International Fertilizer Industry Association

IFA Technical Conference

Marrakech, Morocco
28 September-1 October 1998

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

Date of receipt: 9 May 1998

PHOSPHATE RECOVERY FROM LOW GRADE ROCK AT ESHIDIYA MINE - DEVELOPMENT OF PHASE II[1]

A. Ghosheh, D. Amara and L. Dabbas
Jordan Phosphate Mines Co. Ltd., Jordan

SUMMARY

This paper describes JPMC expansion programme in its Eshidiya Mine in order to maintain its rock phosphate export level of 6 million tons per year and to provide additional material to its Industrial Complex in Aqaba. The exploratory investigation of Eshidiya Phase II, geological composition and the mining techniques are detailed. Also included are chemical composition of the ores from coquina and non-coquina areas and their beneficial features as well as the beneficiation techniques deployed.

RESUME

Cet exposé présente le programme d'expansion de JPMC dans sa mine d'Eshidiya afin de maintenir son niveau d'exportation de phosphate à 6 millions t/an et de fournir des matières premières supplémentaires à son complexe industriel d'Aqaba. L'étude exploratoire de la Phase II d'Eshidiya, la composition géologique et les techniques d'exploitation sont présentées en détail. On inclut également la composition chimique du minerai des zones coquina et non coquina et leurs caractéristiques favorables ainsi que les techniques d'enrichissement employées.

✦ ✦ ✦

HISTORICAL BACKGROUND

Jordan Phosphate Mines Company (JPMC) was established in 1935 as a private company, to exploit the phosphate deposits that cover nearly 60% of Jordan.

JPMC, is the largest corporation in the Hashemite Kingdom of Jordan and is considered to be one of the central figures in the international phosphate industry. It is a world leading phosphate exporter to more than 30 countries and with over 60 years of operating experience, thanks to the excellent geographical location, being close to the large South-east Asian market, advantageous competitive chemical characteristics of JPMC's rock and endowed with low levels of heavy metals.

Jordan ranks as the world's fifth largest phosphate rock producer and the world's second largest phosphate rock exporter with 15% market share along with 0.8 million tons of diammonium phosphate (DAP).

JPMC currently operates three open pit mines: El-Hassa, El-Abiad and Eshidiya. The company started production in the thirties from Ruseifa mine, 17 Km north of Amman. In the sixties the mining operation moved to south, where production started from El-Hassa mine, located 136 Km south of Amman and 200 Km north of Aqaba port. In the late seventies, production started from El-Abiad mine, about 20 km north of El-Hassa mine. In early 1988 the production commenced from Eshidiya mine, where JPMC's strategy is to concentrate its future production plans on the development of Eshidiya mine and gradually to decrease the production at both El-Hassa and El-Abiad mines. Not only does Eshidiya possess significantly greater phosphate reserves but these reserves are generally of higher quality and higher phosphate concentration than those at the El-Hassa and El-Abiad mines.

INTRODUCTION

Phosphate rock deposits in Jordan are sedimentary in origin, endowed with a high phosphate content (P_2O_5), and capable of producing high grade BPL concentrate phosphate rock. Jordan phosphate rock has gained excellent reputation through its good reactivity, grindability and filterability, besides its environmental quality of low level of heavy metals.

[1] *Récupération du phosphate à partir du minerai à bas titre de la mine d'Eshidiya - Développement de la Phase II*

JPMC's strategy is to develop the mining and beneficiation facilities at Eshidiya mine in three phases, destined to boost the production capacity to 10 million MTPY by the end of the year 2005. The phosphate bearing deposits at Eshidiya mines occur in three layers as follows:

1. Layer (A1), which produces phosphate concentrate grade of 68/70 BPL.
2. Layer (A2), which produces phosphate concentrate grade of 73/75 BPL.
3. Layer (A3), which produces phosphate concentrate grade of 75/77 BPL.

