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MINING AND BENEFICIATION OF PHOSPHATE ROCKS FROM THE AKASHAT MINE, IRAQ

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ABSTRACT

This article is meant to cover the general aspects of mining and beneficiation of the Iraqi phosphate rocks. The phosphate deposits in Iraq extend over the Western Desert in Al Anbar Governorate. The Akashat mine, located about 500 Km west of Baghdad, is the first phosphate mine opened in Iraq and has been operating since 1983. The average content of P_2O_5 is about 20%. The tailings constituents are mainly carbonates, silica, and clays. The phosphate ore is mined by open cast mining in two quarries. The mined rock is transported to Al-Qaim fertilizer complex by train where upgrading is carried out in the beneficiation plant through different operations including crushing, homogenization, calcination, slaking, washing and desliming. The beneficiated phosphate rocks, with 29 – 30 % P_2O_5 content, are used for the production of phosphoric acid and phosphatic fertilizers.

استخراج وتركيز الصخور الفوسفاتية من منجم عكاشات، العراق

رضا جاسم جعفر

المستخلص

تعنى هذه الورقه بتغطية عمليات استخراج الصخور الفوسفاتية في منجم عكاشات الواقع غرب العراق ويبعد عن بغداد حوالي ٥٠٠ كم وهو أول منجم للفوسفات وتتم عمليات تركيز الفوسفات منه في مجمع القائم لإنتاج الأسمدة الفوسفاتية. تمت المباشرة بالانتاج من هذا المنجم في عام ١٩٨٣ ويتم استخراج الصخور الفوسفاتية من مقلعين بطريقة المنجم السطحي المكشوف بإزالة الطبقة الغطائية ثم يتم عمل مصاطب لطبقة الفوسفات الصناعيه لتمكين قلعها واستخراجها. تنقل الصخور الفوسفاتية الى المجمع الكيمياوي في القائم بواسطة القطارات لغرض زيادة تركيز الفوسفات (P_2O_5) من ٢٠% الى ٣٠% خلال سلسلة من العمليات تبدأ بالتكسير، المجانسة، الحرق، الإطفاء الجيري، الغسل، التجفيف والضخ الى معامل إنتاج حامض الفوسفوريك والأسمدة الفوسفاتيه.

INTRODUCTION

Phosphate rock is a general term refers to a naturally occurring geological raw material containing high concentration of phosphate minerals. Most of the phosphate rocks are of marine sedimentary origin and most of the sedimentary deposits contain carbonate – fluorapatite as the main phosphate mineral (Zapata and Roy, 2004). Phosphate rocks are considered the basic raw material for different industries; phosphatic fertilizers, phosphoric acid, and other several important chemical compounds.

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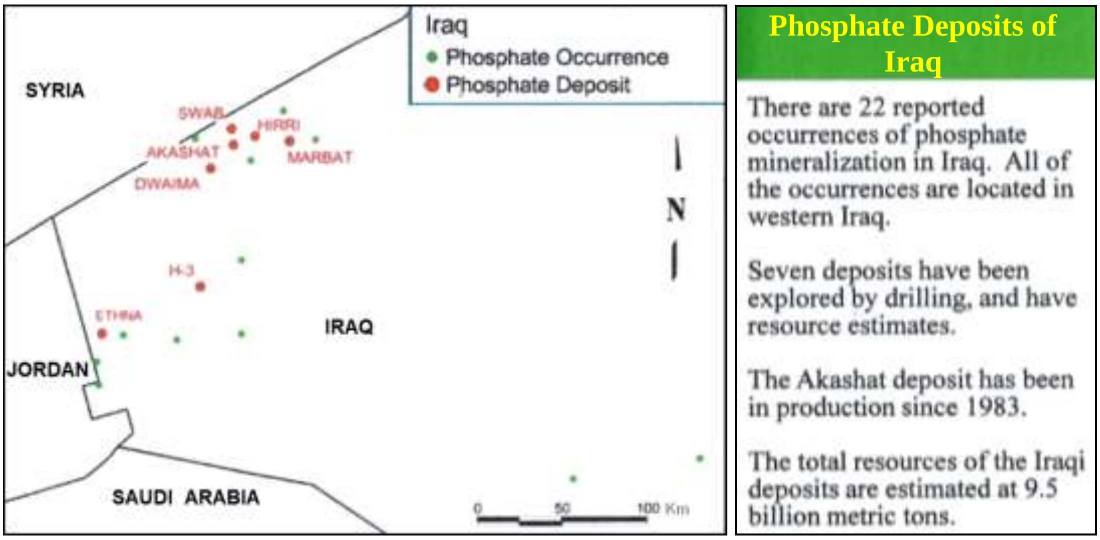
Phosphatic minerals, mainly of the apatite group are found in nature mixed with various types of impurities such as calcite, dolomite, clays, silica and organic matter (Al-Bassam, 2007).

