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United Nations Industrial Development Organization

Expert Group Meeting on the
Processing and Utilization
of Phosphates

Dakar, Senegal, 3-6 January 1990

REFORT

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Explanatory notes

Unless otherwise indicated, the term "dollar" ($) is taken to mean a United States dollar.

The monetary unit of Senegal is the CFA franc (FCFA). The following abbreviations have been used in the report:

AFCFP	Arab Federation of Chemical Fertilizer Producers
APS	Senegal Press Agency
BPL	Bone Phosphate Lime
BRGM	Geological and Mining Research Office
CEAO	West African Economic Community
CESAG	African Centre for Higher Studies in Management
CSPT	Senegalese Taïba Phosphate Company
DMG	Directorate for Mining and Geology
EEC	European Economic Community
FAO	United Nations Food and Agriculture Organization
FERPHOS	National Iron and Phosphate Enterprise
ICS	Senegalese Chemical Industries
IFDC	International Fertilizer Development Centre
IST	Institute for Earth Sciences
MDIA	Ministry of Industrial Development and Handicrafts
NFC	National Fertilizer Co-operation of Pakistan
PANA	Pan African News Agency
pH	Hydrogen Potential
SODEFITEX	Textile Fibre Development Company
SOFRECO	French Research and Counselling Company
SSP	Single Superphosphate
SSPT	Senegalese Thiès Phosphate Company
STPP	Sodium tripolyphosphate
TPI	Triphosphoinositide
TPP	Tetra isopropyl titanate
TSP	Trisodium phosphate
UNDP	United Nations Development Programme
UNIDO	United Nations Industrial Development Organization

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PREFACE

The system of industrial consultations is a device by which the United Nations Industrial Development Organization (UNIDO) can serve as a forum for developed countries and developing countries in their contacts and consultations directed towards the industrialization of developing countries. Among those taking part in the consultations are representatives of the governments, industry, labour, consumer groups and so forth of the countries concerned.

The advantages of the system are, inter alia, an ability to identify obstacles in the way of the industrial development of the relevant countries, to observe trends in the world economy and thereby to work out practical measures for increasing the industrial production of the developing countries as well as to seek new forms of industrial co-operation in North-South and South-South relations.

Since the system was first established in 1975, 1/ the consultations have involved 16 industrial sectors and two main topics. The system of industrial consultations brings together the decision-makers and affords them an opportunity of deliberating on and proposing specific measures promoting the industrialization of developing countries. Numerous innovations (technological alternatives, integrated development and contracts) have been formulated under the programme, opening up possibilities for devising technical assistance projects and ensuring aid from investors and the transfer of techniques.

On account of their consensual and regulatory nature, the consultations have proved to be an efficient way of balancing different interests in the area of international industrial co-operation, thereby considerably helping member countries to develop strategies and policies for industrial development.

The system of consultations is under the permanent and direct supervision of the UNIDO Industrial Development Board. In addition to the annual review and periodic study of the results of its work, in 1989 the system underwent a thorough examination, which showed that it was also conducive to the development and definition of UNIDO's policy and programmes.

1/ Report of the Second General Conference of the United Nations Industrial Development Organization (ID/CONF.3/31), chap. IV.

CONTENTS

INTRODUCTION

1. The Expert Group Meeting on the Processing and Utilization of Phosphates was held at Dakar in Senegal from 3 to 6 January 1990. The meeting took place in conformity with the recommendations of the Regional Consultation on the Phosphatic Fertilizers and Pesticides Industries in Africa (Yamoussoukro, Côte d'Ivoire, 12-16 December 1988). One of the aims of the meeting was to help promote and expand the industry in the African countries, which is playing a critical role in improving agricultural productivity and thereby ensuring self-sufficiency in food production.

A. Background to the expert group meeting

2. Phosphates are of vital importance to the fertilizer sector. The present state of the production of phosphates and their conversion into fertilizers is fraught with a number of major problems at almost every stage of the operations. The known phosphate deposits are numerous, although the producers and exporters of phosphates throughout the world are beginning to encounter difficulties in exploiting them. The demand for high-grade products is leading to new requirements with regard to phosphate enrichment, and the problems arising in energy consumption and environmental protection are also getting worse.

