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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

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RESEARCH AND DEVELOPMENT FOR PHOSPHATE RECOVERY AND PHOSPHATE FERTILIZER PRODUCTION FROM IRON ORE CONCENTRATION TAILS AT SIERRA GRANDE, ARGENTINA*

Prepared by

Makoto Kuwabara**
and
Hector F. Pastorino***

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** Manager, Project Management, UNICO International Corporation, Tokyo, Japan

*** HIPASAM, Buenos Aires, Argentina

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Summary

The tails of the iron ore concentration plant at Sierra Grande are the only known commercially available phosphate resources in Argentina (Annually 65,000 tons of P_2O_5 at rated capacity), where the increase in the use of fertilizers is being promoted. Under a bilateral technical cooperation scheme between the Government of Japan and Argentina, a feasibility study has been undertaken covering the concentration of apatite from the tails and the production of seven type of phosphate fertilizers using the high-Fe phosphate concentrate thus obtained. Two technically viable options (MAP/DAP and NP) were selected for financial and economic analysis, which showed marginal feasibility under the present depressed international phosphate fertilizer market. Efforts are being continued to seek economic recovery of the P_2O_5 values as well as the production of phosphate fertilizer in Argentina.

1. General Features of Agriculture and Fertilizer in Argentina

Grain production and cattle raising have traditionally been relevant to Argentina's economy. The present outputs of the agricultural sector contributed 13% of the gross domestic production, while the share of agricultural products and primary commodities in the total exports was 75%. Agriculture is the key industry of the country. The area in million hectares devoted to the arable and permanent crops is 35.8 and to the pernament pasture is 143.0, respectively.

It is characteristic of the country's agriculture the coexistence of extensive and intensive farmings. The former is typified by grain production and pastures, mainly located in the Pampeana region. Intensive farming produces vegetables, fruits, tobacco, sugar cane and others in areas such as the Provinces of Mendoza, San Juan, Salta, Corrientes and Rio Negro.

The use of fertilizers was first introduced for intensive farming, where its use has reached at present a relatively high level. On the other hand, fertilization for extensive agriculture has been traditionally low, to the extent that the overall consumption of fertilizers in Argentina in terms of kilograms of the three nutrients per hectare is among the lowest in the world: 0.6 kg/agriculture area, 3.1 kg/arable and permanent crops, and 14.5 kg/capita.

Consumption of phosphate fertilizer amounted in 1984 to some 47,000 tons of P_2O_5, 30,000 of which correspond to extensive farming and the rest to intensive agriculture. The INTA (Instituto Nacional de Tecnologia Agropecuaria) has demonstrated the need of a substantial increase in the use of phosphate fertilizers, both to raise productivity and to reverse the diminishing availability of natural phosphates in the soil of agricultural lands. Consumption of nitrogen and potash nutrients in 1984 were 98,000 and 11,400 tons, respectively.

Starting in 1984 the use of fertilizers is being stimulated by the authorities, mainly in connection with extensive farming, aiming at the increase of grain production for the export market. This policy has resulted in a marked increase in fertilized areas and yields. Projection of the estimates to 1990/95 indicates that, under favourable conditions, phosphate fertilizer consumption can reach a level of 100,000/150,000 tons of P_2O_5.

Regarding the relative evaluation among potential phosphate fertilizers in connection with the soil and agricultural conditions in Argentina:

a) In general, phosphate fertilizers with high water solubility, such as in SSP, TSP and MAP/DAP, are more suitable. Marketability of acid soluble phosphates (such as ground phosphate rock or fused magnesium phosphate) is limited to the Mesopotamic area in the Northeast, and to pastures.

b) Compound fertilizers are used in intensive farming, while extensive farming applies mainly nitrogen or phosphate fertilizers separately, as straight fertilizers.

c) Although nitrophosphate has not been widely accepted in Argentina so far, it is judged possible that a market for this product can be developed, especially in the intensive farming sectors. Of course, a proper preparation procedure would be required for a rapid switch from the traditionally used phosphate fertilizers to nitrophosphate fertilizer.

d) Regarding the coproduct of nitrophosphate such as CAN or AN, if the use of nitrogen fertilizer is increased among the wheat growers in the Southern Pampeana region, it is possible that a market for these products can be developed.

2. Fertilizer Production

Argentina has adequate natural gas reserves, but only one medium scale nitrogen fertilizer plant with daily ammonia production capacity of 190 tons is producing urea and ammonium sulfate, and is still depending on nitrogen fertilizer imports. Recently discovered potash reserves in Malargue, Mendoza, are under study for development, while the iron ore concentration tails in Sierra Grande, Rio Negro represent the only known source of domestic phosphates. Fertilizer production based on these natural resources could significantly contribute to the economic recovery and development of the country.

The Sierra Grande tails are presently a waste product from the iron ore concentration plant located at Sierra Grande, Río Negro, and operated by Hierro Patagonico de Sierra Grande S.A.M. (HIPASAM). The company, owned by the Argentine government, started commercial production of iron ore pellets in 1979, the product being shipped to supply the blast furnaces of SOMISA, San Nicolas, North of Buenos Aires. The production of direct reduction quality iron ore pellets is also being considered.