Phosphate rocks are extracted using surface and underground mining methods. At the global level, most phosphate rocks are extracted using surface mining methods, while the contribution of underground mining methods has declined (UNEP, 2001). The phosophate rocks in Akashat are extracted using the conventional surface mining.

Because of the adverse effect of the impurities of phosphate rock in the manufacturing of Phosphoric acid, they must be reduced to the lowest possible level required for the production of phosphatic fertilizers, and many other phosphate compounds. The beneficiation method which is employed to concentrate phosphate rock and to achieve an efficient separation, depends on the impurities present and the properties of the rock (mainly P_2O_5 content and the associated minerals) (Kawatra and Carison, 2014).The calcination process is currently used to beneficiate calcitic phosphate ores. Calcination temperature, in the range 950 – 1000 °C, is conducted to treat carbonate-bearing sedimentary phosphate rocks followed by slaking and rejection of the calcined oxide (CaO) by disliming in a washing plant (Abouzeid, 2008).

OCCURRENCE AND GEOLOGY

The phosphate deposits in Iraq are situated in different locations in the Western Desert of Al-Anbar Governorate (Fig.1). Geologically, the Iraqi phosphate deposits are marine sedimentary in origin, developed in geological formations ranging in age from Late Cretaceous to Eocene. They are found as stratified and nearly horizontal beds in the Digma Formation, Akashat Formation and Ratga Formation. The majority of the deposits, however, are of Paleocene age encountered in the Akashat Formation (Al-Bassam *et al*., 1990; Al-Bassam, 2007). The industrial phosphate layer in the Akashat area ranges in thickness between 9 and 15 m with an average of 11 m. The industrial phosphate bed is gray, oolitic, well sorted, fine grained, medium in hardness, friable at its upper parts and containing hard phosphatic limestone in the middle part. The average P_2O_5 content lies between 20 and 22 %. The carbonate fluorapatite represents about 60% of the mineral constituents, whereas the main diluent is calcite making about 35% of the rock constituents.



Phosphate Deposits of Iraq

There are 22 reported occurrences of phosphate mineralization in Iraq. All of the occurrences are located in western Iraq.

Seven deposits have been explored by drilling, and have resource estimates.

The Akashat deposit has been in production since 1983.

The total resources of the Iraqi deposits are estimated at 9.5 billion metric tons.

Fig.1: Location of main phosphate deposits in Iraq
(after Al-Bassam *et al*., 2012)

MINING

The industrial reserves of the Akashat phosphate deposit were estimated by about 430 million tons (Zainal, 1970; Al-Khalil *et al*., 1973). The rock properties and average chemical composition of the Akashat phosphate deposit are shown in Tables 1 and 2. The Akashat mine is the first phosphate mine in Iraq, the production started in 1983 by open cast mining. The Akashat phosphate mine is an open cast mine, the mining method is a conventional strip mining (surface mining), surface layer (overburden) is removed by wired electric excavator (Drag line) after drilling and blasting the hard rock and the raw phosphate rocks. The blasted materials are extracted by shovels or wheel loaders as in Fig. (2). The process is achieved by dividing the quarry into parallel slices or strips, As long as the mining conditions are suitable for the open pit mining. The haulage of the broken rock from the industrial bed is transported to the crushers in rear-dumper trucks in order to reduce the size to the range of 0 – 250 mm. The design capacity of Akashat mine is 3.4 million ton of crushed rock phosphate per year. Figure (2) show the general routes of phosphate rock mining and crushing at Akashat mine.

