International
Fertilizer Industry
Association

IFA Technical Conference

Amman, Jordan

2-6 October 1994

International Fertilizer Industry Association - Secretariat: 28 rue Marbeuf - 75008 Paris - France
Tel. +33 1 53 93 05 00 - Fax +33 1 53 93 05 45/47 - ifa@fertilizer.org - www.fertilizer.org

FLEXIBILITY IN ROCK PHOSPHATE FLOWSHEETS TO MEET THE SPECIFIC REQUIREMENTS OF INDIVIDUAL PLANTS

N. Hummadi, I. Oweis and M. Mubaideen
JPMC, Jordan

RESUME

En utilisant des techniques relativement simples, les producteurs de phosphate peuvent maintenant satisfaire la plupart des exigences de leurs clients, en ajustant la composition chimique et les propriétés physiques des phosphates afin de se conformer à certains impératifs de procédé et d'environnement.

Ces techniques comprennent l'extraction sélective, le mélange avec des phosphates de différentes qualités, l'addition d'autres substances minérales pour remédier à certaines déficiences et éviter la poussière.

Dans cet exposé, différentes techniques employées par JPMC sont examinées.

◆ ◆ ◆ ◆

INTRODUCTION

Jordan Phosphate Mines Company, JPMC, is one of the world largest producers and exporters of rock phosphates.

The reserves are estimated at two billion tons, while some surveys indicate that more than 60% of Jordan surface area contains phosphate deposits.

Presently JPMC is operating three mines, El Hassa, Al Abyad and Eshydia, with a total installed capacity of 7.5 million tons per year of different rock grades, ranging from 68 to 77 BPL.

JPMC has been a phosphoric acid and fertilizer manufacturer since 1982.

The phosphoric acid plant, located in Aqaba on the Red Sea with a design capacity of 1310 MTPD P_2O_5 is one of the largest single stream plants in the world.

During the past forty years of mining and twelve years of processing operations, JPMC had gained the experience and know-how to deal with a variety of technical problems faced by the phosphate users world wide.

The diversity of available Jordan phosphate ores had allowed JPMC to acquire flexibility in producing rock grades which can meet most manufacturers' requirements.

WHAT QUALITY OF ROCK IS A MANUFACTURER LOOKING FOR?

Phosphate rock whether of igneous or sedimentary origin is a natural product, in which the most valuable constituent is obviously phosphorus. Other components can be literally considered as "impurities" or "filler".

Depending on the end use for the "phosphorus" and the chemical form in which it must be made available, more or less impurities can be tolerated.

Since in practice about 90% of world phosphate rock is used for manufacturing fertilizer products, a phosphate rock producer's main concern must be focussed on how to meet requirements of this particular industry.

What quality of rock is a consumer looking for?

The smartest reply to this question today is: "one which is of good quality and at the right price".

The common practice up to now has been to design a plant based on a given rock phosphate specification which would then allow prediction of the plant's performance (capacity, recovery, specific consumption, etc) and consequently the overall economy of the operation.

For plants which were built with conventional materials of construction the choice of rock feed becomes a matter of **"To be or not to be"!**

The present trend however, is to build phosphoric acid plants with a greater degree of processing flexibility, so that this **"super process",** can economically process "any" type of rock feed. The recent technological developments as they appear, have concentrated in-a-way, **on how to get "the most" from "the worst"**, which leads to the burden being shifted from the phosphate rock producers to the fertilizer manufacturer. Unfortunately to phosphate users, this will not happen very soon, and some plants operators will continue to face the challenge: of how to produce more, from the existing technologies at lower cost, and with less harm to the environment. The feed rock they desire in some cases and for certain processes must be literally **"tailor made"**, to meet all their requirements together.

The stringent regulations for environmental protection and pollution control, have added more burden on the phosphatic fertilizer producers.

DESIRED AND UNDESIRED PROPERTIES OF A COMMERCIAL ROCK

For a non-integrated phosphoric acid plant it is commonly agreed that the phosphate rock should be of following properties:

Chemical:

- High P_2O_5 content (less transportation costs)
- Adequate CaO/P_2O_5 ratio (less sulfuric acid consumption)
- Low content of "harmful" impurities
- Favourable content of "beneficial" impurities

Physical:

- Size distribution (lower content of coarse and fine fractions)
- Product hardness (lower energy consumption for grinding)

The definition of "harmful" and "beneficial" properties of the impurities in the rock depends greatly on their nuisance or positive effects either during processing, or the use/application/discharge of the final, by-product or wastes.