Phosphate rock from layer (A1) at Eshidiya mine, which following crushing and screening is of a low grade (40-50 BPL), with large variations in chemical and mineralogical characteristics, being either calcareous or mixed calcareous siliceous and requires treatment by scrubbing, screening, agitation and desliming before drying to produce 68/70 BPL grade. As for layer (A1) non-coquina, treatment by flotation for (-0.5 mm) producing coarse pebbles (1-0.5 mm). Layer (A2) is a high grade layer, which requires no further treatment other than crushing and screening to achieve 73/75 BPL grade. Phosphate rock from layer (A3) is of a low grade (25-45 BPL), requires flotation treatment to remove silica in order to produce high grade 75/77 BPL phosphate rock.

ESHIDIYA MINE

Eshidiya mine, which covers an area of approximately 130 sq.Km , is located in uninhabited area at the south of Jordan, about 50 Km south-east of the city of Ma'an and about 125 Km north-east of Aqaba. The region has a desert climate and about 1200 people are employed there.

The company strategic plan, of which the Phase II project is an integral part, is to progressively develop the Eshidiya deposit to:

1. Compensate for progressive decrease of production from existing mines (El-Hassa and El-Abiad).

2. Provide additional feed to the Industrial Complex at Aqaba and to the joint venture projects, aiming to increase the local rock consumption used for the production of phosphoric acid and phosphatic fertilizers to about 36% by the year 2002.

3. Maintain / increase export levels of phosphate rock at about 6 million TPY starting 1999.

JPMC has over 2 billion tonnes of total geological phosphate rock ore reserves, of which about 1 billion tonnes of proven reserves are in Eshidiya mine. Eshidiya Phase II project, will increase the Eshidiya annual capacity from 3.25 million TPY to 7.45 million TPY of high quality phosphate rock product by the year 2001, as follows:

PHOSPHATE GRADE (%)	PRODUCTION CAPACITY (TONNES)
65 TCP	178,000
68/70 TCP	809,000
73/75 TCP	2,050,000
75/77 TCP	1,172,000
TOTAL	**4,209,000**

ESHIDIYA PHASE II EXPLORATION

Between 1992 and 1996, JPMC completed an intensive exploration program in another part of the western ore body, east of Eshidiya Phase I area in order to evaluate reserves for Eshidiya Phase II. This program included:

1. Investigation of a 43 sq.Km area in the vicinity of Phase I reserves by loose-grid drilling (800m x 800m). This preliminary work led JPMC to select a net area of 25.62 sq.Km to satisfy the requirements of the phase two development for 20 production years.

2. Another smaller network space of (400m x 400 m) boreholes was conducted to identify the chemical and physical changes in the phosphate beds. The total of boreholes drilled in the network system reached 200 boreholes, with an additional 25 boreholes drilled at two transects at 100, 200 and 300 m along the two major directions of the mine to assess, detect small scale spacial variability. This work revealed that about 65 % of the mine area is covered with coquina, and about 35% of the area is without coquina.

3. A total of 55 exploration pits of 1.25 m diameter, were dug to collect large samples from the phosphate beds for pilot plant beneficiation and reserve character correlation.

The phosphate bearing deposits at Eshidiya (of upper Cretaceous origin) occur in continuous beds with a significantly reduced thickness of the over-burden and accordingly a considerably lower stripping ratio compared to El-Hassa and El-Abiad mines, thereby rendering the mining and production processes at Eshidiya more economical, in addition to the superior characteristics of Eshidiya's ore, in respect of grade, and low content of cadmium, arsenic and other heavy metals.

The phosphatic layers (shown in the stratigraphical column) are described vertically from top to bottom as follows:

1. Phosphatic layer A1.

2. Phosphatic layer A2.

3. Phosphatic layer A3.

These phosphatic layers, are divided by highly siliceous, low phosphate bearing parting. The ore body was classified into two areas: the coquina and non-coquina area.