Table 1: Raw material specifications

Rock properties:	
Chemical formula of major minerals	$Ca_{10}(PO_4, CO_3)_6F_2 + CaCO_3 + SiO_2 +$Al-silicates
Bank density	1.84 Ton/m^3
Exported density	1.424 Ton/m^3
B.P.L	46% (bone phosphate of lime)
P_2O_5	21.04%
Moisture Dry	

Table 2: Average chemical composition of the Akashat phosphate rocks

Compound	Average (wt.%)
P_2O_5	21.47
CaO	50.98
MgO	0.60
CO_2	17.26
SiO_2	2.24
SO_3	1.70
F	2.88
Cl	0.13

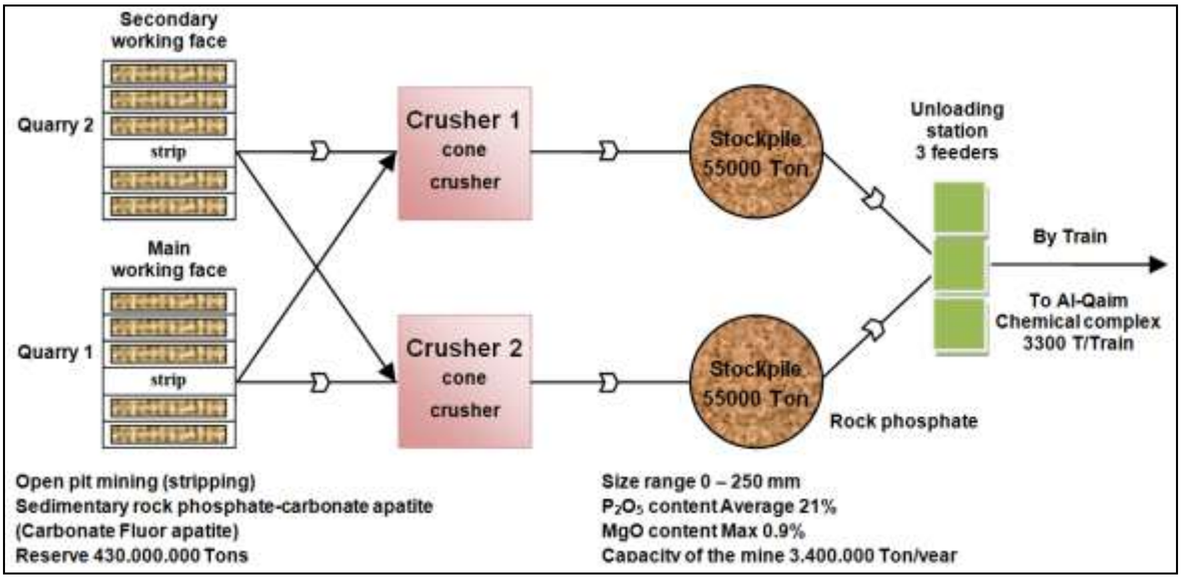


Fig.2: General routes of phosphate rock mining and crushing at Akashat mine

BENEFICIATION

The main important component in the rock phosphate is apatite, the rest of the minerals are considered as contaminants that must be reduced in order to meet the requirements of the phosphate industry. Carbonates, silicates, and clays are the most common gangue minerals (Abouzeid, 2008). Upgrading the P_2O_5 content of the Akashat raw phosphate rocks is done by beneficiation in the beneficiation plant at Al-Qaim fertilizer complex through; crushing, calcination, slaking and washing (Fig.3a).The phosphate rocks undergo many operations in order to increase the ratio of P_2O_5 content from 20% up to 30% to be used in the manufacturing of phosphoric acid plant and fertilizers plant, the sequence of these operations are as follow.

