosphate company from ore called A3 and sieve analysis were carried out for it, after that the fraction of the sieve sent to chemical analysis. Different weights of this fraction were made as different D50.

The result of this study of different size of D50 will be uses in the phosphate flotation.

Phosphate rock needs processing to reduce the content of gangue minerals such as silicates; to meet the requirements of the phosphate industry. Flotation of apatite is complicated, due to its physicochemical similarity with other minerals in phosphate ores.

Despite this, relatively few studies have been done on the effect of operating parameters, such as particle size and pulp conditions and collector dosage on the lab experiment flotation.

In this research, the results of batch flotation tests to assess the influence of operating variables on the flotation experiment are discussed. Pulp pH, collector dosage, conditioning and feed size affected recovery significantly. For the collector dosages and the feed size are factors influenced the concentrate grade and conditioning is essential for the whole flotation process.

The test results indicated that could produce a commercial-grade phosphate product in a single stage of separation but for high-grade need for another stage.

Product quality ranged between 65-71% T.C.P (tri calcium phosphate = T.C.P%/2.185= (29.75-32.5) %P2O5) and (6-17) % A.I.R% (acid insoluble residual). T.C.P% recoveries reached 81% as T.C.P%.
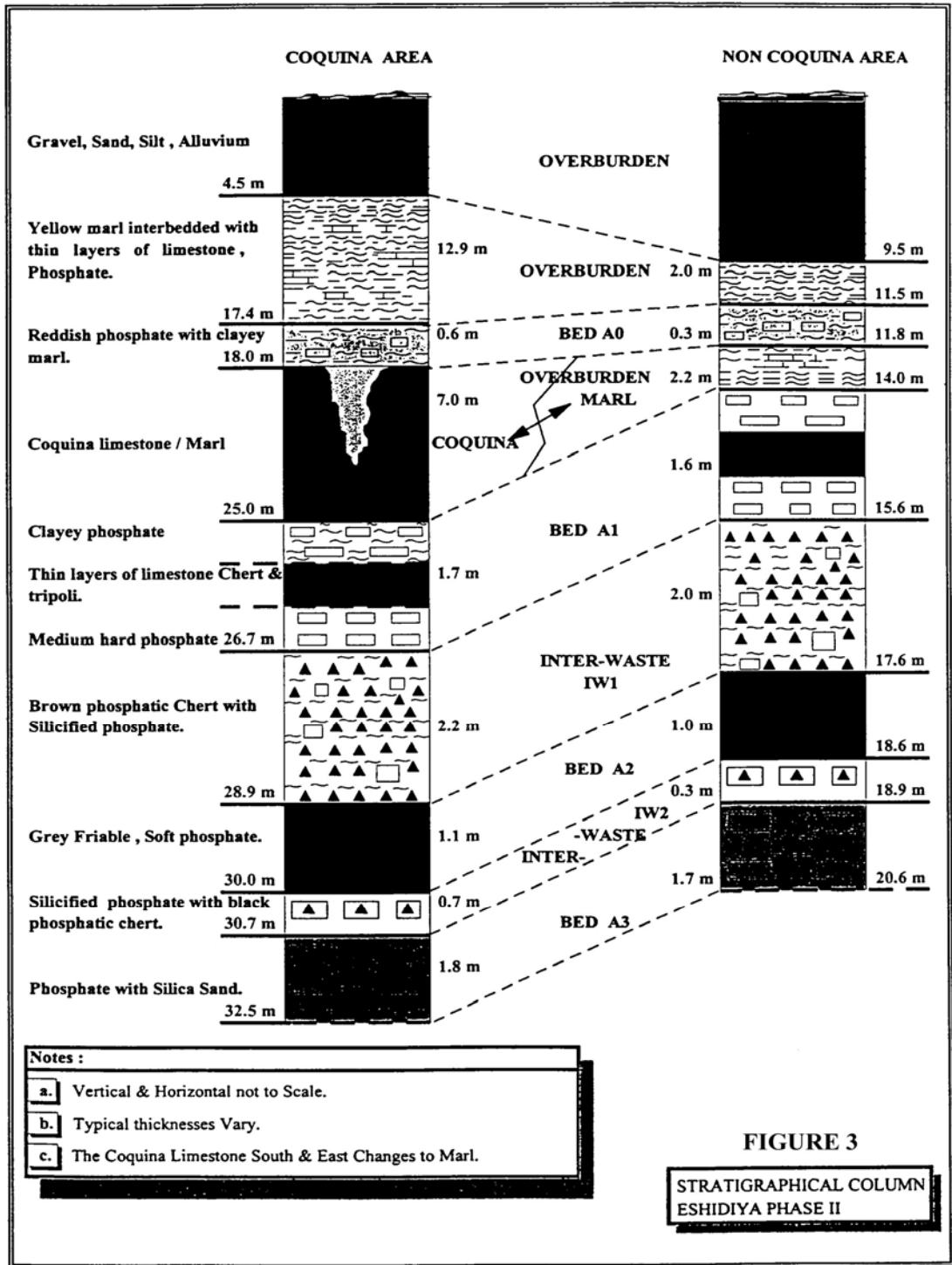
Geology:

The phosphate deposits at Eshidiya comprise about 125 sq. km. and are from the upper cretaceous period; estimated to be 65 million years old. However, deposits are sedimentary in nature (laid down in beds) and are thought to have been formed in the following 5-step sequence:

- ♦ Upwelling of cold, phosphate rich, seawater into warm shallow waters.
- ♦ Growth of algae, plants, fish, and mammals due to the rich nutrients.
- ♦ Phosphatization of calcareous, siliceous, and clay sediments on the shallow sea floor along with deposition of phosphate-rich teeth and bones from animals.
- ♦ Reworking of the phosphate sediments by current, or wave, action.
- ♦ Weathering of the phosphate sediments, after the seawater receded, with rains that leached the softer limestones and left behind the quartz and less soluble phosphates.

The deposits at Eshidiya are comprised of overburden, four phosphate beds (**A0, A1, A2 and A3**), a coquina/marl waste bed, and two solidified phosphate/chert interwaste beds.

The lithology and stratigraphic column is shown in Figure 3. At the present time, A0 bed is considered to be waste. Bed A1 requires crushing and beneficiation to make a saleable product, while bed A2 requires only crushing. Bed A3 requires crushing, beneficiation, and flotation to produce a saleable product.

COQUINA AREA   **NON COQUINA AREA**

Gravel, Sand, Silt , Alluvium

OVERBURDEN

4.5 m

Yellow marl interbedded with thin layers of limestone , Phosphate.

12.9 m   OVERBURDEN   2.0 m   9.5 m

17.4 m   11.5 m

Reddish phosphate with clayey marl.