3. Furthermore, in some of the African countries there are phosphate deposits which by virtue of their middle-grade or low-grade content are difficult to mine and the exploitation of which is hampered by technological and economic constraints. An exchange of experience on the many subjects associated with the production of phosphates and development of the phosphatic fertilizer industry is hence essential.

4. Some of the African countries, among them Morocco, Tunisia and Senegal, count as the biggest world producers of phosphates and have gained extremely valuable experience in the area of mining, concentrating and processing the phosphates. The phosphate industry provides one of the main exports from those countries.

B. Objectives of the expert group meeting

5. The objectives of the meeting were as follows:

(a) Evaluation of the processing techniques (more especially techniques for reducing impurities to an acceptable level) by which to enrich low-grade and medium-grade phosphates so as to use them as raw materials in the manufacture of phosphatic fertilizers;

(b) Identification of the possibilities and limits of application for low-grade and medium-grade natural phosphates and concentrates in the form of mini-granules, with consideration as well for the partial acidulation process;

(c) Exploration of possibilities and conditions for setting up pilot plants and commercial facilities for mining and processing phosphates from the deposits existing in some of the African regions, using conventional and modern techniques for the purpose;

(d) Submission of an evaluation report based on a survey of the enrichment techniques successfully used for mediocre and medium-grade phosphates, especially in the case of the procedures applied in some developing countries (Brazil, India, Pakistan, Tunisia etc.);

(e) An account of prospects for the development, production and application of non-conventional fertilizers such as liquid products and those applied in small amounts, depending on the type and content of nutrients, derived from low-grade and medium-grade phosphates.

CONCLUSIONS AND RECOMMENDATIONS

6. Given the fact that few African countries have a population big enough to consume the fertilizers produced by world-level plants built in countries possessing raw materials, it is advisable not to launch such projects unless a feasibility study shows for certain that the products obtained are competitive with similar world-trade products both in terms of export and import and, if that condition is filled, to promote transnational co-operation at regional or subregional level so as to further the development of the activities of that industry.

7. This recommendation also applies to less important projects or even to the mini-plants located in enclaved areas with natural indigenous resources. If their area of influence goes beyond the frontiers, an attempt should be made to enable them to cover that area.

8. The next technical meeting should take stock, extremely succinctly, of the current technical potential of mini-plants of all types producing sulphuric acid, ammonia, superphosphate, partly acidified phosphate and so on, as well as conventional and alternative building materials (namely those that can be found in the developing countries).

9. When a project of local interest has been defined and shown to be viable, it should be implemented without delay and attempts should not be made to turn it into a world project - which would doom it to failure through lack of sufficient outlets.

10. UNIDO should identify the undesirable though useful by-products such as sulphur dioxide, sulphuric acid and so on that are not being used at the present time and seek potential consumers for them.

ORGANIZATION OF THE MEETING

11. The Expert Group Meeting on the Processing and Utilization of Phosphates was organized by UNIDO and jointly sponsored by the Senegalese Chemical Industries (ICS), Senegalese Taïba Phosphate Company (CSPT) and Senegalese Thiès Phosphate Company (SSPT) under the supervision of the Ministry of Industrial Development and Handicrafts, in collaboration with the African Centre for Higher Studies in Management (CESAG) which provided the logistic support for the meeting.

12. The meeting was attended by representatives from 12 countries, among them eight African countries (Algeria, Burkina Faso, Burundi, Guinea, Malawi, Niger, Rwanda and Senegal) and international organizations - United Nations Development Programme (UNDP), Food and Agriculture Organization (FAO), West African Economic Community (CEAO), Liptako-Gourma Authority and International Fertilizer Development Centre (IFDC).

13. The agenda for the meeting is shown in annex I, a list of participants in annex II, the list of papers presented in annex III and the abstracts in annex IV to this document.