Coquina area is distinguished by the presence of a relatively thick , overburden in which phosphatic layers (A0) lies on top of coquina, followed by the sequence of 3 phosphatic layers separated by inter waste rock, thus dictate certain selective mining techniques are needed, for the removal of overburden and phosphatic layers. The characteristics of the ore are its high CaO/P_2O_5 ratio, low chlorine and R_2O_3 content.

Where in the non-coquina area, the free carbonate content of the ore is practically nil, clayey components are much more plentiful and the TCP content of phosphate bearing elements is higher, low CaO/P_2O_5 ratio, relatively high chlorine, silica and R_2O_3 content.

Layer A1, has sub-levels of different hardness. The ore in layer A2 is generally friable. The ore from layer A3 has a sandy appearance. The main minerals of the three layers are: phosphatic materials (whenever the limestone is absent, the phosphatic elements have a 80-83% TCP contents and 76-80% where it is present), quartz (particularly common in A3 ore), chert and flint, clayey minerals and carbonates (mainly calcite found in the sector where the coquina bench is present).

MINING AREA

JPMC exploration has defined an optimal Eshidiya Phase II project area for the production of an additional 4.2 million tonnes per year of phosphate rock over a 20 year period. This area is approximately 25 sq.Km, located completely within the western ore body, to the East and North-East of Eshidiya's Phase I project area.

The geometry of the 25 sq.Km project area is very simple with relatively shallow overburden and flat phosphate beds which makes overburden suitable for removal by draglines.

The overburden thickness in the southern part of the project area ranges between 8-20 m, while it varies between 10-37 m in the northern part of the project area. The mining plan for the Phase II mine will be divided into two operating pits: Pit One in the north with a total area of 13.2 sq.Km and Pit Two in the south with a total area of 12.4 sq.Km. The northern pit has the phosphatic layers A1, A2 and A3 completely covered by coquina rock layer, while only 20 % of the southern pit is covered by coquina.

ESHIDIYA PHASE II DESCRIPTION

The overburden of Eshidiya Phase II mining area, is first removed by draglines (two draglines in each pit), the phosphate layers and the inter-waste, are then selectively mined by means of hydraulic backhoes and dump trucks. The run off mine ore (ROM) from the two pits will then be transported via 50 T, rear dump trucks to two scalping stations which will removes the +250 mm barren lumps and boulders. The scalping stations are located in fixed positions within the pits.

After scalping, the different phosphate ores will be conveyed by two conveyor belts and fed onto two screening and crushing stations located to the west of the selected mining area north to the existing screening and crushing station of Phase II. The different screened phosphate ores from the screening stations will be conveyed and temporarily stockpiled in a linear storage according to their layer (A1, A2 and A3). The screened ore mine storage capacity will be about 100,000 tonnes. The different ores will be reclaimed in sequence by means of several extraction devices (vibrating feeders) by a conveyor belt installed in a reclaiming tunnel underneath the mine storage.

The reclaimed screened phosphate ores will be conveyed to the millsite (beneficiation plant) by a conveyor belt (about 3.5 Km long). The screened ore from the A2 layer will be conveyed and stored in vertical cylindrical concrete silos, having 40,000 tonnes live storage capacity. The A2 will be reclaimed, dedusted and fed into final product vertical cylindrical storage having 60,000 tonnes live capacity. The A2 phosphate rock has an in-situ average moisture content below 3%. However the dedusting plant (fine removal) will be equipped with hot gas generator to be used in case moisture content of A2 is above 4%. A2 screened phosphate rock will be by-pass the dedusting plant in case fines percentage is within acceptable limits, specified by customers.

The A2 final product will be reclaimed from the 60,000 tonnes storage, via vibrating feeders and a conveyor belt located in a reclaiming tunnel underneath the store, and fed either onto a truck loading terminal at a rate of 1000 TPH, or onto a train loading station at a rate of 1800 TPH.