0.6 m   BED A0   0.3 m   11.8 m

18.0 m   OVERBURDEN   2.2 m   14.0 m

7.0 m   MARL

Coquina limestone / Marl   COQUINA   1.6 m

25.0 m   15.6 m

Clayey phosphate   BED A1

Thin layers of limestone Chert & tripoli.

1.7 m   2.0 m

Medium hard phosphate 26.7 m   17.6 m

    INTER-WASTE IW1

Brown phosphatic Chert with Silicified phosphate.

2.2 m   1.0 m

18.6 m

BED A2

28.9 m   0.3 m   18.9 m

    IW2

Grey Friable , Soft phosphate.

1.1 m   -WASTE

30.0 m   INTER-   1.7 m   20.6 m

Silicified phosphate with black phosphatic chert.   30.7 m

0.7 m   BED A3

1.8 m

Phosphate with Silica Sand.

32.5 m

Notes :

a. Vertical & Horizontal not to Scale.

b. Typical thicknesses Vary.

c. The Coquina Limestone South & East Changes to Marl.

FIGURE 3

STRATIGRAPHICAL COLUMN
ESHIDIYA PHASE II

In general, at Eshidiya show that more overburden must be stripped off to reach the ore zone.

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Product qualities at Eshidiya are present as pure apatite. Detrimental product impurities (Fe_2O_3, Al_2O_3, and MgO) at Eshidiya are some of the lowest in the World.

Ore Characteristics:

In mining terminology, matrix is the "ore" that is mined. In sedimentary deposits, such as found in Jordan, the ore generally consists of phosphate particles ranging from 20 mm to 50 microns in size, sand ranging from 1 mm to 50 microns, and clay. The clay can be present in large lumps, but scrubbing and wetting with water will generally reduce it to its natural grain size of less than 2 microns. The ore bed generally rests on hard limestone and is overlain by overburden sand.

The thickness of the ore, its depth below the surface, its richness (amount of phosphate rock present), its association with minor detrimental elements (iron, aluminum and magnesium), and its pumpability and processability are all factors that determine its economic value.

Mining Of Phosphate:

The method by which phosphate ores are uncovered and mined is dictated primarily by the nature of the deposit:

- ♦ Overburden depth and toughness
- ♦ Ore depth, thickness, and character
- ♦ Water intrusion
- ♦ Tonnage of product required
- ♦ Other

The reserves at Eshidiya consist of two ore bodies; an eastern ore body and a western ore body. Presently, mining is carried out in two pits (the western pit and the eastern pit) within the western ore body. One of the pits is in the coquina area while the other is in the non-coquina area. For Phase II, two more pits are opened up in the western ore body; a northern pit completely covered by the coquina rock layer and a southern pit only 20% covered with coquina. The Eshidiya Mine areas are shown in Figure 4.

Figure (4)
Eshidiya Phase I and II
Mine Areas
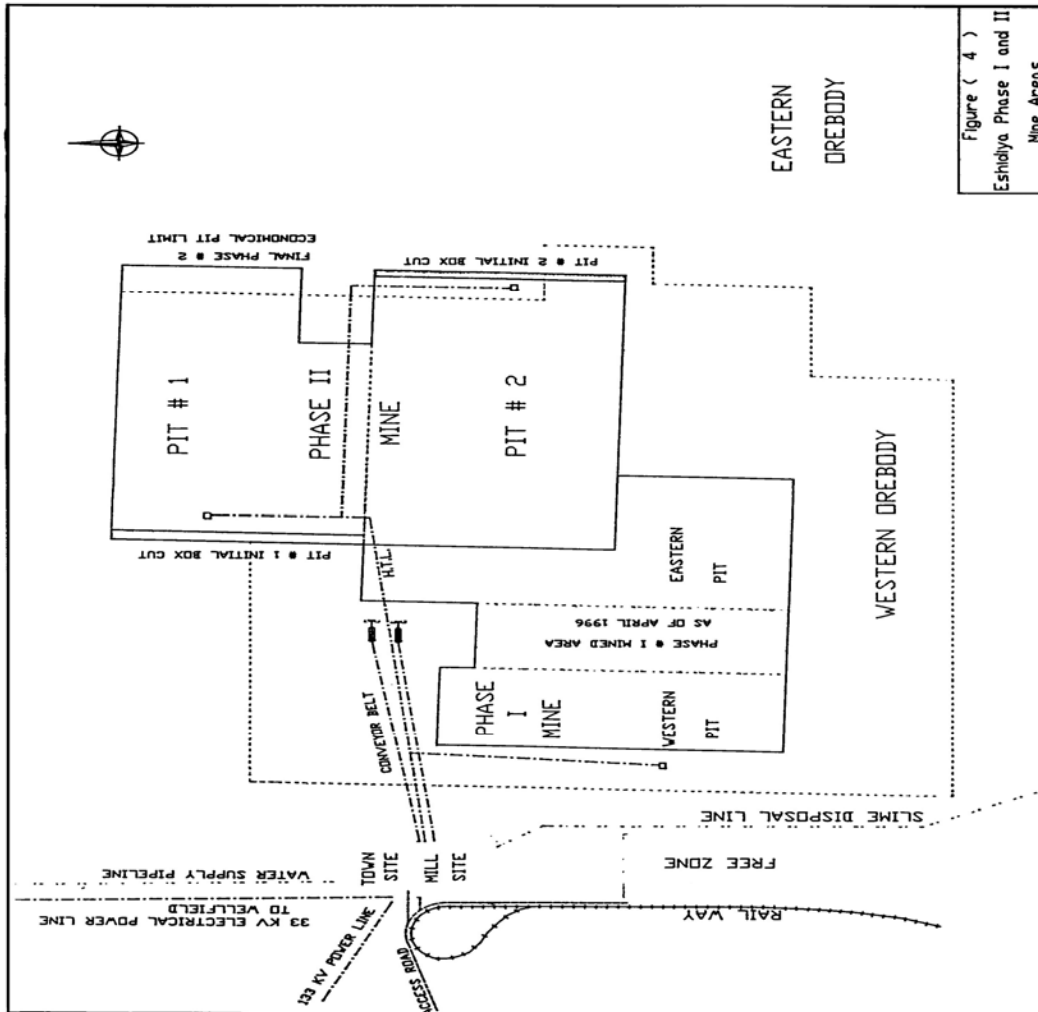
At Eshidiya, the overburden is drilled and blasted and then removed with draglines. Overburden removal is down to the top of layer **A1.** The phosphate ore layers **A1, A2**, and **A3** and the two inner waste layers are selectively removed with a system of shovels and trucks.

It is important to note that the ore beds are kept separate since they upgrade in different manners and produce different grade products:

- ♦ **A1 Ore** – Requires crushing, scrubbing, screening and desliming to produce a 68-70% product.