In phosphoric acid manufacturing most of the producers consider the following impurities harmful: -Cl, F, quartz SiO_2, CO_2, organic matters, K_2O, Na_2O, SrO_2, carbonate and excessive content of MgO, Al_2O_3, Fe_2O_3 and heavy metals.

Table 1 summarizes the effects of the various impurities in the manufacture of a filter-grade wet process phosphoric acid.

Other than the typical chemical and physical specifications many rock phosphate importers now have to satisfy new specific requirements, imposed either by new regulations for environmental protection, or by the process technology.

In Europe, Eastern Asia, and Australia, for example control of dust emission during unloading and handling of the rock phosphate, caused by higher content of fines, is becoming one of the rock importers and exporters major concerns.

Cadmium, in final product, by-products and in waste is becoming a real issue in Europe and in some other parts of the world.

Since the removal of cadmium in the manufacturing facilities is not yet practised for obvious reasons, the problem is being shifted in a way back to rock phosphate producers.

A low content of other trace elements such as As, Hg and Pb is of great importance to manufacturers of food/feed grade phosphoric acid and derivatives. Uranium and other radio-active elements could be disturbing in countries using the gypsum for building materials or disposing of it in rivers or in the nearby populated areas.

Some producers, who operate plants in the vicinity of large cities are facing troubles with odours released from the stacks in phosphoric acid manufacturing facilities. Research carried out in this respect has shown that the odour is caused primarly by organic sulfur compounds present in the exhaust gases.

From the processing point of view some of the producers, require extra low chlorine in high BPL grades while maintaining a good balance of other components such as alumina, iron and silica. Excessive chlorine level may be detrimental to process equipment such as agitators, filters and pumps built of traditional stainless steel.

HDH plants prefer slightly higher SiO_2 and alumina content, in addition to a high P_2O_5 content, in order to minimize the consumption of diatomeous earth, or similar additives usually used as filtration aid.

Conventional DH and HH plants require a balanced SiO_2/F ratio in order to avoid corrosion, and achieve a higher fluorine release in the case of defluorinated acid manufacture.

Producers who use low impurities high grade rocks for upgrading indigenous high silica or other rocks containing undesirable impurities, prefer lower SiO_2 content rock (as low as 0.2% SiO_2), again with all other components maintained within the specified range.

A further example, is a phosphoric acid manufacturer who had to continue operating the plant at its rated capacity without operation of the rock mill. In this case the rock had to be screened on 2 mm opening mesh screens or less, at the rock suppliers end, in order to enable the desired level of performance and P_2O_5 recovery to be achieved.

The list of case histories is inexhaustible!

HOW DO JPMC MEET CUSTOMERS REQUIREMENTS?

JPMC has been a producer and exporter of phosphate rock for more than 40 years, and a manufacturer of phosphoric acid since 1982.

This long experience in the field, and continuing contact with the customers has enabled JPMC to better understand and satisfy the individual producers' requirements.

In recent years during which drastic changes have taken place in this industry, JPMC like other phosphate producers has had to share and meet the challenges with its customers.

Understanding the specific needs of each user, and objectives as with any other business is the key to success. The following is a brief review of the techniques used by JPMC to cater for the specific requirements of some of its 75 customers or more located in twenty phosphate rock importing countries.

Dedusting

In order to reduce dust emission at the port of destination, and to meet stringent environmental regulations imposed by the relevant authorities of some users countries, JPMC has adopted and installed dedusting units in all its mines.

Every dedusting unit is composed of a battery of cyclones, belt conveys and hoppers to remove dust at the outlet of the beneficiated rock dryers. The number and size of cyclones depend on the flow rate of dried rock and the quantity of "dust" to be removed.

In practice JPMC's dedusting system at Al Abyad mine is composed of some 1440 cyclones, and El Hassa of 400 cyclones.

The fines are collected and transported by trucks to the JPMC Aqaba phosphoric acid plant, for blending with other rock feeds. Fines which will be removed from the rock at the Eshydia Mine after its completion will be processed in the joint-venture phosphoric acid plant presently being implemented in the close proximity to the mine site.