Screened ores from A1 and A3 layers will be reclaimed from the 100,000 tonnes mine storage, conveyed in sequence by the long conveyor belt to millsite and stockpiled via a rail mounted stacker in a blending yard having a total storage capacity of 2 x 60,000 tonnes.

The A1 and A3 phosphate rock from blending yards will be reclaimed via two bridge reclaimers at a rate of 500 TPH each and fed into the beneficiation plant via belt conveyor system.

At the beneficiation plant A1 and A3 phosphate will be subjected to scrubbing, wet screening, agitation, desliming via hydrocyclones, sizing into coarse and fine fractions by hydrosizers, conditioned and then fed to flotation cells for the removal of silicate impurities in the ores. The filtered concentrate containing 16%-18% moisture will be stockpiled in a linear open storage of 100,000 tonnes capacity, via two rail mounted stacker for natural dewatering before drying in drying kilns down to below 3% moisture.

Two sub-commercial grades will be produced in the beneficiation plant:

1. 67% TCP grade from A1 layer, produced by washing and desliming only, this portion will be mixed with A1 flotation product (76.7% TCP grade) to produce 69.6% TCP grade.

2. A 65% TCP grade representing (-2 +1 mm) fraction of A3 phosphate rock feed, which can be produced by simple scrubbing and wet screening only. This sub-commercial grade represents about 13% of A3 product and will be delivered wet to nearby phosphoric acid plants.

The dried A1 and A3 phosphate rock will be stored in two vertical concrete cylindrical silos having 30,000 tonnes storage capacity each and conveyed afterwards either to the truck loading terminal at 1000 TPH, or to train loading station at 2000 TPH. Belt conveyors are designed and arranged in a flexible manner to enable blending of different phosphate rock products when needed, before loading onto trucks or train wagons.

BENEFICIATION

Eshidiya Phase II beneficiation is nearly identical to the adjacent Eshidiya Phase I reserves which are now being processed in the Phase I commercial beneficiation facilities. Substantial pit samples were collected from the proposed mining area and were bench and pilot scale tested at the JPMC Research Laboratory. Findings show that ore beds A1 and A3 will require scrubbing, sizing and desliming plus flotation for portions of A1 and all of A3.

Process development findings were utilized to derive the process for Eshidiya Phase II ore types as follows:

A2 ORE

A2 ores from both coquina and non-coquina areas are basically a direct shipping high grade ores which are dry screened to reject oversize waste in two stages of screening (12.5 mm & 4.0 mm) to obtain a 73/75 BPL grade. Because it is not washed and deslimed A2 will normally be dedusted with the fines recovered as a sub-commercial product.

A1 ORE

A1 ore, underlying the coquina bed can produce an acceptable product with simple screening, scrubbing and desliming (washing), in order to eliminate the clayey cement and surrounding fine gangue to yield clean fractions with acceptable aluminum and iron contents, the resultant A1 product will normally be (-1 + 0.053 mm).

A3 ORE

A3 ore requires flotation to reject fine silica sand. Prior to flotation the A3 ore must be sized, scrubbed and deslimed in basically the same manner as the A1 ore to produce a clean (-1 mm) feed for flotation.

Direct flotation is considered, where the phosphatic elements are floated by anionic flotation, using an aqueous blend of tall oil and diesel oil as phosphate collector and sodium silicate as clay dispersent and silica depressant for both fine and coarse fractions, with several roughing and cleaning stages.

Phosphatic ores A1 (fine fraction -0.5 + 0.05 mm) from the non-coquina area and A3 ores from both coquina and non-coquina areas (-1mm + 0.05 mm) show favorable tendency for silica phosphate separation. In order to ensure satisfactory flotation, selectivity and moderate consumption of collectors, the ore should undergo both thorough cleaning and removal of particles below 40 microns before flotation. But since Eshidiya rock is friable, this factor appears to effect and lead to variation in the collector consumption and recovery of coarse sized phosphate which might be attributed to the amount of phosphate slime generated in conditioning and flotation. This slime has a high surface area, thus collector consumption will increase. The conditioned fine and coarse output goes separately to flotation cell banks, where it is separated from silica. The phosphate concentrate is hydrocycloned and filtered to produce a high grade concentrate (75/77 BPL) with about 18% moisture content.