1. Primary crushing in the mine site to reduce the size of the rock to ≤ 250 mm.
2. Secondary crushing in the chemical complex in Al-Qaim to reduce the size of the rock down to ≤ 25 mm.
3. Homogenization process in order to prepare the rock for the calcination process, since the rock has variable P_2O_5 content.
4. Calcination process by burning the rock at temperature of 950 °C → 1000 °C in two rotary kilns, leading to the disintegration of the carbonate phase as follow:

$$CaCO_3 \xrightarrow{950 - 1\,000\ ^\circ C} CaO + CO_2 \quad \ldots\ldots\ldots 1$$

5. Slaking process which is mainly quenching the free lime by spray of water to convert CaO to $Ca(OH)_2$ according to the equation:

$$CaO + H_2O \rightarrow Ca(OH)_2 \quad \ldots\ldots\ldots\ldots\ldots 2$$

6. Washing process and grinding to reduce the size of the rock phosphate down to 40 – 200 microns produced $Ca(OH)_2$ will be washed out by hydro cyclone. Another problem represented by the presence of magnesium oxide MgO which must not exceed 1% in the product (beneficiated rock phosphate); this is done by using special hydro cyclones which cut the particles to less than 70 microns as overflow which is then disposed off to the slime

disposal. High content of MgO will make problems in the filtration stage for phosphoric acid plant, where layer of gelatin impede the process of filtration.

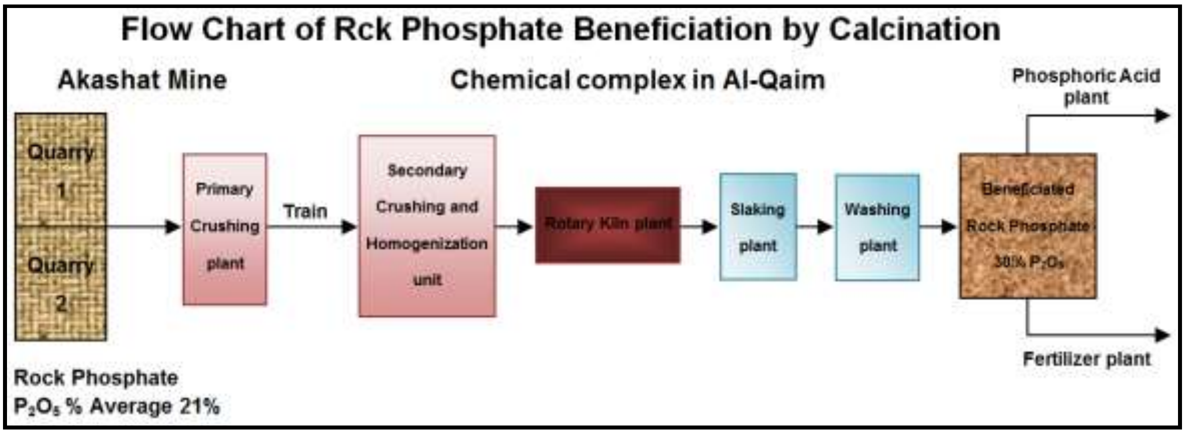


Fig.3a: The general route of phosphate rock handling starting from Akashat mine down to beneficiation plant at Al-Qaim fertilizers complex

- **Calcination Process**

The heat treatment of phosphate rock is defined as heating up the ore to a certain temperature (between 950 – 1000 °C) to obtain a product with specific properties that can be slaked and after that washed in order to increase the concentration of the P_2O_5 content.

