



PHOSPHATE ROCK PROCESSING AND FERTILIZERS PRODUCTION AT AL-QAIM FERTILIZERS COMPLEX, IRAQ

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ABSTRACT

Phosphate rocks that have been discovered in Akashat area/ Anbar Governorate, provided the basis to establish the phosphate fertilizers industry in Iraq. The State Company for Phosphate was established for the investment and management of phosphate rocks in Akashat mine and fertilizer complex in Al-Qaim. The company's products (including intermediate products) include sulfuric acid, phosphoric acid, and phosphate fertilizers such as TSP (Triple Super Phosphate), MAP (Mono-Ammonium Phosphate), and the compound fertilizers (NP and NPK). Production in the company began in 1983, but has faced many problems, especially since 1991. During this period, the production rate was not at the required level. Now Akashat mine and Al-Qaim fertilizers complex require complete rehabilitation in order to get the phosphate fertilizer production level back to its designed capacity.

معالجة الصخور الفوسفاتية وإنتاج الأسمدة في مجمع القائم للأسمدة في العراق

هجران زين العابدين طعمة

المستخلص

وفرت صخور الفوسفات التي تم اكتشافها في منطقة عكاشات/ محافظة الأنبار الأساس لإنشاء صناعة الفوسفات في العراق. تأسست الشركة العامة للفوسفات لاستثمار وإدارة وتشغيل منجم عكاشات ومجمع الأسمدة في مدينة القائم التي تبعد ٤٠٠ كيلومتر عن بغداد. منتجات الشركة (بما في ذلك المنتجات الوسيطة) تشمل حامض الكبريتيك، وحامض الفوسفوريك، والأسمدة الفوسفاتية مثل سماد السوبر فوسفات الثلاثي (TSP)، وسماد أحادي فوسفات الأمونيوم (MAP)، والأسمدة المركبة (NP و NPK). بدأ الإنتاج في عام ١٩٨٣، ولكن الشركة واجهت العديد من المشاكل، وخاصة منذ عام ١٩٩١. وخلال هذه الفترة، كان معدل الإنتاج ليس بالمستوى المطلوب. الآن منجم عكاشات ومجمع الأسمدة في مدينة القائم تحتاج إلى إعادة تأهيل من أجل إعادة وتيرة إنتاج الأسمدة الفوسفاتية إلى مستوى الطاقات التصميمية.

INTRODUCTION

The Western Desert of Iraq is one of the most interesting regions as far as mineral resources are concerned (Al-Bassam, 2007a). It has been mapped and explored over the last 60 years or so by many foreign and Iraqi institutes. Phosphate rocks were discovered in this region in the fifties of the past century (Cobbett, 1954). The deposits of Akashat provided the basis to establish the phosphate industry in Iraq, especially the production of phosphoric acid and phosphate fertilizers. In 1976, the State Company for Phosphate was established for the exploitation and management of the phosphate deposits in Akashat and production of

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phosphate fertilizers at Al-Qaim fertilizers complex. The construction work started in the same year by Sybetra-Union Miniere (Belgium) and the production commenced in 1983. This paper is concerned mainly with the technological routs to produce the phosphoric acid and consequently the phosphate fertilizers at Al-Qaim plant.

The phosphate raw material is extracted from the Akashat mine, located in the Western Desert, some 150 Km west of Al-Qaim in Al-Anbar Governorate, and 550 Km west of Baghdad. Akashat rises about 600 meters above main sea level. The mine that was designed and built by Sybetra-Union Miniere includes five quarries, of which only two are working. Production in the mine started in 1982; the estimated reserves of the Akashat phosphate deposit was about 430 million tons of phosphate rock (Zainal, 1970; Al-Khalil *et al.*, 1973). The mine was designed to produce 3.4 million tons/year with 21 – 22 % P_2O_5 concentration. The raw material undergoes preliminary crushing at Akashat and then transported by rail to Al-Qaim complex where it is beneficiated by calcination and wet treatment and a concentrate of about 30% P_2O_5 is used to produce phosphoric acid and phosphate fertilizers.