- ♦ **A2 Ore** – Basically a direct shipping ore, which requires only 2 stages of dry screening to produce a 73-75% TCP product.

- ♦ **A3 Ore** – Must be washed, scrubbed and deslimed in a manner similar to A1 and then floated to remove fine silica in order to make a 75-77% TCP product. A 65% TCP sub commercial product is also produced.

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Materials and Methods:

Phosphate ores usually contains more than one type of the gangue minerals. Many of the sedimentary phosphate deposits contain mixtures of undesired constituents. These ores require series of upgrading operations depending on the type of gangue minerals existing in each ore.

This may include, after size reduction, combination of attrition scrubbing, desliming, flotation, gravity separation, and/or calcinations.

Many techniques for upgrading apatite $(Ca_5(PO_4)_3)(F,OH)$ phosphate ores are currently available. The choice of these techniques depends on the type of ore as well as the associated gangue minerals. One of common techniques is size reduction and screening which utilizes the differences in friability between phosphate minerals and associated gangue and cementing matrix (carbonates, silica, and silicates). In most cases, phosphate minerals are friable while gangue minerals are hard. So by crushing and screening, the fine fraction will be rich in phosphates, but high percentage of P_2O_5 is lost in the coarse fraction (Sis and Chander, 2003).

In order to use phosphate in fertilizer industry, phosphate feed should meet the following stringent specifications:

- P_2O_5 Content grater than 30%.

- $\dfrac{Cao}{P_2O_5}$ Ratio less than 1.6.

- Mgo Content less than 1%.

Due to the following reasons:

Provides flexibility and economy in formulations. High Biological availability. Its Môn calcium phosphate content and high solubility ensure its superior biological value. Narrow calcium to phosphorus ratio. Outstanding physical qualities provide for ease of handling and uniform dispersion in mixed feeds and minerals. Provides maximum economy per unit of biologically available phosphorus.

However, most of Phosphate ores do not meet these criteria. So it is required to remove their impurities by some means of beneficiation. Beneficiation of phosphate ores by flotation

has been an important part of the concentration process since the 1920s at which time it became possible to recover those fine particles of apatite by flotation. Some beneficiation methods (e.g. calcinations, acid leaching, and magnetic separation) applied in the industry have certain limitations and disadvantages when compared to flotation.

Because of the increasing demand on phosphate rock for fertilizers, it is becoming more and more common to mine and process low grades of phosphate deposits. The majority of these low grade deposits are of sedimentary phosphates and the rest are of different origins. These deposits occur in the form of ore bodies in one thick bed or several successive beds intercalated with non-phosphoric materials. (Abouzeid et al., 1980).

In general, a sieve separates wanted/desired elements from unwanted material using a tool such as a mesh, net or other filtration or distillation methods. It also used for classification of powders by particle size, or for size measurement as an analytical technique. In the mining industry, a mesh used to separate fine particles from coarse ones. Sieve analysis is a practice or procedure used to assess the particle size distribution of a granular material.

Particle size distribution is often a critical factor in determining the way the material performs in use, due to mechanical energy required to achieve the whole process. It can be used for any type of non-organic or organic materials including sands, clays, granite, feldspars, coal, soil, and a wide range of manufactured powders. It can also be used for grain and seeds. Procedure used in sieve analysis can be summarized as follows:

- A typical sieve analysis involves a nested column of sieves with wire mesh cloth.
- A representative weighed sample is poured into the top sieve which has the widest openings.
- Each lower sieve in the column has smaller openings than the one above. At the base is around pan, called the receiver.
- The column is typically placed in a mechanical shaker.
- The shaker shakes the column for a fixed amount of time.
- After the shaking is complete the material on each sieve is weighed.
- The weight of the sample of each sieve is then divided by the total weight giving a percentage retained on each sieve.

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However, sieve analysis has some limitations. In general sieve analysis has been used for decades to monitor material quality based on particle size. For coarse material, sizes that range down to #100 mesh (150μm) (H. Halberstam and H. E. Richert); sieve analysis and particle size distribution is accurate and consistent. However, for material that is finer than 100 meshes, dry sieving is significantly less accurate. This is because the mechanical energy required making particles pass through an opening and the surface attraction effects between the particle and the screen increase as the particle size decreases. Usually wet sieve analysis can be utilized where the material analyzed is not affected by water. In wet sieving, flowing water flushes fine material through the sieve much more efficiently than shaking the dry material. On the other hand, and over the limitations of sieve analysis is that sieving assumes that all particles will be round or nearly round and will pass through the square openings. For elongated and flat particles sieve analysis will not yield reliable results, as particle size reported will be based on an assumption of similar sizes in three dimensions.

The ore sample used in this work was collected from Eshidiya mine in Jordan from ore called A3. As received ore was then screened by dry sieve using tech sieve shaker for 15 minutes using a charge of 1 kg. Size fraction less than 25 micron were discarded as slime. Sieve size analysis was then conducted and the results are shown in Table 1.

Table 1 the results of sieve analysis

Size interval (Micron)		Mean size (Micron)	Weight (g)	%wt	%cumulative Oversize	%cumulative undersize
1000	850	925	1405	3.50	3.50	96.50
850	710	780	2085	5.19	8.69	91.31
710	500	605	7481	18.63	27.32	72.68
500	355	427.5	12284	30.59	57.90	42.10
355	250	302.5	7104	17.69	75.59	24.41
250	180	215	5677	14.13	89.72	10.28
180	125	152.5	2060	5.13	94.85	5.15
125	90	107.5	727	1.81	96.66	3.34
90	75	82.5	436	1.09	97.75	2.25
75	53	64	577	1.44	99.19	0.81
53	45	49	228	0.57	99.75	0.25
45	38	41.5	78	0.19	99.95	0.05
38	25	31.5	21	0.05	100.00	0.00
Sum			40163	100.00		

Head samples from as received ore and of each size fraction were taken for chemical analysis. Phosphate and gangue (silica) contents in these samples are given in Table 2.

Table 2 Chemical analysis of as received ore and size fractions

Lower Mean size (Micron)	T.C.P%	A.I.R%
850	64.54	16.42
710	64.4	17.48
500	49.7	36.86
355	39.2	49.9
250	48.44	35.08
180	64.54	18.44
125	66.5	12.14
90	62.72	15.2
75	58.24	19.88
53	58.1	20.68
45	57.68	18.66
38	58.66	17.52
25	57.4	18.22
As received ore	51.38	32.56

Synthetic size distribution was prepared from previous size fractions by mixing different weights of each size fraction. The total weight of each size distribution was 8 kg while their D50 sizes were 500,493.4, 489.52,355, and 250 micron. The weight of each size fraction used to construct these distributions is shown in Tables 3-7.