Thermal treatment of apatite ore includes the following steps:

1. Drying process i.e. evaporation of the moisture content within the temperature range of 120 – 150 °C.
2. Pyrolysis of the organic matter within the temperature range 650 °C – 750 °C.
3. Thermal decomposition of the carbonates by calcination within the temperature range of 950 °C – 1000 °C (equation no. 1).

The rotary kiln is operated in the counter-current mode with respect to the relative direction of gas and rock phosphate flow. The kiln is gently sloping (usually up to 0.03 m/m) with rotation speed of 1.5 revolution per minute. According to the results of XRD and XRF analysis in terms of mineralogical content, It is evident that the major impurities in the phosphate ore are calcite, accordingly all the potential issues parameters of calcination have been taken into consideration, such as appropriate crushing to minimize the generation of slimes and determine the optimum time and temperature by the proper design of the rotary kiln, to ensure the energy recovery system and finally optimizing the overall concentration circuit. Fundamentally, rotary kilns are heat exchangers in which energy from a hot gas phase is extracted by the rock phosphate. During its passage along the kiln, the rock phosphate will undergo various heat exchange processes, covering the main stages; drying, heating and chemical reactions that cover a broad range of temperatures. The most effective parameter in the rotary kiln operations is the counter current flow of the rock phosphate against the gas flow in opposite direction. Moreover, particle size range, temperature, and duration of calcinations should also be carefully optimized (Fig.3b).

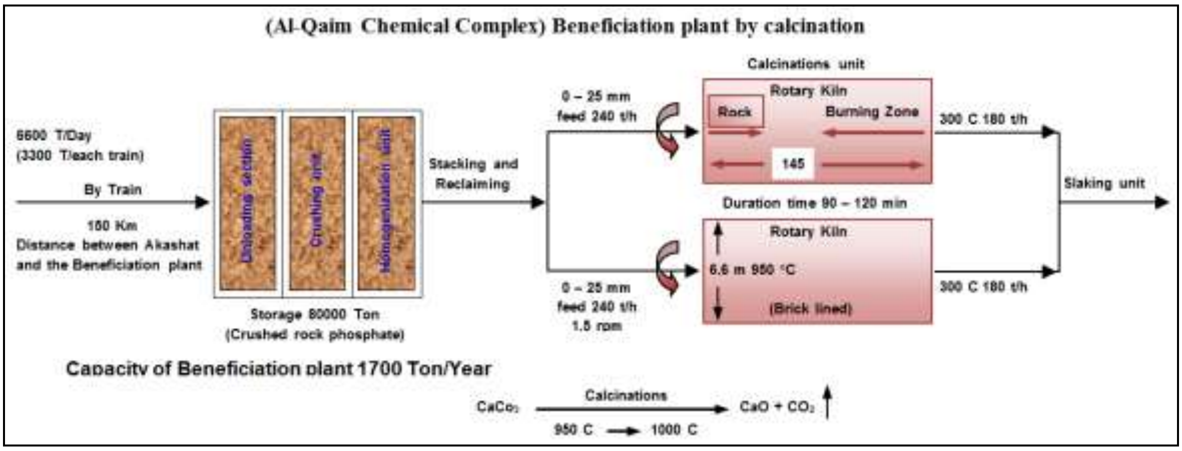


Fig.3b: Beneficiation process at the calcination stage (Al-Qaim fertilizers plant)

- **Slaking Process**

After calcination and carbonates decomposition, the output of the kilns will enter the slaking process in which calcined particles are rapidly quenched with cold water, resulting in rapid heat loss release of CaO and formation of $Ca(OH)_2$ according to equation no. 2.

- **Washing (Desliming) Process**

After slaking process the calcined rock phosphate will go through washing process or desliming in order to remove the $Ca(OH)_2$ by passing the slurry through multi-stages of hydro cyclone and tanks in the washing plant which has two identical lines each line has a capacity of 220 Ton/hour of slaked phosphate .The process can be described as the follows (Fig.4).