Blending

Adjusting the different constituents of a given grade of rock can be achieved to a certain degree of accuracy by blending different grades with varying composition. At JPMC this technique is applied either in the mines during various stages of beneficiation, treatment and handling, or alternatively at the export terminal.

Adjustment of the SiO_2 content can for example, be achieved by blending 73/75 grade containing low silica with 68/70 or 70/72 BPL grade containing a higher percentage of silica.

This requires obviously full analysis of the grades to be blended, a consistent metering of the quantities, thorough sampling and analysis both during the blending and later the ship loading stages.

The purpose of frequent sampling and analysis is to assure the product consistency and avoid upsetting the balance and the levels of all constituents in the targetted rock grade.

Use of Additives

Following the request of certain customers, to adjust certain "desired impurities" in the rock, (mainly silica and alumina), JPMC began a few years ago to add clay materials to the rock before or during shipment. In fact industrial trials of clay addition at Aqaba phosphoric acid plant had demonstrated that there is a positive effect on filtration. The gypsum crystal habit changed from the usual elongated rhombic to cluster shape with significantly improved filtration rates. The clay used for the trials contained some 15-20% Al_2O_3 and 48-54% SiO_2.

The addition of clay however requires, particular attention while dosing in order to avoid any undesired changes in the rock composition required for a specific use. Complete analysis of both the rock and the additive, as well as exact determination of quantity to be added is of vital importance.

FLEXIBLE MINING AND BENEFICIATION SCHEME

One of the major actions taken by JPMC was to adopt a "flexible scheme" in its mining and beneficiation activities in order to enhance its ability to produce different rock grades with balanced compositions. **Table 2** shows the typical analysis of current rock phosphate grades produced by JPMC.

Implementation of this "flexible scheme" philosophy necessitated on one hand a complete survey of ore bodies and layers in every mining site, including the review of chemical analysis, physical properties, and mining economics and on the other hand required a full awareness of the specification of targetted rock grade or grades to be produced.

Blending of material from different ore bodies, or even different locations to obtain a desired quality of a rock is also practiced in some cases.

Selective Mining

Resulting from the diversity of ore reserves, selective mining for the preparation of "special quality" products is another possible route to satisfying the specific requirements. In the last few years for example, low cadmium and low arsenic 73/75 BPL grades were successfully produced to meet one of JPMC customers needs.

Open-cast mining techniques using travelling draglines and the use of appropriate handling such as small earth moving equipment has allowed the removal of outer waste and undesired layers, thus enhancing a relatively economic selective mining operation.

In practice, extraction of selected phosphate layers is performed by splitting and dosing followed by loading on trucks and transportation to crushing and screening facilities. At the crushing unit blending for fine adjustment if necessary is also a possibility.

Beneficiation

Flexibility during beneficiation is achieved at JPMC, by the use of multi-stage cyclones and agitation, allowing efficient control of size distribution, chlorine content, and fine particles removal.

During the upgrade of the P_2O_5 content special attention is paid while removing quartz, carbonates and clay, not to wash out too much of the "desired impurities" which are concentrated in the clay.

JPMC has learnt over the years how to adjust the operating parameters of the washing and desliming in order to produce a well balanced product.

Filter cake containing 16-18% moisture is dried in rotary dryers and the final product may be dedusted by the extracting the minus 53 micron fines using an electrostatic precipitator and dust collecting cyclone.

For rock importers requiring product which is free of lower fractions, extra "dust" removal can be arranged by additional cycloning as described above.

A further step taken by JPMC for its new mine at Eshydia is the application of a flotation process aimed at producing a 75/77 BPL concentrate.

The flotation facility is designed to treat silicious ore from the so-called A3 layer at Eshydia Mine, containing about 45 BPL.

The circuit comprises a multi-stage flotation cell system which produces a well balanced final product in terms of P_2O_5 and silica content.

Block diagrams of the flotation and washing/desliming flowsheets under implementation are shown in **Figures 3 and 4**.

Quality Control

Quality control in JPMC starts at the early stages of phosphate exploration and from the geological survey of the mining area extending all the way through the operation steps right up to final shipping. Samples collected from each phase are analysed to determine the chemical and physical properities such as P_2O_5, F, Cl, Al_2O_3, Fe_2O_3, SiO_2, CaO, CO_2 organic matters, heavy metals, etc. The size distribution is also determined to assist in the processing and beneficiation stages.