Table 3 Sieve analysis of synthetic distribution No.1 (D50=500)

Mean size (micron)	Wt (g)	%Wt	%cumulative Oversize	%cumulative undersize
850	80	1.00	1.00	99.00
710	416	5.20	6.20	93.80
500	3504	43.80	50.00	50.00
355	2400	30.00	80.00	20.00
250	800	10.00	90.00	10.00
180	560	7.00	97.00	3.00
125	80	1.00	98.00	2.00
90	96	1.20	99.20	0.80
75	16	0.20	99.40	0.60
53	16	0.20	99.60	0.40
45	27.6	0.35	99.95	0.05
38	1.6	0.02	99.97	0.03
25	2.8	0.04	100.00	0.00
Sum	8000	100.00		

Table 4 Sieve analysis of synthetic distribution No.2 (D50=493.4)

Mean size (micron)	wt (g)	%wt	%cumulative Oversize	%cumulative undersize
850	375	4.69	4.69	95.31
710	795	9.94	14.63	85.38
500	1005	12.56	27.19	72.81
355	3358	41.98	69.16	30.84
250	390.7	4.88	74.05	25.95
180	1070.48	13.38	87.43	12.57
125	600	7.50	94.93	5.07
90	199	2.49	97.41	2.59
75	44.22	0.55	97.97	2.03
53	100	1.25	99.22	0.78
45	55	0.69	99.91	0.10
38	4.58	0.06	99.96	0.04
25	3.02	0.04	100.00	0.00
Sum	8000	100.00		

Table 5 Sieve analysis of synthetic distribution No.3 (D50=489.52)

Mean size (micron)	Wt (g)	%Wt	%cumulative Oversize	%cumulative undersize
850	420	5.25	5.25	94.75
710	340	4.25	9.50	90.50
500	462	5.78	15.28	84.73
355	3500	43.75	59.03	40.98
250	1851	23.14	82.16	17.84
180	600	7.50	89.66	10.34
125	330	4.13	93.79	6.21
90	100	1.25	95.04	4.96
75	141.18	1.76	96.80	3.20
53	192	2.40	99.20	0.80
45	45	0.56	99.76	0.24
38	14.82	0.19	99.95	0.05
25	4	0.05	100.00	0.00
Sum	8000	100.00		

Table 6 Sieve analysis of synthetic distribution No.4 (D50=355)

Mean size (micron)	Wt (g)	%wt	%cumulative Oversize	%cumulative undersize
850	100	1.25	1.25	98.75
710	400	5.00	6.25	93.75
500	1950	24.38	30.63	69.38
355	1550	19.38	50.00	50.00
250	2499.3	31.24	81.24	18.76
180	1303.7	16.30	97.54	2.46
125	40	0.50	98.04	1.96
90	54	0.68	98.71	1.29
75	35	0.44	99.15	0.85
53	30	0.38	99.53	0.47
45	20	0.25	99.78	0.22
38	12	0.15	99.93	0.07
25	6	0.08	100.00	0.00
Sum	8000	100.00		

Table 7 Sieve analysis of synthetic distribution No.5 (D50=250)

Mean size (micron)	Wt(g)	%wt	%cumulative Oversize	%cumulative undersize
850	430	5.38	5.38	94.63
710	134	1.68	7.05	92.95
500	560	7.00	14.05	85.95
355	1476	18.45	32.50	67.50
250	1400	17.50	50.00	50.00
180	2142.82	26.79	76.79	23.21
125	1010	12.63	89.41	10.59
90	278	3.48	92.89	7.11
75	199.6	2.50	95.38	4.62
53	239	2.99	98.37	1.63
45	80.4	1.01	99.37	0.63
38	45	0.56	99.94	0.06
25	5.18	0.06	100.00	0.00
Sum	8000	100.00		

Samples from the previous distributions were sent to the chemical analysis and the results are shown in Table 8.These synthetic distributions were divided in to 500 g samples in order to be used in flotation experiments.

Table 8 Chemical analysis of synthetic distributions

Distribution number	D50	T.C.P%	A.I.R%
1	250	56.28	26.08
2	355	51.8	34.14
3	489.52	49	35.5
4	493.4	53.06	30.66
5	500	51.52	32.84

Discussion and results:

Results of the sieve analysis presented in Table 1 showed that the most weight of the ore sample is in the interval range of (-500+180) micron   while the T.C.P% in the range of (-180+90) micron and (-850+710) micron with an average of 64.59 %, and 64.47%, respectively. The synthetic distribution with highest T.C.P was D50=250 micron with 56.28 % while D50=489.52 micron was the one which has the lowest T.C.P (49 %).

Figure 5 shows cumulative particle size distribution of as received phosphate sample. It confirmed that most of ore sample weight was in the range of (-1000 +200) micron. The results from the figure can be divided into two distinctly different particle parts; Fine particles with size less than 250 micron and coarse one with size greater than 250 micron. The percentage of fine particles was 10.28% of the total sample weight.
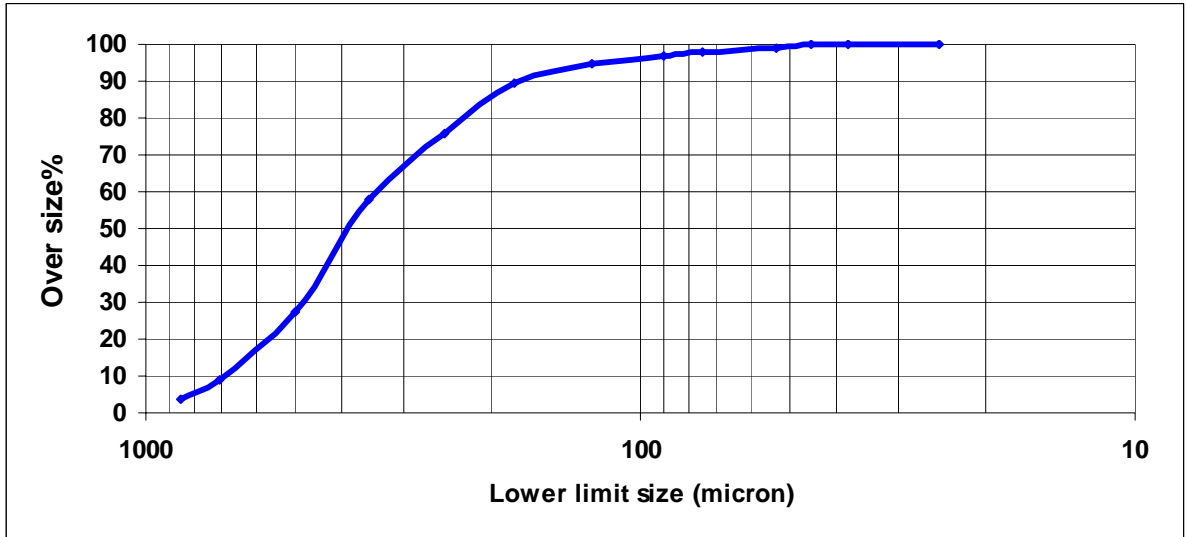
Figure 5 Sieve size distribution of as received sample.