A. Opening of the meeting

Statement by the Private Secretary to the Minister of Industrial Development and Handicrafts

14. After a speech by the UNIDO representative, the meeting was opened by the Private Secretary to the Minister of Industrial Development and Handicrafts. He stated that the items on the agenda for the meeting were of topical relevance in view of the situation prevailing in the branch and of its economic and social repercussions. In effect, despite the measures adopted, there were still constraints in the matter of production and the sale of products on both the local and export markets which very much influenced development of the relevant branch of industry. Measures were therefore necessary for its revitalization, more especially the adoption of an integrated approach to production and to its utilization as well as to the selection of technological options. That was the aim to which all efforts should be directed.

15. In Africa there were many regions with over-exploitation of the soil, which might easily lead to a decline in agricultural production with all the associated consequences. There had to be regeneration of the soil by encouraging the production and consumption of fertilizers. That not only presupposed that the finished product should be accessible to the rural population - the main users - but also that it should be rich material by virtue of its components. In short, there was room for important improvements in the manufacture of the product.

16. With regard to the choice of the technological options, the exploitation and beneficiation of small phosphate deposits, often to be found in enclaved regions, were of particular importance. That was why the establishment of small viable fertilizer plants meeting local needs should be closely studied. Once that approach had been adopted by the expert group meeting, there would be need to look into the conditions for applying it through international co-operation, for which UNIDO was one of the principal agencies.

17. A technical visit was arranged for those attending the meeting to the premises and facilities of the Senegalese Chemical Industries (ICS) and those of the Senegalese Taïba Phosphate Company (CSPT) located near Dakar.

B. Summary of the discussions

18. Participants were unanimous in believing that there had to be an integrated approach to the problem and that, within that approach, a distinction should be drawn between the areas of priority. The very first consideration was self-sufficiency in food and, therefore, agriculture. In order to step up agricultural production, which needed recourse to inputs (including fertilizers), ways and means had to be found to overcome all the obstacles to their application. Those obstacles were classified as follows in order of decreasing importance:

- Financing of the cost of inputs;

- Training and provision of information for peasants;

- Physical distribution of the inputs;

- Social organization of relationships between landowners and farmers on the basis of sharecropping contracts;

- Risks involved in not finding in time a market able to absorb surplus products (problem of preservation of perishable foodstuffs).

19. If these obstacles can be overcome, the industry should be organized to provide inputs of the quality required at the right time and at the better "root return" price. The notion of a "root return" price is essential in Africa, as pointed out by the FAO delegate. It includes, apart from the cost ex-factory or port of entry, the set of delivery costs: transport, storage, transaction and commission, these being in certain cases more than the starting cost.

20. What can be concluded from the above as far as fertilizers are concerned? It has been suggested that there are two different cases, namely:

- Open regions. These are situated at least 500 km from the seaports. The price of the fertilizers there should be the price of the international transactions plus delivery costs of the order of about 10 per cent of the starting price. Any industrial plant in these areas should be able to face such local competition and to counteract it by selling its surpluses for export.

- Enclaved regions. In enclaved regions the delivery costs increase as one moves away from the ports, which offers a greater chance for local small-size production based on indigenous resources.

21. In both cases the concept of production units requires total professionalism on the part of the contractors both in determining the phosphate deposit - quantitatively and qualitatively - and in working the deposit or in economical conversion of the ore into a phosphatic fertilizer, by means, if necessary, of ore enrichment and/or a procedure to solubilize the phosphorus.

22. The contractor also has to be supervised by officials or promoters whose complete integrity is based on undoubted competence so as to judge the quality of the information received and the suitability of the options proposed on a completely independent basis.

23. Finally, overall consideration has to be given to lucid organization of the transfer of technology, covering the three essential stages - training, assistance and guidance. When this has been done, it has to be organized, the cost of it calculated and the finances settled, within or beyond the budgetary limits or beyond those limits but at an appropriate time.

24. The small local units for manufacturing fertilizers should be simple, rustic and adaptable, inexpensive and easy to operate. Given the advantage that they offer (possible savings in currency, benefit of local production in terms of guaranteed supply and reduced cost of delivery), it was agreed that there should be encouragement of these plants either by tax exemption or by temporary subsidizing of fertilizer sales.