The data collected during exploration is analysed using appropriate computer programs to determine the quality of the ore reserves and its potential exploitation.

During the beneficiation, ore quality is monitored through an intensive sampling scheme during the various stages of the process. Samples are also taken at the inlet and outlet of the rotary dryers in order to control the final product specifications. Sampling statistics indicate that some 36 chemical analysis and 18 physical analysis are performed on each ton of produced phosphate throughout the various stages of exploration, mining and shipment.

The phosphate produced from all mines is loaded on trucks or trains and transported to the Aqaba terminal for export or to JPMC Aqaba Fertilizer Complex for processing. The phosphate rock is stored in the Aqaba terminal in several warehouses equipped to allow ample flexibility of blending.

Product sampling and chemical analysis for "cross checking" is also performed at the terminal, where trucks and trains are received. These analyses help calculate with a high degree of certainty the quantities which need to be blended from each store in order to adjust a given grade.

Technical assistance and feed back from the customers

In order to cater for ever changing requirement of rock phosphate users, JPMC has developed, like other rock exporters, a system which allows efficient provision of technical assistance to its customers when needed.

To this effect, a convertible process (DH/HH/HDH) pilot plant was constructed by JPMC in the mid-eighties to help determine optimum process conditions when using different grade rocks in order to achieve improved performances.

This pilot plant together with the facilities of other JPMC research centers are made available to serve rock phosphate users.

On the other hand, feedback from customers concerning the results which they achieve when using a given phosphate feed, or alternatively the difficulties which they may encounter, is of great importance to JPMC in order to cater for the specific requirements and the resolution of problems.

In this respect, JPMC has during the past 40 years worked hard to establish an efficient system for exchange of information and receipt of feedback from the customers.

Finally, it is worthwhile to mention that during the past five years or so JPMC engineers and chemists have successfully accomplished some 60 missions to 25 plants around the world.

The assistance they offered varied from working with producers staff to optimize process parameters and improve performances up to trouble-shooting and technical problem solving.

CONCLUSION

In conclusion, phosphate rock exporters have to face another challenge, in order to meet new requirements of their users and cater for the various changes in their needs, imposed by both technical and environmental considerations.

Enhanced flexibility in rock treatment in order to adjust the composition, together with strict quality control, are means of achieving this goal.

REFERENCES

1. Pierre Becker, Phosphate and Phosphoric Acid, Second Edition 1989, Marcel Dekker Inc. New York and Basel.

2. Paul Smith, What is a High Grade Phosphate, or are impurities a bonus or penality? Paper

3. Najim Hummadi, JFI's Experience in Manufacturing Phosphoric Acid from Jordan Rock Phosphate. Paper presented to Fertilizer Seminar, Goa, India, September 1985

4. Responding to Processing Challenge, Impurities in Phosphate Rock, Fertilizer International No. 283, March 1990

5. Phosphate Rock Grade and Quality. Phosphorus & Potassium No. 178, March-April, 1992

6. JPMC Internal Reports

Table 1: The effects of impurities in the manufacture of a filter-grade wet process phosphoric acid

Impurities	Practical Levels found in feed rock	Desirable properties	Undesirable Properties	Amount of impurity passing into acid
Aluminium	0.2-0.3% Al_2O_3	Reduces corrosion by fluoride ion.	Forms complex phosphates which impair filtration, increase acid viscosity, and precipitate	70-90%
Iron	0.1-2% Fe_2O_3	May be recoverable as iron oxide.	Forms complex phosphates strong Influence on acid viscosity; forms sludge.	60-90%
Magnesium	0.2-0.6% MgO	May have nutrient value.	Forms complex phosphates and fluosilicates; impedes filtration; affects downstream product quality.	
Fluorine	2-4% F	Can be recovered as by-product	Liberated partly as HF; part held by filter, part may contribute to sludge formation. More fluorine generated during concentration. If H_2SiF_6 formed by reaction with SiO_2 may modify gypsum crystal structure.	25-75%
Silica	1-10% SiO_2	Converts HF to less corrosive fluosilicic acid (H_2SiF_6).	In high proportions, causes corrosion.	5-40%
Strontium & lanthanides	0-3.0 SrO (for example)		Inhibits recrystallization of hemi-hydrate gypsum. Insoluble compounds formed in 40% P_2O_5 Acid.	n.a.
Chlorine	0-0.05%		Above 0.03% can cause severe corrosion with wrong materials.	100%
Carbonate	0.7-8.0%		Increases sulphuric acid consumption.	15-70%
Organics	0.1-1.5%C		Stabilize foams during acidulation. Impair. Filtration by "blinding" cloth.	
Cadmium	0.8-255 ppm		Toxic risk, both in acid and in by-product gypsum.	70%
Uranium	35-400 ppm U_3O_8	Is recoverable from acid as by-product.		75-80%