The first stage of washing is to pass the quenched rock phosphate into a drum mixer where the slurry phase is formed after treatment with water, through a vibrating screen for separating big particles (greater than 3 mm), in order to mill the rock phosphate to less than 200 micron. The mixture is then milled by a ball mill under flow (slurry) will go through two stages of cyclones, the first cuts 90 microns and then group of cyclones (eight cyclones) to remove the particles of less than 40 microns (overflow) as slime which will go to the thickener which contain mainly $Ca(OH)_2$, then the slimes of the thickener after settling will be pumped to the slime disposal through a 500 mm diameter pipeline.

The two-stage cyclone must be operated twice: before the ball mill (pre-grinding) and after the ball mill (post-grinding). Underflow of the cyclones which has particle size greater than 40 microns and less than 200 microns due to the action of the ball mill will be forwarded to centrifuges for separating the rock phosphate from the slurry. Finally, the whole products of the washing plant with moisture content 11 – 13 % will go to either the storage of 80,000 Tons capacity or to the pumping station from which it will feed the rock phosphate through pipelines to the unit of phosphoric acid plant or to the fertilizer plant according to their requirements as shown in Fig. (5).

The MgO content must not exceed 1% in the beneficiated rock phosphate product, otherwise it may create problems in the filtration stage in the phosphoric acid plant due to the formation of a gelatin-like layer that impede the processes of filtration. When high content of MgO is present, then, special cyclones will be used to cut the particles of less than 70 microns as overflow from the slime cyclones (Fig.6).

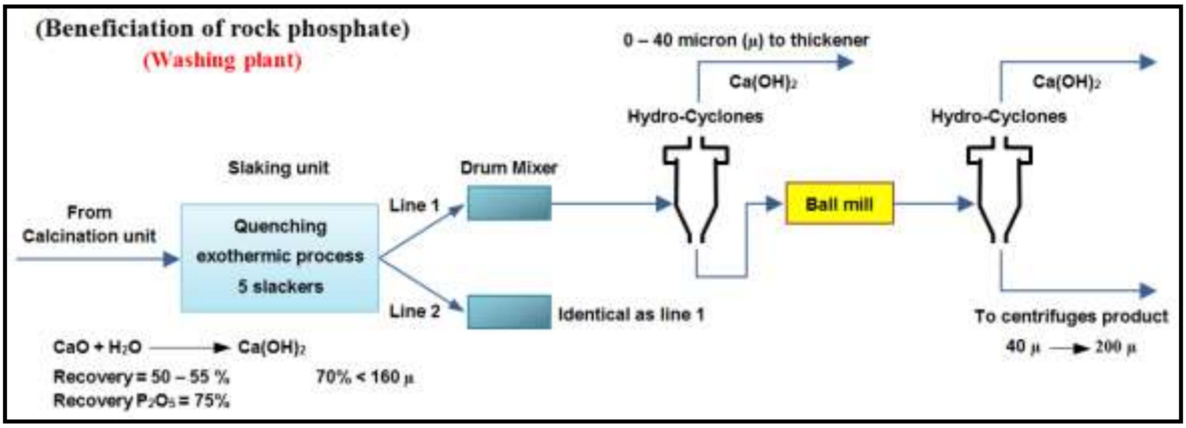


Fig.4: Beneficiation process at the Washing stage (Al-Qaim fertilizers plant)