ASSESSMENT OF ESHIDIYA'S ORE

Several chemical and physical pilot plant tests, were conducted at JPMC Research Center on Eshidiya's phosphate rock, aiming at evaluating its performance for phosphoric acid and fertilizers production.

Different phosphate concentrates from layers A1 (68/70 TCP), A2 (73/75 TCP) and A3 (75/77 TCP) were tested under hemihydrate, dihydrate conditions. The results proved the excellent quality of the rock and its suitability for use in the production of phosphoric acid and phosphatic fertilizers.

The following conclusions and observations were noticed:

1. High reactivity and solubility of the phosphate rock.
2. Low content of impurities and heavy metals.
3. Relatively low sulfuric acid consumption.
4. Lower operating cost, minimum grinding and use of antifoaming agents.

ORE CHEMICAL ANALYSIS

1. PHOSPHATIC BED (A1)

COMPONENT	COQUINA AREA	NON-COQUINA AREA
TCP	44.4 %	50.7 %
LOI	12%	5%
SiO2	21.8%	29.4 %

2. PHOSPHATIC BED (A2)

COMPONENT	ANALYSIS
TCP	70.5 % (average)
CaO/P2O5	1.5
SiO2	6.5%(coquina) & 10.7 %(non-coquina)
R2O3	0.5 % (coquina) & 1.3 %(non-coquina)
Cd	4 ppm
As	5 ppm

3. PHOSPHATIC BED (A3)

COMPONENT	ANALYSIS
TCP	38.22 %
SiO2	63.4 % (coquina area) & 46.1% (non-coquina)

Pilot Plant Tests
Average Recovery For Bed A3

WASHING SECTION	TCP	AIR	LOI	TCP%	Recovery	Wt%	Recovery
- ½ “	36.65	51.62	2.51	100		100	
- 12.5 + 2 mm	43.46	46.36	---	6.31		5.31	
- 2 mm + 1 mm	61.41	22.92	---	6.68		3.93	
- 1 mm	30.65	59.7	---	---		---	
- 1 mm + 0.5 mm (Coarse Material)	34.28	57.30	---	43.12		46.61	
- 0.5 mm + 0.05 mm (Fine Material)	30.72	63.24	---	39.10		40.25	
- 0.05 mm (Slimes)	46.13	27.67	---	4.90		3.90	
FLOTATION SECTION	TCP	AIR	LOI	TCP%	Recovery	Wt%	Recovery
				- 12.5 mm	F. F	- 12.5 mm	F. F
Fine Feed to Flotation (FF)	31.03	60.42	---	42.55		40.88	
Flot. Concentrate	76.20	5.26	---	36.42	94.8	17.45	39.06
Sink	9.44	87.98	---	6.12		23.25	
Flotation Section	TCP	AIR	LOI	TCP%	Recovery	Wt%	Recovery
				- 12.5 mm	F.F	- 12.5 mm	F.F
Coarse Feed to Flotation (FF)	32.30	48.30	1.72	43.12	100	49.80	100
Flot. Concentrate	76.81	5.50	4.01	32.33	75.60	15.71	31.72
Sink	12.42	80.80	---	10.89	24.40	34.08	68.28