Figure 6 shows the relation between size fraction lower limit size and material over that size, while Figure 7 shows the size analysis of synthetic distributions.
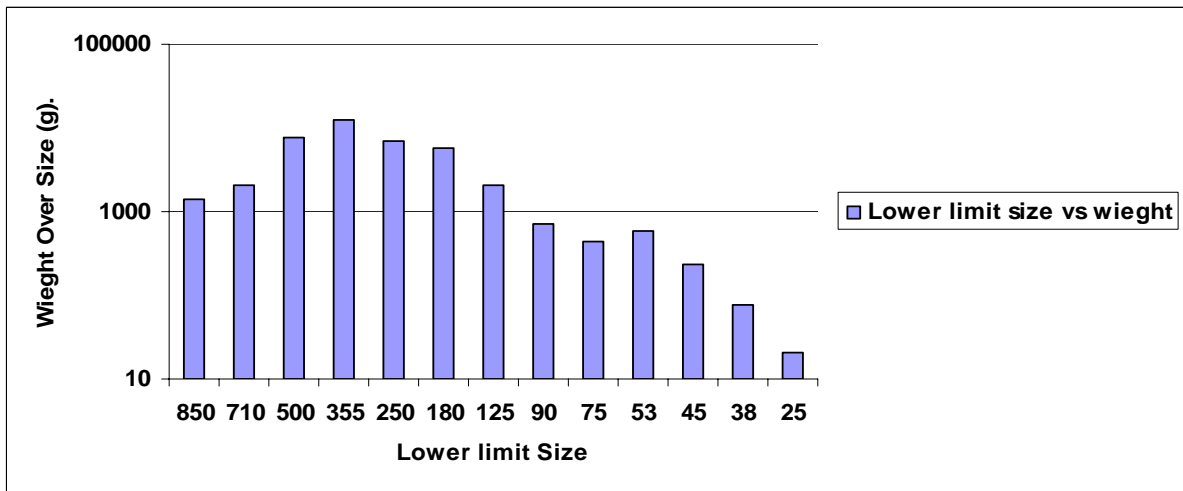

Figure 6 Lower limit of sieve size versus weight over size of mass retained.

Graphical distribution of size fractions used in the synthetic distributions is shown in Figure 8.
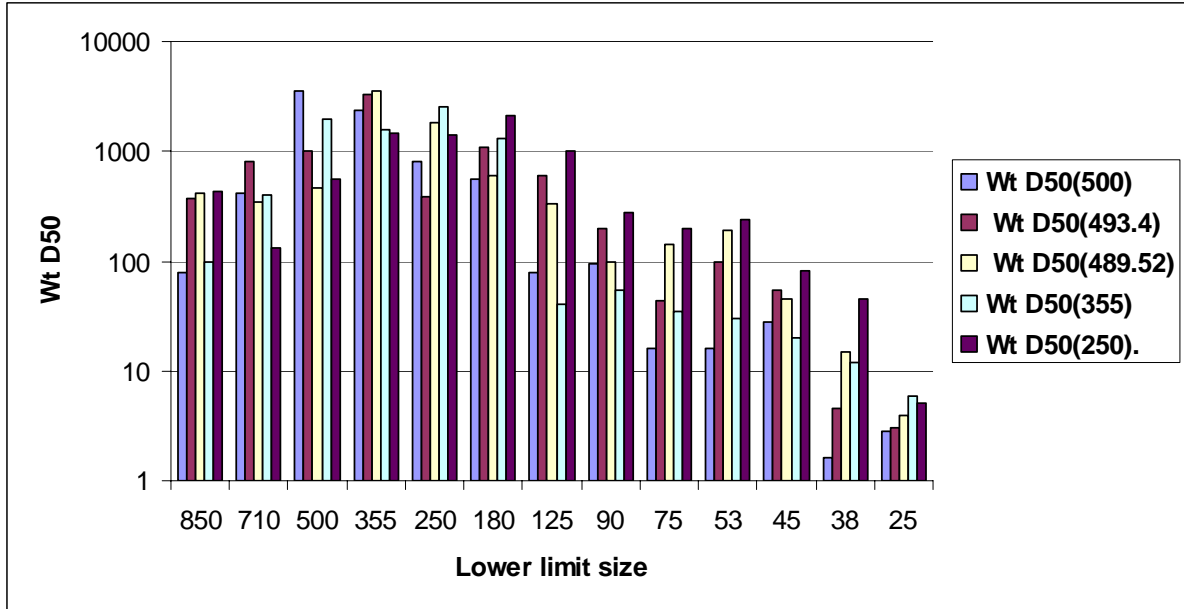

Figure 8 Lower limit of sieve size versus weight for each synthetic distribution.

Chemical analysis of each of the synthetic distributions as shown in Figure 9 showed that the highest TCP content was in distribution of D50=250 micron while the distribution with the lowest AIR was the distribution of D50=489.52 micron.
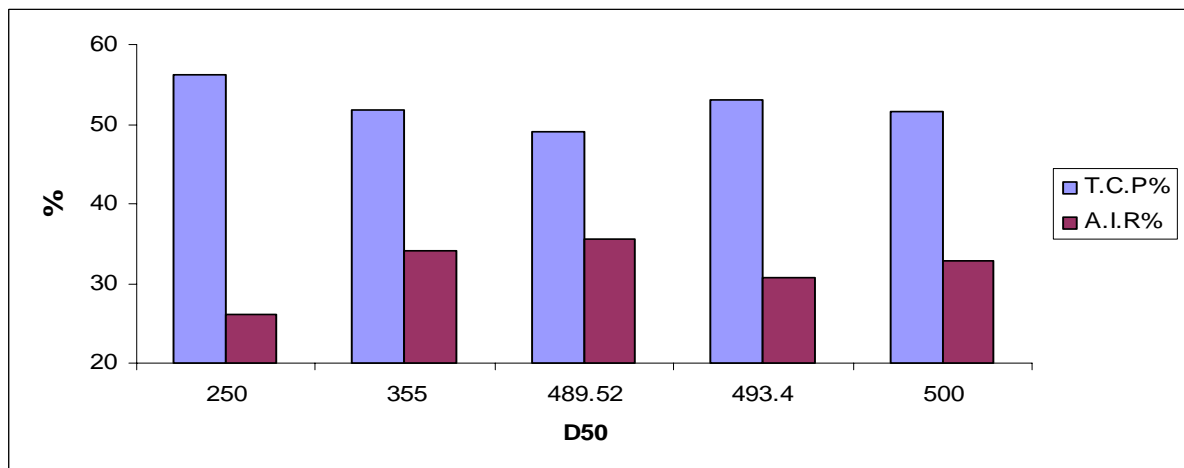

Figure 9 D50 of the synthetic distributions and their chemical analysis.