25. The participants seemed, however, to be unanimous in considering that the advantages should not be of a permanent nature; for if that were the case, it would mean that the benefiting plant would not have an economic or social justification. To implement such projects, it was necessary to train specialists who could follow up the project from the outset and to assign them to the project until it was finally completed. New techniques should not be trusted, rather it was better to resort to proven methods.

26. However, if the case was a unique one - by dint of the raw materials or the conditions for access to enrichment agents, there was need to proceed with care and to make successive checks before industrial implementation.

27. Some participants pointed out the existence of potential sources of nuisance raw materials such as sulphuric acid stemming from copper ore calcining plants in South America or the non-recovered sulphur dioxide from some calcining plants, which created local or regional environmental problems. Those participants hoped that UNIDO would bring the parties concerned into contact with potential users so as to verify whether there was supply and demand and whether the means available for doing so were economical, for example by prudent organization of transportation or by swaps.

28. Stress was placed on the importance of promoting regional co-operation to encourage industrial development on the basis of broader markets, but it was realized that such should be done under the conditions of competition mentioned above. (It was noted on this point that there was bitterness among the Senegalese Chemical Industries which had given NAFCON the right of first refusal for their sales of ammonia, although NAFCON had not returned the compliment in the case of its sales of phosphoric acid.)

29. Several Senegalese participants complained of the fact that their fertilizers faced competition on certain markets from products coming from the industrial countries in the form of dumping, which was permitted because those countries made "gifts" to developing countries. On this subject the International Fertilizer Development Centre (IFDC) pointed out that it had approached the donors and requested them to invite tenders from the countries of the region as well.

30. African producers hoped that it would be possible to reactivate fertilizer consumption by overcoming the first obstacle mentioned: the financing of fertilizers. Agriculture was subsidized throughout the world, but in their countries it was forbidden to do so. Fairness demanded that they should be able to subsidize their own agriculture - modestly and on a temporary basis - in order to start the process of intensification.

31. One participant pointed out that it was not enough for the experts to be convinced of the usefulness and limitations of mini-projects of local interest, but that there was further need to convince national government officials of the usefulness of such small-size projects and to request them not to convert them into larger and more costly enterprises purely for the purpose of satisfying their own vanity, but at the risk of making them into something inappropriate and bringing about their failure.

32. UNIDO was called upon to organize a practical meeting on the subject of smaller units together with industrial technologists. It had expressed its willingness to help to implement specific projects which were put forward and had at the time recorded a project proposal aimed at exploiting the Kodjari phosphate deposit in Burkino Faso as well as a project for the exploitation of the phosphate deposits in member States of the Liptako-Gourma Authority (Burkina Faso, Mali and Niger).

33. UNIDO had offered to sell its COMFAR data processing system which was able to evaluate not only the economic profitability of projects, but also their social advantages. Use of that program would enable project promoters to have a sounder basis for submitting their project(s) to financial backers.

34. Emphasis was placed on numerous occasions on the fact that:

- The soils not only lacked mineral elements, but were also suffering from a deficiency in organic matter. The peat available in a number of countries could to some extent solve that problem;

- More imagination would have to be shown in exploiting local phosphate resources and, for example, in avoiding or limiting imports of sulphur or other basic materials used for the manufacture of sulphuric acids by resorting, whenever justified, to the use of crushed phosphate or partly acidulated phosphate;

- Mini-projects should be put into effect by sacrificing parameters such as the material yield and, furthermore, there should be a search for funds that were not linked to a supplier country, so that use would be made of the market and advantage taken of competition (but the specifications had to be complete and precisely defined).

C. Closure of the meeting

35. In his closing address, the representative of the Senegalese Ministry of Industrial Development and Handicrafts pointed out that the recommendations and conclusions adopted by the meeting were evidence of the quality of the work undertaken beforehand and the discussions proper of the meeting. He also expressed his conviction that only an agricultural policy encompassing all the components of agricultural development would make it possible to define a fertilizer strategy for the African countries. Those countries often had need of support and assistance from international agencies as such as UNIDO in their programmes and projects for the production and application of fertilizers. Such international co-operation could usefully help in the adoption of an integrated and multisectoral approach to the development of the fertilizer industry and fertilizer application in Africa. The strong demographic growth of the continent, which had brought about massive urbanization, gave rise to additional need for food, the satisfaction of which of necessity took the form of a major increase in agricultural productivity and, therefore, enhanced fertilization of the continent's soils.