The Akashat phosphate mine is an open pit mine, the mining is a conventional strip mining (surface mining) where the overburden is removed by dragline excavator and the ore is removed by off-road mine dump trucks which are loaded by electric shovels or mine wheeled loaders. Figures (1 and 2) show Google earth map of Akashat phosphate mine with two quarries and the phosphate mine with the dragline used in mining process. Before transporting, the phosphate rocks are crushed by cone type crusher then conveyed to a loading station by conveyer belts. The Akashat mine site is considered an integrated production unit, where it has workshops, mechanical equipments, warehouses, and all facilities that sustain operations (Shrtouh and Azziz, 2010).



Fig.1: Google earth map of Akashat phosphate mine with two quarries areas



Fig.2: Akashat phosphate mine with dragline used in mining process

AL-QAIM FERTILIZERS COMPLEX

Al-Qaim fertilizers complex is located near Al-Qaim town on the Euphrates River, some 400 Km west of Baghdad (Figure 3). The purpose of the complex is to convert phosphate rock produced in Akashat mine into final products. The Chemical complex was established by Sybetra as a general contractor. The complex consists of a set of integrated plants to produce phosphate fertilizers as a final product. These plants include; ore beneficiation plant, sulfuric acid plant, phosphoric acid plant, utilities plant, fertilizers plants, ammonia plant, fluorine salts plant, and materials handling unit. Figures 4 and 5 show general view of Al-Qaim fertilizers complex. A concise information about plants and units in Al-Qaim fertilizers complex are given below (SCP, 1982a; MIM/ID, 2008; JICA, 2010).



Fig.3: Location of Al-Qaim Fertilizers plant

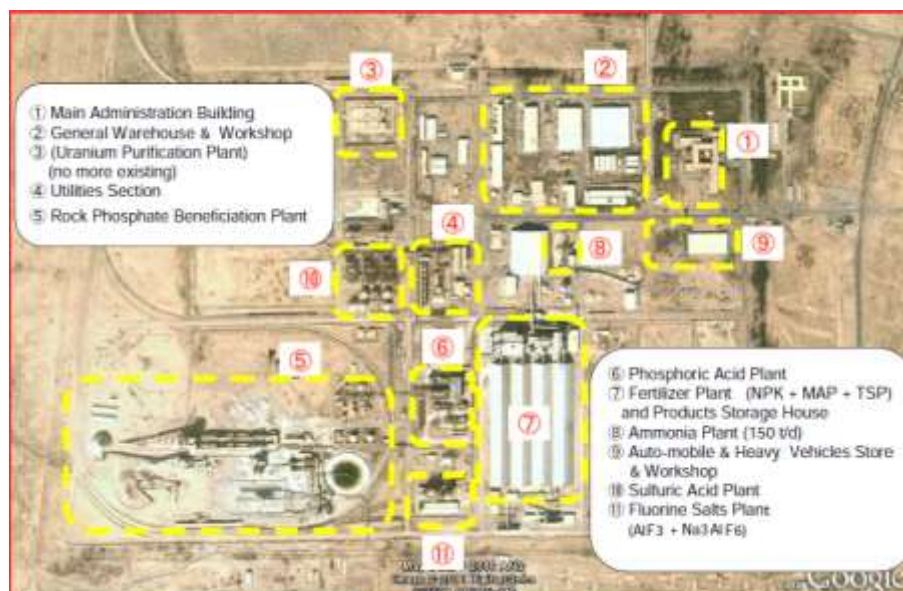


Fig.4: Google earth image of layout of general processes plants in the complex
(modified from Google map and JICA, 2010)



Fig.5: General view of some plants in Al-Qaim fertilizers complex

The complex was designed to produce phosphoric acid, sulfuric acid, and fertilizers products such as; TSP (Triple Super Phosphate) and MAP (Mono-Ammonium Phosphate), compound fertilizers (NP and NPK). Aluminum fluoride and cryolite are also produced using by-products from the phosphoric acid plant. The general routes of phosphate and finished products in Al-Qaim fertilizers complex are outlined in Figure (6).