Economic recovery of phosphates is limited to naturally concentrated phosphate mineral deposits. The low grade ore must be concentrated for economic utilization. Froth flotation method has been an important part of the concentration process since the 1920s and today, more than half of the world's marketable phosphate is produced by this method. Based on the results of this work the samples derived from the mentioned synthetic distributions to conduct laboratory froth flotation experiments.
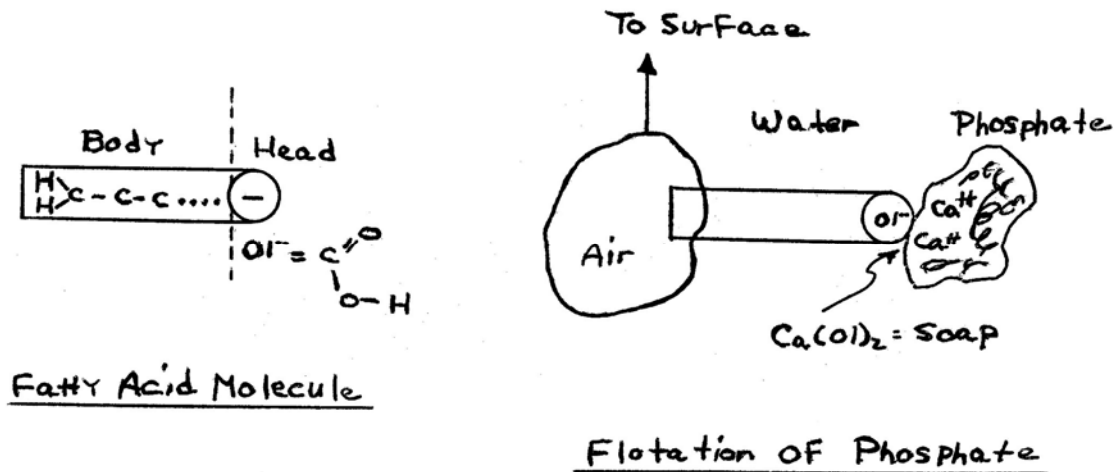
Flotation:

The actual separation of phosphate and gangue (sand) minerals is done in a flotation cell. Most of what is going to happen (recovery, grade of rougher concentrate, etc.) is determined during conditioning. The flotation machines are simply the devices that bring the air, water, and reagentized solids together and make the separation. Factors that influence the performance of the flotation cells are discussed as following:

- **Condition at Proper % Solids** – This means high % solids prior to rougher flotation; 70-75% using neat tall oil and 60% and above using soap.
- **Good Sizing** – Size feed well in both fractions. Properly sized feed generally results in higher recovery of the coarser fractions in the feed and more selective concentrates from the finer fractions at reduced reagent usage.
- **Clean Water** – Water used prior to flotation can be somewhat dirtier than that used directly in flotation but should be relatively free of solids. Water used directly in flotation should be as clean as possible.
- **Proper Reagent Dosages** – Use what is required but not more. This item may be modified somewhat at Eshidiya since additional reagent is sometimes needed to aid downstream operations such as filtering and to avoid scaling.

Theory:

Tall oil reagents are used to float phosphate particles. Certain 18 carbon chain fatty acids (oleic, linoleic, and linolenic acids) present in the tall oil act as a collector by forming a chemical bond with the phosphate mineral during conditioning. The fatty acid molecule has an uncharged body consisting of 18 carbon and hydrogen atoms and a negatively charged head consisting of one carbon, two oxygen and one hydrogen atom. The surface of the phosphate rock (calcium phosphate) contains many calcium sites. When the pH is adjusted to 9.0 the fatty acid converts to soap by attaching to the positive calcium site on the phosphate and forming a calcium oleate. This reaction is similar to the one used to make lye soap from caustic and animal fat. After the reaction has taken place, air bubbles attach to the uncharged end of the fatty acid and float the phosphate mineral to the surface.

Fatty Acid Molecule

Flotation of Phosphate

At Eshidiya, the fatty acid is premixed with caustic and partially converted to soap prior to use as a flotation collector. This partial conversion is called "Saponification" and allows better collector absorption onto the phosphate mineral at the lower conditioning % solids used in the plant.

It is the unique ability of a reagent to attach to a specific mineral that makes it a collector. Fatty acid in not a particularly selective collector since it also attaches to other calcium bearing minerals; such as, calcite and dolomite. The fatty acid also has a tendency to attach to calcium in the water and more is needed when phosphate flotation takes place in hard (high calcium) water. The bond between the fatty acid and phosphate rock is very strong. Warmer temperatures produce better flotation because the chemical reaction goes faster. Conversely, colder temperatures require more fatty acid to overcome the slower reaction rate.

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Conditioning:

Conditioning fatty acid and fuel oil reagents onto the surface of the phosphate minerals is the single, most important step in the overall flotation process.

Feed conditioned well, will float well, but feed conditioned poorly will never float well. The design of conditioners and the effect of various parameters on conditioner performance are discussed following:

Conditioning for fatty acid flotation requires high % solids to be successful. The basic design objectives are as follows:

- ◆ Provide for the ability to suspend the solids with a minimal amount of water present. The conditioners need to be able to handle 70-76% solids pulps in other areas of the world without choking and 60-65% solids at Eshidiya. The addition of water to avoid choking is usually self-defeating.

- ◆ Provide for optimal retention time; longer times can generate slimes on soft feeds while shorter times do not give complete reagent coverage. Three (3) to five (5) minutes is a good range.

- ◆ Provide for good mixing within the unit.

- ◆ Reduce short-circuiting by using a minimum of three (3) and a maximum of five (5) units.

- ◆ Provide for adequate flows between units; the discharge chutes should be large and well sloped to avoid choke ups.

Flotation experiments were conducted by use 500g of phosphate samples in 3L Denver flotation cell as shown in the figure 10 below. Sodium silicate and caustic soda ($NaOH, Na_2SiO_3$) were added to the cell filled with pulp at 60 % solids, and then the solution is agitated to 3 minutes. Then tall oil added and the pulp agitated for further 1 minute. After conditioning the pulp was diluted to 25 % solids then the air valve was opened and flotation was started. Flotation was continued until barren flotation was obtained. Flotation concentrate and grade were dried, weighted, and sent to chemical analysis. Figure 10 shows froth formation in the flotation cell.