Source : Fertilizer Inernational No. 283 March 1990.

Table 2: Chemical analysis of JPMC rock phosphates

Component	70/72 BPL	73/75 Abyad/Hassa	73/75 Eshydia	75/77 Eshydia(*)
P_2O_5	32.04-32.95	33.40-34.32	33.4-34.32	34.1-35.00
CaO	49.00-50.50	51.00-53.00	50.00-51.50	51.00-52.00
SiO_2	4.50-6.50	2.00-3.00	3.00-5.50	2.0-4.0
CO_2	4.00-5.00	4.00-5.00	3.00-4.00	3.0-4.0
F	3.50-3.80	3.60-3.90	3.50-4.00	3.8-4.0
Cl	0.08-0.15	0.025-0.04	0.03-0.06	0.02-0.04
Fe_2O_3	0.18-0.30	0.15-0.20	0.15-0.30	0.2-0.4
Al_2O_3	0.40-0.50	0.20-0.32	0.20-0.40	0.2-0.3
Org.C	0.12-0.20	0.12-0.20	0.10-0.20	0.1-0.15
SO_3	1.10-1.40	1.00-1.40	1.00-1.50	0.8-1.20
Na_2O	0.40-0.60	0.40-0.60	0.40-0.60	0.4-0.6
K_2O	0.03-0.05	0.02-0.04	0.02-0.04	0.03-0.06
MgO	0.20-0.35	0.20-0.40	0.1-0.25	0.10-0.20
Comb. H_2O	1.80-2.20	1.80-2.20	1.8-2.2	1.80-2.20

(*) Will be produced as of 1996

Figure 3: Flotation Flowsheet

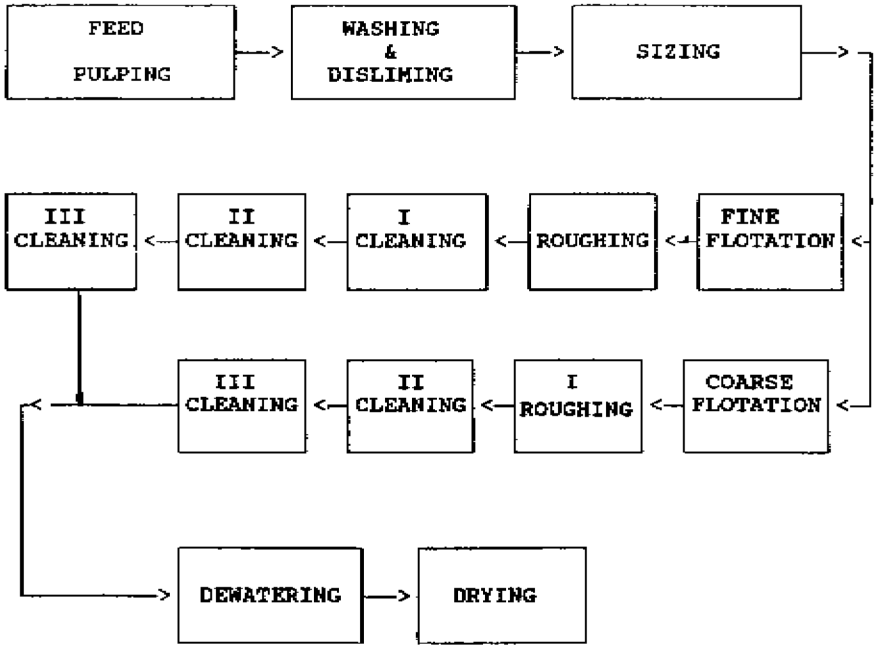

Figure 4: Washing and disliming flowsheet