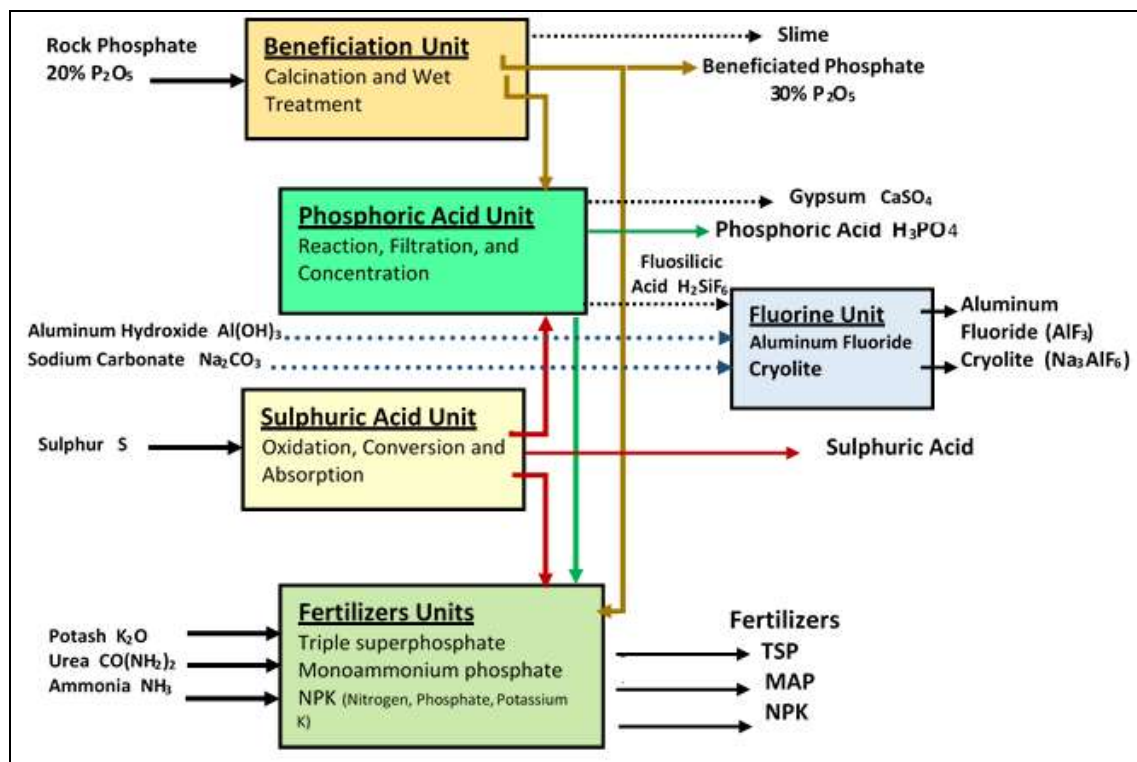


Fig.6: General routes of phosphate and products in Al-Qaim fertilizers complex
(modified from SCP, 1982b)

- **Beneficiation plant**

The plant designed and built by FL Smidth (Danish company) in two production lines to beneficiate the phosphate rock (Figure 7). The beneficiation plant capacity is 3400000 tons

per year of 20% P_2O_5 phosphate rock to produce 1700000 tons per year of 30% P_2O_5 . The purpose of raising the concentration ratio (21% to 30%), by crushing, grinding, calcining, washing, de-sliming, and drying processes, is to make the phosphate raw material suitable for the manufacture of phosphoric acid and phosphate fertilizer. Phosphate is transported by train from Akashat mine, and downloaded at the phosphate unloading station. Phosphate is then conveyed through a conveyor belt to storage silos then conveyed to the kiln for calcination. In the calcination unit, the crushed raw phosphate is burned in two rotary kilns at 950 – 1000 °C to remove organic and volatile material. The thermal decomposition of carbonates is an endothermic reaction which requires high energy; the reaction goes as follows (Abuzaid, 2008):



In slaking stage, water is added to the calcined phosphate to convert calcium oxide to calcium hydroxide as in the following equation:



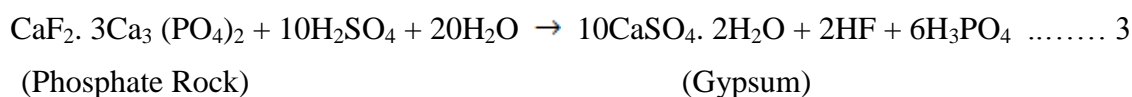
After the process of calcination and slaking, the washing process is carried out in set of grinding and separation equipments in the washing unit, to enrich the phosphate material and separate the fine fraction which contains most of the lime minerals. The beneficiated phosphate material (29 – 30 % P_2O_5), produced from the washing unit, is carried either directly to the repulping installation or as surplus material transferred to an 80000 tons store.