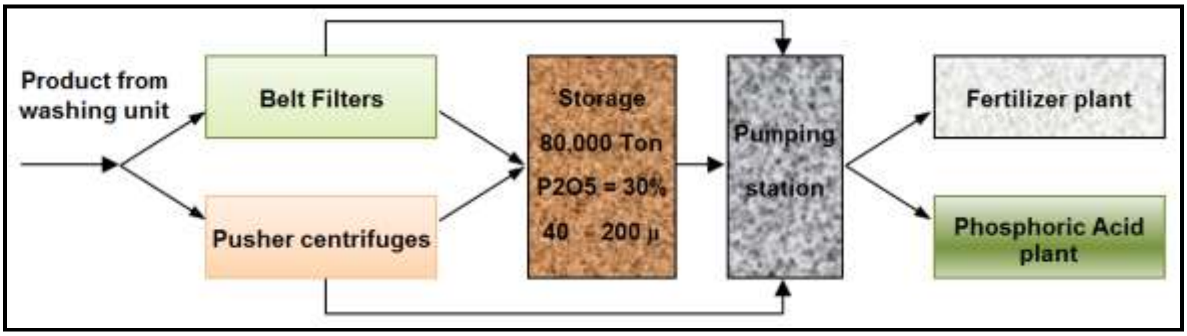


Fig.5: Dewatering unit and storage

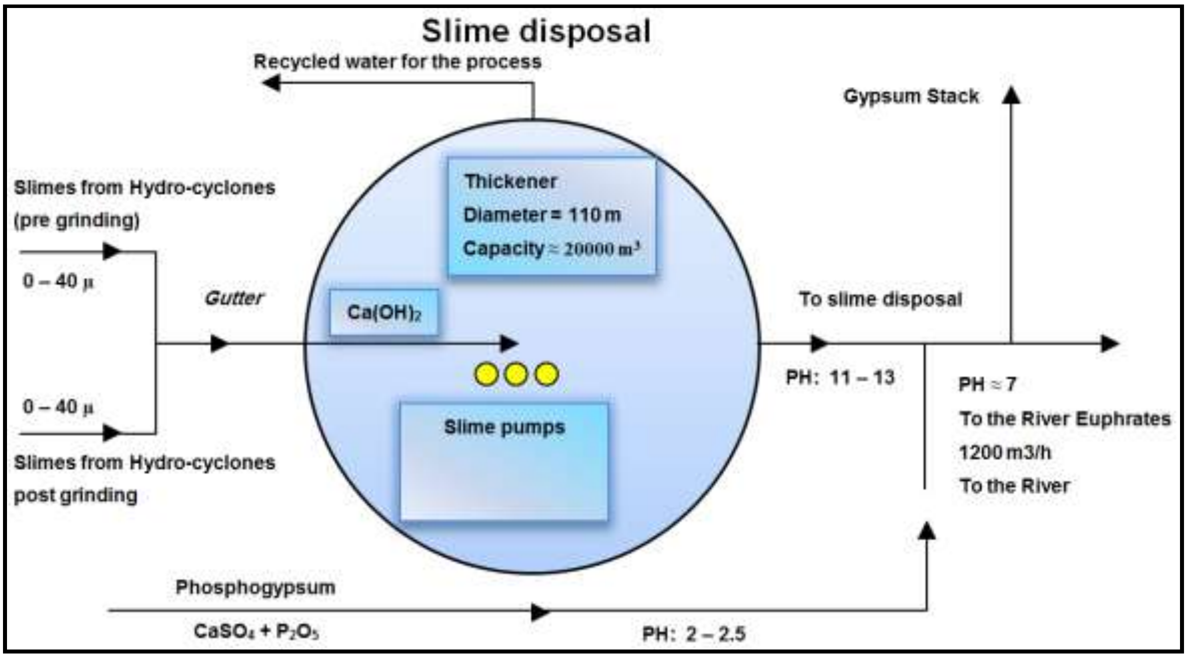


Fig.6: Slime disposal process (Al-Qaim fertilizers plant)

CONCLUSIONS

The run-off mine phosphate raw material in Akashat is of medium grade (about 20% – 22% P_2O_5) which needs upgrading to 30% P_2O_5 to be suitable for the production of fertilizers and other phosphate compounds. The extracted sedimentary phosphate rocks, having carbonate – fluorapatite as the main phosphate mineral and containing calcite as the main impurity, make the calcination process as the best solution for upgrading these phosphate rocks. However, other routs of beneficiation, such as floatation or size differentiation may be worth investigating in the future.

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