Figure 10 Froth formations in the flotation cell.

The laboratory flotation cell has the same general internal configuration of the machine used in the flotation plant. As a result, the laboratory cell makes a convenient way to simulate plant flotation cells performance.

As shown previously, flotation experiments were conducted by taking 500 g of feed. Flotation of floatable particles until no more froth reports to the overflow.

A properly conditioned feed should finish floating in 30-45 seconds. Longer flotation (slow float) generally indicates a conditioning problem.

As shown, feed sizes are prepared from A3 phosphate sample from Eshydia mine.

Chemical analysis and size distribution of these synthetic distributions are given in Tables 9and 10.

Table 9 Particle size distribution of the synthetic size distributions of flotation feed

Sample sieve		D50 of synthetic distribution				
		500	493.4	489.52	355	250
Lower limit size	wt	wt	wt	Wt	wt	wt
850	1405	80	375	420	100	430
710	2085	416	795	340	400	134
500	7481	3504	1005	462	1950	560
355	12284	2400	3358	3500	1550	1476
250	7104	800	390.7	1851	2499.3	1400
180	5677	560	1070.48	600	1303.7	2142.82
125	2060	80	600	330	40	1010
90	727	96	199	100	54	278
75	436	16	44.22	141.18	35	199.6
53	577	16	100	192	30	239
45	228	27.6	55	45	20	80.4
38	78	1.6	4.58	14.82	12	45
25	21	2.8	3.02	4	6	5.18
sum	40163	8000	8000	8000	8000	8000

Table 10 Chemical analysis of synthetic distributions

D50	T.C.P%	A.I.R%
250	56.28	26.08
355	51.8	34.14
489.52	49	35.5
493.4	53.06	30.66
500	51.52	32.84

Tables 11 shows flotation results of different feed size using 90 ml of tall oil and different quantities of sodium silicate (Na_2SiO_3).   The results show that the highest T.C.P% was obtained in experiment no 5 when using 30 ml sodium silicate and 90 ml tall oil and 3ml sodium hydroxide. Also, the tabulated chemical analysis results show that there are still phosphates in the sink. This show the necessity to use concentrates cleaning stage.

Table 11 Chemical analysis of some flotation results for D50=500 micron distribution

	Experiment Wt(g)		Chemical analysis				Chemical Dosages (ml)		
Sample No	sink wt	conc. wt	T.C.P%	A.I.R%	sink%	A.I.R%	Tall oil	(Na_2SiO_3)	($NaOH$)
1	325.8	149.8	70.7	6.08	44.38	41.62	90	5	3
2	260.9	210.4	70.56	6.14	41.02	48.92	90	10	3
3	282.6	190.3	70.84	6.08	41.3	48.8	90	15	3
4	293.5	178.8	70.14	6.24	49.42	38.16	90	20	3
5	321.8	149.3	71.12	5.84	52.36	34.16	90	30	3

Table No 12 expresses the affect of the suitable dosage of the toil oil and sodium hydroxide in the flotation process the suitable range of chemical are (60-70)ml toil oil and (20- 30) ml of Na_2SiO_3 as shown in the table.

Table 12 Chemical analysis of some flotation results for D50=250 micron distribution.

D250 Sample	Experiment Wt(g)		Chemical analysis				Chemical Dosages (ml)		
	sink wt	conc. wt	T.C.P%	A.I.R %	sink%	A.I.R %	Tall oil	(Na_2SiO_3)	($NaOH$)
1A	457.6	41.2	65.16	14.54	53.2	29.46	39	22	3
1B	425.4	62.1	67.62	8.5	50.82	32.48	39	114	3
4B	280	216.9	71.4	7.26	42	43.54	55	114	3
4A	247.9	204.6	70.28	7.24	35.7	50.26	60	22	3
2A	148.6	340.4	65.94	13.82	23.8	65.24	68	22	3
2B	168.4	328	66.94	13.82	23.1	66.28	68	114	3
3A	194	297.5	68.04	11.14	26.32	61.4	74	22	3

In table No 13 shows that the effect of chemical dosage of toil oil and Na_2SiO_3 at the size distribution D50 (355) we can see that the highest T.C.P % at the dosage of (60-70) ml toil oil and (20-30)ml of Na_2SiO_3 and same dosage of $NaOH$ and the effect of excusive dosage of these chemical will effect both T.C.P % and recovery%.

For experiment No 2 express the effect of conditioning in the flotation process when no conditioning at all this affect the process and will be no flotation at all.

Table 13 Chemical analysis of some flotation results for D50=355 micron distribution

SIZE	D50(355)							
Test#	Tail oil(ml)	Na_2SiO_3 (ml)	Conc. Wt (g).	T.C.P%	A.I.R%	Sink Wt(g)	Sink%	A.I.R%
1	39	22	47.1	70.14	11.44	427.4	53.48	31.88
2	39	114	NA	NA	NA	NA	NA	NA
3	68	22	121.3	69.4	10.3	367.9	50.24	33.08
4	68	114	180	68.6	11.6	314.9	32.96	61.42
5	74	22	78.1	69.68	12	416	34.5	60.18
6	74	114	75.7	69	11.16	420	52.56	44.58

In the table 14 the result confirms the effect of actual dosage of chemical in the flotation process as shown in the table.

Table 14 Chemical analysis of results for D50=489.5 micron distribution

SIZE	D50(489.52)							
Test#	Tail oil(ml)	Na_2SiO_3 (ml)	Conc. Wt (g).	T.C.P%	A.I.R%	Sink Wt(g)	Sink%	A.I.R%
7	39	22	114	66.3	14.22	370	46.06	38.64
8	39	114	214.1	65.8	17.16	272.3	55.44	29.84
9	68	22	119.6	65.62	14.14	361.2	52.36	30.86
10	68	114	230	64.54	18.02	265.6	35.28	49.66
11	74	22	210.6	65.94	16.22	285.4	46.76	40.36
12	74	114	215.1	64.84	17.44	275.7	35.98	55.44

Good selective flotation that maximizes recovery and grade and minimizes reagent costs requires number of things to be done properly.

For phosphate, flotation is more sensitive than for many other minerals and this require taking on greater importance. Process requirements for phosphate flotation are listed the following in their order of importance.

- The presence of clays and other fine minerals during conditioning and flotation can consume excessive amounts of reagents and hinder recovery and product grade.

- Conditioning at Proper % Solids – This means high % solids prior to rougher flotation; 70-75% using neat tall oil and 60% and above using soap.

- Good Sizing – Size feed well in both fractions. Properly sized feed generally results in higher recovery of the coarser fractions in the feed and more selective concentrates from the finer fractions at reduced reagent usage.