Fig.7: General view of beneficiation plant at Al-Qaim fertilizers complex

▪ Phosphoric acid plant

The plant was designed to produce 1260 tons daily (about 400,000 tons annually.) of phosphoric acid of 52 – 54 % P_2O_5 . The plant was built by Coppee Rust after SNC-Lavalin (Belgium Company) (Figure 8). The concentrated phosphoric acid is produced by the acidulation of beneficiated fine grind phosphate rock with sulfuric acid, using "Prayon" dehydrate wet process. Low concentration phosphoric acid, 28% P_2O_5 , produced from filters, is concentrated by heat-exchangers to 52% P_2O_5 using vacuum evaporation at three concentration steps. About 5 tons of phosphogypsum are produced for each ton of phosphoric acid produced. The overall reaction is as follows (Becker, 1989; Speight, 2002):



Fluosilicic acid (H_2SiF_6), at 20% concentration is produced as by-product material from phosphoric acid production process according to the following equations (Becker, 1989; Speight, 2002):



Fig.8: General view of the phosphoric acid plant at Al-Qaim fertilizers complex

▪ **Fertilizers production plants**

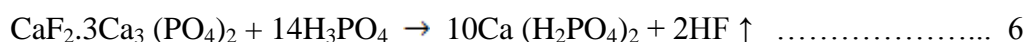
These plants include; Triple superphosphate (TSP) plant with 2 production lines, Monoammonium phosphate (MAP) plant, and compound fertilizers (NP, NPK) plant with 2 production lines (Figure 9).



Fig.9: General view of fertilizers plant at Al-Qaim fertilizers complex

– **Triple Superphosphate TSP:** Triple superphosphate TSP, is produced at annual capacity of 300000 tons in each of the two identical lines, totaling 600000 tons per year designed capacity. The plant was designed according to Fisons process and built by Davy Makee, (British Company) named previously as (Davy Power Gas). The produced fertilizer contains 45 – 46 % P_2O_5 , which is soluble and granular to make easy for absorption by plants and

vegetation. To produce this fertilizer, phosphoric acid from phosphoric acid plant is pumped to the reaction tank, where it reacts with the ground beneficiated phosphate rock provided by the beneficiation plant to produce the slurry according to the following reaction (Taylor, 2004);



The produced slurry in the reactor is pumped to the fertilizer granulator where it is mixed with the fertilizer returns. The product from the granulator falls directly to the dryer, then conveyed for screening and crushing to get the required size of (1 – 4 mm).

– **Monoammonium Phosphate (MAP):** The plant was designed according to Fisons Miniphos process and built by Davy Makee (British company) to produce 280,000 tons annually as designed capacity. Another configuration was applied since 1992 and uses a Norwegian process called Norsikhydro process. MAP is produced by the reaction of concentrated phosphoric acid (about 50 – 54 % P_2O_5) with gaseous ammonia according to the following reaction (Roy, 2007):



The hot slurry produced from the reactor is passed through a special spray nozzle into a spray tower where it is dried by evaporation during descending. The product fertilizer contains 10 – 12 % nitrogen and 50 – 53 % P_2O_5 in the form of round granular particles, mainly small, ranging in size from 0.1 to 1.5 mm. The designed production capacity of the plant is 280000 tons per year. The product is frequently used as an intermediate raw material of compound fertilizer.

– **Compound Fertilizers NPK:** The plant with two lines is designed according to Fisons Process and built by Davey Power Gas to produce about 655000 tons per year of different grades of compound fertilizers. Many different raw materials used to produce different grades of compound fertilizers such as MAP, TSP, Ammonia, Sulfuric acid, Urea (from Basrah or Biji nitrogen fertilizers plants), and Potash (potassium chloride) (imported from Jordan). The grades of compound fertilizers produced in this plant are; NP 27: 27, NP 23: 23, and NPK 18: 18: 18.