The Sierra Grande ore is a sedimentary magnetite containing 54.8% Fe and 3.2% P_2O_5, mainly as hydroxyapatite, fluorapatite and other complex minerals. The beneficiation process includes crushing, dry magnetic separation, wet grinding and magnetic separation for reducing P_2O_5 to approximately 0.69%, followed by reverse flotation lowering P_2O_5 content to around 0.27%. As a result, a concentrate containing 68% Fe is obtained, which is later pelletized. The processing of ore to produce at the rated annual capacity of 2.0 million tons of pellets would generate 920,000 tons of magnetic separation tails with 27.5% Fe and 7.1% P_2O_5, equivalent to 65,000 tons of P_2O_5. These tails are finely ground (85% under 400 mesh) and, as mentioned before, are the only available phosphate source identified to date in Argentina.

3. Feasibility Study on Phosphate Fertilizer Production

In December 1982, HIPASAM, the Direccion General de Fabricaciones Militares (DGFM) and the Japan International Cooperation Agency (JICA) started a feasibility study under bilateral technical cooperation scheme for the establishment of a phosphate fertilizer plant using the Sierra Grande tails as raw material. The JICA appointed UNICO, Japan, to perform the study, which was completed in August of 1984.

4. Phosphate Recovery

A representative sample of 700 kg of tails was obtained at Sierra Grande in 1983 and used in laboratory and pilot plant scale tests on phosphate concentration and also to conduct mineralogical studies; 15 kg of apatite concentrate were produced and used for evaluation tests for the conceptual design of seven alternative scheme for the production of phosphate fertilizers. The results of the concentration tests were the following:

a) Phosphate minerals in the tails are mainly fluorapatite and hydroxyapatite; apatite crystals are locked with iron minerals and chlorite.

b) Minor phosphate minerals other than apatites have been detected; these are blue and brown colored and include iron as a constituent.

c) There are inclusions of iron minerals in apatite crystals and the iron minerals seem partly diffused in the apatite crystals.

d) A small amount of iron is homogeneously dispersed over the entire surface of the apatite crystals, as detected by X-Ray observation.

e) Even if the tails are ground to diameter of 0.01 mm, it is impossible to achieve crystal grain isolation or liberation of iron minerals, chlorite and apatites.

f) Chlorite, which contains iron, has a Zeta potential similar to that of apatites; consequently, the concentration of phosphate rock from chlorite by flotation and magnetic separation would be difficult.

g) With the purpose of determining the lower limit attainable for residual iron in the phosphate rock, HGMS (high gradient magnetic separation) was also applied; a highly purified phosphate rock of 39.55% P_2O_5 and 1.84% Fe was obtained. However, even when the product grade was improved, the P_2O_5 recovery was 22.1% and was judged to be not suitable for industrial application at the present state of the art.

h) The concentration of phosphate rock by flotation, due to the specific characteristics of the Sierra Grande ore, requires a higher than normal consumption of electric energy for intensive grinding, as well as of flotation collector; the P_2O_5 recovery is also relatively low. The situation in Sierra Grande is differ from that of Svenskt Stål, Grängesberg, Sweden or Luossavaara Kürunavaara AB, Kiruna, Sweden where purified phosphate rock is commercially produced at higher P_2O_5 recovery rate from magnetite ore concentration tails.

On the basis of the concentration tests results, it was confirmed that the following conceptual design for the phosphate rock concentration plant would be rational:

- Phosphate rock quality:	P_2O_5	36.0%
	Fe	6.0%
	CaO	44.3%
	F	1.5%
- Recovery of P_2O_5:		56.0%
- Concentration process:	Grinding, rougher flotation, cleaner flotation (5 stages), sedimentation, filtration and drying.	
- Annual production capacity:	Phosphate rock;	100,000 tons
	P_2O_5 ;	36,000 tons
- Plant location:	Sierra Grande, Rio Negro, Argentina	

5. **Phosphate Fertilizer Production**

No precedent exists in the world for the production phosphate fertilizer from a phosphate rock of this quality, especially regarding its Fe content, making it necessary to undertake evaluation and trial tests for the seven phosphate fertilizer alternatives. Conceptual design of such plants were prepared.

During the tests, the following specific characteristics of the phosphate rock obtained from the Sierra Grande tails were clarified:

a) The concentration of P_2O_5 is sufficiently high.

b) The iron content in the phosphate rock is high and the quality of phosphate fertilizer obtained from it is not satisfactory, particularly in connection with the water solubility of phosphate in the fertilizer.

c) Most of the iron is ferrous from Fe (III).

d) Although the phosphate rock is finely ground, the reactivity with acids is very low.

e) The contents of organic matter and carbonates are low, and no foaming is observed during acid digestion with nitric and sulfuric acid.