- Clean Water – Water used prior to flotation can be somewhat dirtier than that used directly in flotation but should be relatively free of solids. Water used directly in flotation should be as clean as possible.

- Proper Reagent Dosages – Use what is required but not more. Since additional reagent is sometimes needed to aid downstream operations such as filtering and to avoid scaling.

There are two basic formulas that can calculate various mass and T.C.P splits within a given circuit or for the overall:
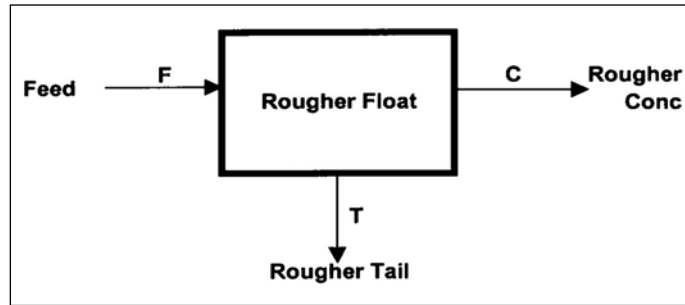
$$\text{Recov}ery\ T.C.P\ \% = \frac{\dfrac{coc\ T.C.P}{100}(Wt\ conc)}{\dfrac{Feed\ T.C.P}{100}(Wt\ Feed)}(100)$$

$$\text{Mass recovery }\% = \frac{C\ (Wt\ )}{(C+T\ )Wt} * 100\ \%$$

The (T.C.P & Mass) % of the phosphate minerals in the feed reported to the concentrate while (100- (T.C.P & Mass)) % was lost to the tails.

Table 15 shows the calculations of phosphate recovery using different Combinations of feed size and collector and represents dosages while figure 5 shows the flotation performance of D50=500 micron feed using collector at different dosage in ml for Toil oil and sodium silicates (Na_2SiO_3) and equal quantity of ($NaOH$).

Table 15 TCP and Mass Recovery Calculations.

Sample No.	Experiment Wt(g)		chemical analysis		Recovery%		Size
	sink wt	conc. wt	T.C.P%	A.I.R%	T.C.P%	Mass%	D50
1(500)	260.9	210.4	70.56	6.14	61.14	44.64	500
2(500)	325.8	149.8	70.7	6.08	43.22	31.50	500
3(500)	282.6	190.3	70.84	6.08	55.37	40.24	500
4(250)	293.5	178.8	70.14	6.24	51.54	37.86	250
5(250)	321.8	149.3	71.12	5.84	43.75	31.69	250
1A	457.6	41.2	65.16	14.54	9.56	8.26	250
2A	148.6	340.4	65.94	13.82	81.56	69.61	250
3A	194	297.5	68.04	11.14	73.18	60.53	250
4A	247.9	204.6	70.28	7.24	56.46	45.22	250
1B	425.4	62.1	67.62	8.5	15.31	12.74	250
2B	168.4	328	66.94	13.82	78.59	66.08	250
4B	280	216.9	71.4	7.26	55.38	43.65	250
1	427.4	47.1	70.14	11.44	13.44	9.93	355
2	NA	NA	NA	NA	NA	NA	355
3	367.9	121.3	69.4	10.3	33.22	24.80	355
4	314.9	180	68.6	11.6	48.17	36.37	355
5	416	78.1	69.68	12	21.26	15.81	355
6	420	75.7	69	11.16	20.34	15.27	355
7	370	114	66.3	14.22	31.87	23.55	489.52
8	272.3	214.1	65.8	17.16	59.11	44.02	489.52
9	361.2	119.6	65.62	14.14	33.31	24.88	489.52
10	265.6	230	64.54	18.02	63.84	46.41	489.52
11	285.4	210.6	65.94	16.22	57.18	42.46	489.52
12	275.7	215.1	64.84	17.44	57.99	43.83	489.52

CONCLUSIONS AND RECOMMENDATIONS:

The following conclusions are based on my experience at the Eshidiya Beneficiation Plant during the year 1996-2007 and are:

The Eshidiya project faces a number of challenges as it strives to meet JPMC's budgets. Much work remains to be accomplished, but I believes that Eshidiya project has the potential to become a World Class phosphate mining and processing operation.

As my experience the study clearly showed that testing with laboratory conditions typical of scientific research yields different results than laboratory testing with plant-like conditions. The effect of test conditions on laboratory results should be considered and addressed in the future by investigators planning and conducting applied research for the Phosphate ore.

Fatty acid is the collector that attaches to the phosphate mineral. Caustic and soda ash are pH modifiers. Sodium Silicate is a depressant for silica minerals and diesel oil is an extender. At Eshidiya, the fatty acid is made into soap by saponifying it with caustic soda prior to conditioning. The diesel oil at Eshidiya is also used to modify the resulting froth in the presence of slimes and to help float the coarser phosphate.

The % solids of the slurry are the most important variable that an operator has to work with during the conditioning step. For the most part, this variable is controllable through adjustments in feed cyclones or classifier overflows. Typically, conditioned feed should approach the appearance of the skin of an orange for best results, although, different feeds sometimes will appear differently in the conditioners. High % solids actually accomplish six (6) positive effects during conditioning:

- ♦ Increase the reaction rate of the collector/mineral attachment since there is less dilution with water.
- ♦ Increase retention time in the units because there is less dilution with water.
- ♦ Increase the ability of the reagents to be "smeared" on the surface of the phosphate.
- ♦ Require fewer reagents to be used.
- ♦ Increase the "speed of float" in the flotation cells.
- ♦ Negate, to some extent, the influence of slimy feeds.

The pH during conditioning is critical since it must be in the proper range for absorption of fatty acid to take place on the phosphate mineral. The addition of caustic soda "sets the table" so to speak. Beyond this point operator experience is necessary. Different pH levels are sometimes required for different feeds; slimy feeds may require a lower pH while good clean feeds may require a higher pH for optimum results. Coarse feeds at Eshidiya seem to require a high pH for good flotation, while fine feeds require no pH adjustment at all. It should be remembered that caustic soda is also a froth modifier to some extent; so much of what the operator does to optimize his float using caustic soda depends upon the character of the froth on the flotation cells and the amounts of other reagents being used. A general rule to follow for pH is; better to be a little high than to be a little low and lose recovery.

Phosphate rock needs processing to reduce the content of gangue minerals such as silicates, carbonates, and clays to meet the requirements of the phosphate industry so during the screening of the phosphate rock in different fractions it is better to check the concentration of every fraction separately for its T.C.P% and A.I.R%. This determines the required beneficiation method.

Good, selective flotation that maximizes recovery and grade and minimizes reagent costs requires that a number of things are done properly.

For phosphate, flotation is more sensitive than for many other minerals and these requirements take on greater importance.