36. On behalf of all those present, the Algerian representative thanked the UNIDO Secretariat for having taken the initiative in organizing the meeting and having ensured that it was efficiently conducted. He also expressed his gratitude to the Government and authorities of Senegal for having acted as such cordial hosts and for having accorded the participants such generous hospitality.

Annex I

AGENDA

Wednesday, 3 January 1990

4 - 5 p.m.	Registration of participants
5 - 6 p.m.	Official opening of the meeting by Mr. Famara Ibrahima Sagna, Minister for Industrial Development and Handicrafts, followed by a cocktail party given by the Government of Senegal.

Thursday, 4 January 1990

10 a.m.	Commencement of work.
10 a.m. - Noon	Papers presented by the SSPT, CSPT, ICS and the Directorate for Mining and Geology.
2.30 - 5 p.m.	Papers presented by UNIDO, IFDC, FAO, CEAO and national delegates.

Friday, 5 January 1990

9.30 - 10.30 a.m.	Enrichment techniques, possibilities and limitations; accounts of actual cases by the participants.
11 a.m. - 12.30 p.m.	Fertilizers made from low-grade phosphates with and without chemical processing.
2.30 - 3 p.m.	Consideration of the possibility of setting up small-size units using simple technology and a maximum of local resources.
4 - 5 p.m.	Conclusion of discussions and recommendations.

Saturday, 6 January 1990

8.30 a.m. - 6.30 p.m.	Technical visits to the Taïba phosphate deposits of the ICS.

Annex II

LIST OF PARTICIPANTS

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Guinea

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Kuwait

Mr. Wadié Abboud, Head of the Department of Information and Publications, Arab Federation of Chemical Fertilizer Producers (AFCFP), P.O. Box 23696, Safat, 13097, Telex: 22747 afcfp.

Malawi

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Niger

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Rwanda

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Senegal

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Mr. Chérif El Waly Diop, Geologist, Engineer, Directorate for Mining and Geology/Ministry of Industrial Development and Handicrafts (DMG/MDIA), P.O. Box 1238, Dakar.

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Senegal (continued)

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INTERNATIONAL ORGANIZATIONS

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Mr. Philippe Ouedraogo, Mining Engineer, in charge of industrial projects, P.O. Box 619, Ouagadougou, Burkina Faso, Telex: liptako 5247 bf.

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Annex III

PAPERS PRESENTED

The Senegalese Thiès Phosphate Company (SSPT):

- Applications of Lam-Lam tricalcium phosphate;

- Applications of Thiès alumina phosphate (phosphal).

Mr. Babacar Diagne, Director for Mining, CSPT:

- Exploitation of Taïba ore;

- Targets for improving the recovery of Taïba phosphate - slimes.

Mr. Doudou Fam, engineer, ICS:

- Exploitation of phosphate slimes.

Mr. Chérif El Waly Diop, geological engineer, DMG:

- Description of the phosphate branch;

- Beneficiation of Matam phosphates.

Mr. Oussaynou F. Dia, lecturer at the Cheikh Anta Diop University of Dakar:

- Phosphate resources in West Africa.

Mr. Robert Faure, SSPT, France:

- An example of fine natural phosphate in Senegal.

Mr. Armand L. Davister (Belgium), UNIDO consultant:

- Manufacture of fertilizers from low-grade phosphate rocks.

Mr. Zahid Aziz, UNIDO consultant NFC:

- Processing and use of medium- and low-grade phosphates: the situation in Pakistan.

Messrs. I. Bajwa, Zahid Aziz, M. Rashid and Raza Hussain, NFC:

- The use of phosphal as a phosphatic fertilizer and source of phosphorus for manufacturing fertilizer with multiple nutrients: Pakistani experience.