▪ Sulfuric acid plant

Sulfuric acid is produced in three units with 98.5% concentration, and a designed daily capacity of 1,500 tons for each unit (annual production 1.5 million tons). Sulfur used in producing sulfuric acid is delivered from the Mishraq sulfur mine in Nineva Governorate and oil refinery in Kirkuk Governorate. A general view of the sulfuric acid plant at Al-Qaim fertilizers complex is shown in Figure (10).

The technology used is from Mechim Company according to Ralph Parsons Double Contact/ Double Absorption (DC/DA) process. This plant includes the following processing steps

- Liquid and solid sulfur unloading and storage facilities.
- Solid sulfur preparation including melting, settling and filtering.
- Sulfur furnace and waste boiler section.
- Air drying.
- SO_2 to SO_3 oxidation.
- SO_3 absorption.
- Acid storage and loading facilities.



Fig.10: General view of sulfuric acid plant at Al-Qaim fertilizers complex

▪ **Ammonia plant**

The plant designed and built by Howe-Baker/ US company with 50000 tons annual production capacity of ammonia. The production of this plant used in fertilizers plants, primarily used for the production of the (MAP, NP) fertilizers.

▪ **Fluorine salts plant**

The Fluorine Salt Plant was built by Alesa (Swiss company) and was designed according to the Alesa and Chemie Linz Process (Figure 11). This plant was formed to consume fluorosilicic acid (H_2SiF_6), a by-product from phosphoric acid concentration units, to produce two types of fluorine salts:

- Aluminum fluoride (AlF_3); fluorosilicic acid and aluminum hydroxide used as raw material to produce 11000 ton per year of aluminum fluoride.
- Cryolite (Na_3AlF_6); 6400 ton per year of Cryolite produced using fluorosilicic acid, aluminum hydroxide and sodium carbonate as raw materials.



Fig.11: General view of fluorine salts plant at Al-Qaim fertilizers complex

▪ **General facilities unit**

This unit provides the general services for the industrial infrastructure required for the operation of the production units. Water, for industrial and public uses, is provided through

water intake facility and treatment plant near the Euphrates River, about 10 kilometers from the Al Qaim fertilizer complex. The water treatment plant design capacity is about 180,000 cubic meters per day pumped to Al-Qaim complex and Akashat mine. This water is processed again in industrial utility unit in Al-Qaim complex to produce de-mineralized water, cooling water, firefighting system, drinking water and other public uses.

Power supply/ Electrical energy for industrial services at Al-Qaim fertilizer complex are provided by two diesel power generators and two steam turbines generators, total design capacity is 34.8 MW. Compressed air, in certain specification and pressure, with 144,000 cubic meters per day design capacity is produced to be used in equipment and control devices in plants through a number of air compressors in the industrial utility unit. Two steam boilers in industrial utility unit are also installed to produce steam to be used in other production plants.

Roads and railroads are well developed to connect production plants in Al-Qaim complex with each other and with the outside. Roads and railroads are also connected to major cities such as Baghdad, Baiji, Mosul, Kirkuk and Basrah and used for transportation of raw materials and products shipment. There is a special cargo line to connect with the phosphate rock mining site of Akashat. There is also a warehouse for product exportation in Umm Qasr port south of Basrah from which products are exported.

▪ **Waste disposal facilities.**

About 4 – 5 tons of phosphogypsum are generated per ton of P_2O_5 produced as phosphoric acid. In the phosphoric acid plant, the slurried phosphogypsum from the filter is transported by pipes to the gypsum stack in tailing pond near Al-Qaim complex. The phosphogypsum stack area is completely lined with high density polyethylene sheet to prevent pollutants from reaching the ground water system. The acidic water coming from stack is collected in acidic water pond then mixed with water coming from slime pond inside the neutralization plant. The huge volume of slime from beneficiation plants is also generated then pumped as slurry to be disposed of in slime pond. Water from the slime pond is collected and pumped to neutralization plant.