The results of the evaluation of phosphate fertilizer production are summarized in below:

Phosphate Fertilizer Alternatives	Process Plant Configuration (Daily Capacity)	Process Applicability	Product Quality Evaluation
- Ground Phosphate Rock (GPR, 0-34-3)	PRC (340TPD) GPR (350TPD)	Applicable	Low in $C-P_2O_5/T-P_2O_5$ and $F-P_2O_5/T-P_2O_5$
- Fused Magnesium Phosphate (FMP, 0-21-0)	PRC (340TPD) FMP (570TPD)	Applicable (Open hearth furnace)	Excellent in $C-P_2O_5/T-P_2O_5$
- Single Super Phosphate (SSP, 0-20.5-0)	PRC (340TPD) H_2SO_4 (200TPD) SSP (572TPD)	Not applicable, Low reactivity, High H_2SO_4 consumption	Low in $Av-P_2O_5/T-P_2O_5$ and $W-P_2O_5/T-P_2O_5$, High in free acid
- Triple Super Phosphate (TSP, 0-47.3-0)	PRC (340TPD) H_2SO_4 (192TPD) P_2O_5 (82TPD) TSP (243TPD)	Not applicable, Low reactivity, High H_2SO_4 consumption	Low in $Av-P_2O_5/T-P_2O_5$ and $W-P_2O_5/T-P_2O_5$, High in free acid
- Wet Process Phosphoric Acid (P_2O_5, 0-100-0)	PRC (340TPD) H_2SO_4 (270TPD) P_2O_5 (115TPD)	Applicable, Limited in P_2O_5 concentration, Evolution of SO_3	High in viscosity and sludge formation, Concentration up to 40% of P_2O_5
- Ammonium Phosphate (MAP/DAP, 10-46-0)	PRC (340TPD) H_2SO_4 (270TPD) P_2O_5 (115TPD) MAP/DAP(244TPD)	Applicable, Fe is transferred in MAP/DAP	Slightly low in grade but satisfactory for domestic market, Low in $Av-P_2O_5/T-P_2O_5$, $W-P_2O_5/T-P_2O_5$ and W-N/T-N
- Nitrophosphate (NP, 20.8-20.8-0)	PRC (340TPD) NH_3 (303TPD) NA (534TPD) NP (551TPD) AN (360TPD)	Applicable, Fe is partially transferred in NP	Excellent in $Av-P_2O_5/T-P_2O_5$ and $W-P_2O_5/T-P_2O_5$

Note: PRC = Phosphate Rock Concentration, NA = Nitric Acid,
AN = Ammonium Nitrate, $F-P_2O_5$ = Formic Acid Soluble P_2O_5,
Phosphate fertilizer products are all in granular form and in bags.

6. Financial and Economic Viability

According to the comparative evaluation of the seven alternatives, the projects for the production of MAP/DAP and of NP were the most favorable.

In the case of MAP/DAP production, the financial and economic feasibility was not favorable due to the following reasons:

a) In spite of the high residual iron content in the phosphate rock, the production of phosphoric acid was proved to be technically feasible. However, the quality of the MAP/DAP product was a little lower than that of the traditional product.

b) The cost of ancillary raw materials such as sulfur and ammonia is comparatively high, due to the need of importing small lots from overseas or local production at a small scale plant. Although there are H_2SO_4 and NH_3 plants in Argentina, their production is committed and would not be available for the project.

c) The production capacity of phosphate rock (340 TPD) and of MAP/ DAP (244 TPD) are both small in scale due to the limited availability of tails at Sierra Grande; consequently, the fixed cost burden is higher in comparison with the world scale phosphate rock and phosphate fertilizer plants.

d) MAP/DAP production would cover only one half to third of the requirements of the local Argentine market.

In the second case, production of NP is technically viable, but its financial feasibility is low due to the low capacity utilization. The major reasons for this are the following:

e) The N/P_2O_5 ratio in NP is higher than that in fertilizers traditionally used in Argentina (mainly DAP); replacement would not proceed at a high rate.

f) Half of the N in NP and co-produced nitrogen fertilizer is nitrate nitrogen; replacement of traditionally used nitrogen fertilizers (urea and ammonium sulfate) would not proceed at a high rate.

g) The production capacity of the ammonia plant required for the project is 303 TPD. This scale is rather small; but if the already existing ammonia plant continues its operation, the combined nitrogen capacity would be larger than the slow-growing domestic market. The nitrogen fertilizer surplus would not be competitive in the export markets.

7. Present Status and Prospect

In 1985, following the feasibility study recommendations and taking into account the authorities' efforts to promote the increase of grain and cattle production through the use of fertilizers, new technical efforts have been undertaken for the recovery of P_2O_5 values from the Sierra Grande tails. Further, working group has been established with the participation of official agencies and research centers, aiming at the improvement of the technical and economic aspects of the research and development of phosphate fertilizer production.

At present, the activity of the group is concentrated in three directions:

a) Optimization of the fertilizer product mix from the apatite concentrate with high Fe content.

b) Economic feasibility of production of fertilizers with low water-solubility but with high solubility in weak acids, for application to acidic soils and pastures.

c) Feasibility of application of new technologies; attack with gaseous SO_3, use of microbiology and others.

It is open to any proposal involving technology applicable to the economic production of phosphate fertilizer starting from a raw material having the specific characteristics of the phosphate rock from the tails of HIPASAM, Sierra Grande, Argentina.