Pilot Plant Tests
Average Recovery For Bed A1

WASHING SECTION	TCP	AIR	LOI	TCP%	Recovery	Wt%	Recovery
- ½ “	52.60	25.37	5.16	100		100	
+ 4 #	44.62		---	15.39		21.42	
- 2 mm + 1 mm	56.72	23.93	---	8.44		8.85	
- 1 mm	57.50	17.12	---	---		---	
- 1 mm + 0.5 mm (Coarse Material)	70.17	11.34	---	33.11		20.12	
- 0.5 mm + 0.05 mm (Fine Material)	60.40	17.90	---	18.97		16.14	
- 0.05 mm (Slimes)	36.84	38.96	---	21.10		33.494	
FLOTATION SECTION	**TCP**	**AIR**	**LOI**	**TCP%**	**Recovery**	**Wt%**	**Recovery**
Fine Feed to Flotation (FF)	60.40	17.92	---	18.97		16.14	
Flot. Concentrate	70.13	7.58	---	11.89		8.78	
Sink	42.37	39.68	---	6.38		7.36	
Without Flotation –1 + 0.053	65.82	14.26	---	52.08		36.26	
- 2 + 0.5	66.06	15.00	---	41.57		25.97	
Sub. Commercial + F. Concentrate	67.01	13.77	---	53.43		37.75	

LAB SCALE TESTS

FOR A3 MINE 2

Bore Hole No.	Fine Feed Head Sample	Fine Concentrate	Coarse Feed Head Sample	Coarse Concentrate
1122	TCP % 23.78 AIR % 71.28 LOI % 1.01	TCP % 81.76 AIR % 2.04 LOI % 3.50	TCP % 37.46 AIR % 55.10 LOI % 1.52	TCP % 81.91 AIR % 2.12 LOI % 3.56
1132	TCP % 34.61 AIR % 53.90 LOI % 2.85	TCP % 74.48 AIR % 4.60 LOI % 5.58	TCP % 40.33 AIR % 48.02 LOI % 3.31	TCP % 73.43 AIR % 4.72 LOI % 5.17
1136	TCP % 21.82 AIR % 72.76 LOI % 1.79	TCP % 79.52 AIR % 2.74 LOI % 3.97	TCP % 34.91 AIR % 59.86 LOI % 2.18	TCP % 77.80 AIR % 5.02 LOI % 3.95

LAB SCALE TESTS

FOR A1 MINE 2

Bore Hole No.	Head Sample	Washing Concentrate Coarse –1 + 0.5 mm	Washing Concentrate Fine – 0.5 + 0.053 mm
1122	TCP % 54.53	TCP % 72.98 AIR % 11.20 LOI % 3.60	TCP % 63.61 AIR % 18.54 LOI % 3.85
1132	TCP % 55.11	TCP % 66.48 AIR % 10.48 LOI % 6.12	TCP % 63.56 AIR % 14.24 LOI % 5.92
1136	TCP % 54.68	TCP % 71.02 AIR % 12.00 LOI % 3.79	TCP % 66.94 AIR % 15.58 LOI % 3.95

Comparative Data Between
Eshidiya Mine A1 and Eshidiya A2
Bed A3

	Pilot Plant Test Eshidiya Mine No. 2 Bed A3 Non. Coquina		Eshidiya Mine No. 1 Bed A3 Design	
Rom Ore % TCP	36.65		47.40	
Concentrate % TCP	76.50		75.70	
Sub. Comm. Prod % TCP	61.40		63.50	
Conc. % Wt of Rom	33.16		33.50	
Sub. Comm Wt of Rom	3.93		6.30	
<u>TCP % Flot. Recovery</u>				
Coarse Circuit	75.60		78.00	
Fine Circuit	94.80		89.20	
Total Flotation	85.20		85.00	
Slime % wt of Rom	3.90		8.90	
Chemical Consumption	Fine Feed	Coarse Feed	Fine Feed	Coarse Feed
Kg Tall Oil / F. Feed	1.86	2.76	2.74	4.07
Kg Na2SiO3 / TF. Feed	0.53	0.65	0.74	0.73
Kg NaOH / TF. Feed	0.19	0.27	0.28	0.33