▪ **Packing unit**

Finished bulk fertilizer is stored in four large separated storages; they can house up to 300,000 tons of different types of fertilizers (TSP, MAP, NP, NPK). Conveyor belts and handling system transport fertilizers from the stockpiles in bulk storage building to packing unit for the bagging operations or loading directly to trucks.

▪ **Uranium extraction plant**

The Iraqi phosphate rocks contain trace level of uranium, generally ranging from (20 – 50) ppm and reaching up to 100 ppm in some deposits (Al-Bassam, 2007b). During the 1982 to 1984 period, uranium extraction plant from the phosphoric acid was designed, constructed and commissioned by Mechim Company (Belgium) at Al-Qaim fertilizers complex in Al-Anbar Province. The extraction process in this plant was based on solvent extraction technology, namely DEPA-TOPO process. In 1991, during the Gulf War II, the plant was bombarded and destroyed. During 1990s, the "International Atomic Energy Agency (IAEA)" closed and sealed the uranium extraction plant.

PHOSPHATE FERTILIZERS PRODUCTION TREND IN IRAQ

The histogram of the production rate in the period 1983 to 2009 is shown in Figure (12). It can be noted that maximum production capacity was reached in 1988. However, the average production rate did not exceed 30% of the designed capacity (JICA, 2010). Production has been disrupted since 1991 when sanctions interfered with the import of materials and maintenance items. Ensuing conflict and instability in the region has continued to depress the production capacity.

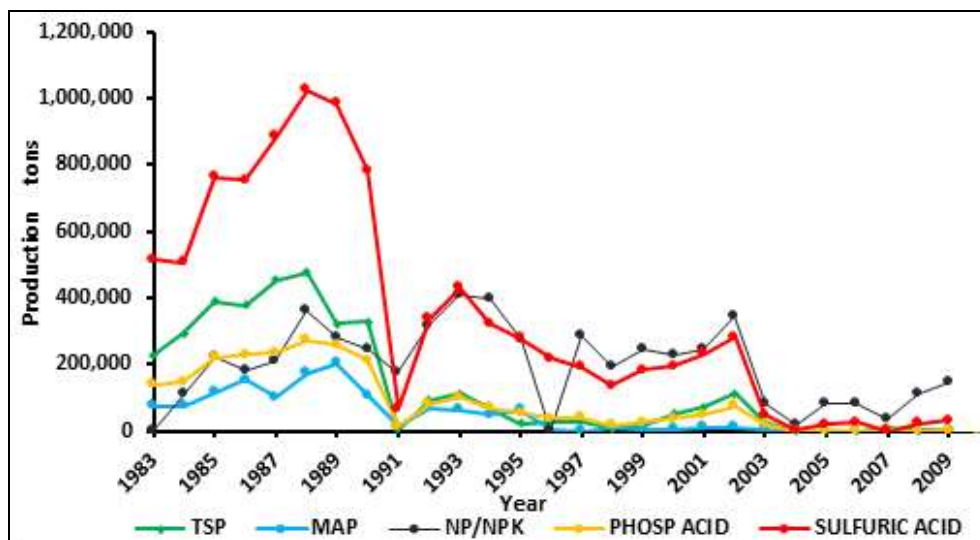


Fig.12: Trend of SCP production capacity in the period 1983 – 2009 (JICA, 2010)

THE CURRENT SITUATION AND FUTURE VISION

The State Company for Phosphate faced big problems, since the second Gulf War in 1991 when aerial bombardment was intensified on the company's sites and laboratories and the subsequent siege extended to 2003. During that period, the rate of production did not exceed 20 – 40 % in most of the company's plants. After 2003 no real rehabilitation of major operations has taken place in the company (apart from some partial rehabilitation) and the production continued to be low.

After 2010, some rehabilitation efforts were achieved when the needed funds were provided to import some equipment and conduct some maintenance operations. This was expected to increase the production rates in some of the company's plants, but the fall or the occupation of the Al-Anbar Province by (ISIL) stopped all the rehabilitation and maintenance operations. It is not easy to determine the amount of damage in the company facilities, but it is expected to be drastic.

After normalization in Al-Anbar Province and as the company is the only producer of phosphate fertilizers and that Iraq needs to increase its agricultural production and achieve food security, it is very necessary to speed up the assessment of the extent of damage and to carry out the rehabilitation of the company's plants as soon as possible. Lack of accurate information requires a case study to pin point the reality of the company's plants and then determine the percentage of damage and how to address rehabilitation. Modern laboratories with high-tech beyond all previous maintenance and rehabilitation problems are essentially needed. Rehabilitation operations and correct format can also be done in partnership with

private investment companies, which are expected to have a major role in the investment and exploitation of the huge reserves of phosphate in Al-Anbar Province, taking into consideration the global green chemical industry requirement to be in compliance with environment protection requirements.

CONCLUSIONS

Past and ongoing research conducted by specialists about phosphate rock deposits in Iraq show that Iraq is in the rank of countries that have huge reserves ready for investment and fertilizers production. Based on those studies it is found that in spite of the little variations in P_2O_5 content, all these deposits can be mined, processed and used efficiently in phosphate industry in Iraq. The phosphate industry in Iraq has suffered from serious problems especially after 1991, and production levels decreased as a result of wars and siege, in addition to the damage that has not yet been identified after the occupation of the region by (ISIL). However, in view of the existence of infrastructure and expertise in the field of phosphate industry, it is possible to re-operate and develop the plants that were established previously and work on the establishment of new plants. The future trend is expected to be focused on new production techniques that contribute to the return of Iraq again to the ranks of developed countries in the field of phosphate industry and plays a significant role in national economy.

REFERENCES

- Abouzeid, A.Z.M., 2008. Physical and thermal treatment of phosphate ores-an overview. *International journal of mineral processing*, Vol.85, No.4, p.59 – 84.
- Al-Bassam, K.S., 2007a. Uranium in the Iraqi phosphorites, *Iraqi Bulletin of Geology and Mining* Vol.3, No.2, p. 13 – 31.
- Al-Bassam, K.S., 2007b. Mineral resources of the Western Desert, Iraq. *Iraqi Bulletin of Geology and Mining*, special issue, 145-168
- Al-Khalil, A., Zainal, Y., Al-Obaidi, H. Al-Waili, M. Al-Maini, J., Jargees, S. and Toubasi, A., 1973. Geological report on the primary development areas (Quary 1 and 2) and theb estimation of reserves (Akashat phosphate deposit). GEOSURV, int. rep. no. 595.
- Becker, P., 1989. Phosphates and phosphoric acid, raw materials, technology, and economics of the wet process. 2nd edition, Marcel Dekker, Inc., New York, 760pp.
- Cobbett, G.P.R., 1954. Radiometric investigation of the phosphate deposit in the area of (H3) oil pumping station. Site Investigation Co. (UK) report. GEOSURVE, int. rep. no. 23.
- JICA (Japan International Cooperation Agency), 2010. Preliminary feasibility study report on mining and industrial sector in Mid-Western, Iraq.
- MIM/ID (Ministry of industry and Minerals, Investment Department), 2008. Industrial investment opportunities in Iraq (Rehabilitation of State Company for Phosphate), Baghdad.
- Roy, A.H., 2007. Fertilizers and food production. In: Kent and Riegel's handbook of industrial chemistry and biotechnology. Springer Science and Business Media, p. 1111 – 1156
- SCP (State Company for Phosphate) 1982a. Process design manuals-sybeta. State Company of Phosphate library, Al-Qaim, Iraq.
- SCP (State Company for Phosphate) 1982b. Training manual-sybeta, State Company of Phosphate library, Al-Qaim, Iraq.
- Shrtouh, I. and Azziz, O., 2010, Akashat phosphate mine, state company for phosphate, Ministry of Industry and Minerals.
- Speight, J. G., 2002. Chemical and process design handbook, McGraw-Hill Companies, 633pp.
- Taylor, A.W. 2004. Fertilizers. Kirk-othmer encyclopedia of chemical technology. Vol.11, p. 111 – 128.
- Zainal, Y., 1970. Preliminary report on the geological investigation of the Akashat phosphate deposit and estimation of reserves. GEOSURV, int. rep. no. 371.