Mr. M.H. Chaudhry, UNIDO consultant, State Petroleum Refining and Petrochemical Corporation Limited, Pakistan:

- Study of the use of phosphate ores.

Interregional consultant, Chemical Industries Branch, Department of Industrial Operations, UNIDO, Vienna:

- Programme of tests on phosphate solubilization by the fungus PB-50.

Mr. Terry Frederick, Civil Engineering and Training Co-ordinator, IFDC-Africa, Togo:

- Options in the supply of fertilizer for Sub-Saharan Africa.

Mr. Wadié S. Abboud, Chief, Department of Information and Publications, AFCFP, Kuwait:

- The phosphate industry in the Arab region.

Mr. Philippe Ouedraogo, mining engineer at the Liptako-Gourma Authority:

- The project for industrial production of phosphatic fertilizers in member States of the Liptako-Gourma Authority - summary of the results of technological and feasibility studies.

Mr. Grégoire Kaboré, Directorate for Inputs and Agricultural Mechanization, Ministry of Agriculture and Stock-Breeding:

- Survey of the use of phosphates in the crude state and prospects for setting up mini-plants for fertilizers in Burkina Faso.

Mr. M. Jeandrain, fertilizer programme, FAO, Italy:

- Selection of the type of fertilizer: the user's standpoint.

Mr. Ahmed Djellali, Technical Director, FERPHOS:

- The phosphate industry in Algeria.

Mr. Ibrahim A.G. Panjwani, Managing Director, Royal Chemical Enterprises Ltd., Malawi:

- Deposits of group I minerals - Apatite.

Annex IV

SUMMARY OF THE PAPERS PRESENTED

ALGERIA

Algerian phosphates*

The Djebel Onk deposit, which was first mined in 1700, has had to take over from the older mines and act as a platform for the development of the national fertilizer industry.

A. Reserves and content

The known reserves are of the order of 2,000 million tons with a tricalcium phosphate *in situ* ranging from 54-61 per cent. The total thickness of the layer is about 30 m. While at the bottom it is argillacious, the gangue becomes dolomitic in the upper half.

B. Mining

Mining is of the open-cast type, with two terraces being worked at the same time (a sterile terrace 30 m thick and a 30 m phosphate terrace). Conventional equipment is used: drilling machines, dragline excavators, heavyweight trucks.

C. Processing

Wet processing makes it possible to enrich the ore and obtain a tricalcium content between 73 and 75 per cent. This operation is carried out at the DK_1 plants.

Dry processing carried out in the two dedusting plants (DK_2 and DK_3) enables ore containing 63-65 per cent TPI to be obtained.

1. Composition of ore

- Three or four per cent of siliceous material, with an average of 1.8-3.2 per cent silica in argillaceous form and 1.2-0.8 per cent silica in crystalline (quartz) form.

- Lime accompanied by magnesium:

  - Partly in the cement agglomerating the polyliths (mainly exocalcite in the form of crystallized calcite);

  - Partly inside the polyliths (endocalcite), and partly in calcitic form.

2. Mechanical preparation

Having undergone wet and dry processing, the ore is subjected to mechanical preparation, which consists in the following operations:

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* By Mr. Ahmed Djellali, Technical Director, National Iron and Phosphate Enterprise.

- Crushing to reduce the dimensions of the crushed blocks to a grain size of 1-10 mm;

- Screening to make a selection at 8 mm (the rejects are sent to a hopper for collection by trucks and dispatch to slag heaps).

The screenings are fed to three processing lines.

3. The wet process

This form of enrichment covers basically:

- Elutriation mainly to eliminate the wastes;

- Calcination to dissociate the carbonates;

- Washing with water to remove lime, magnesium and suspended particles.

This form of processing makes it possible to obtain a market phosphate with 73-75 per cent TPL from a crude ore producing 54-56 per cent TPT.

(a) Elutriation

The pulped screenings are fed to grids which cut them down to 1 mm. The required grain size of the ore lies between 80 and 1,000 microns. The material passing through the curved grids is cycloned in order to eliminate the grain size 0-80 microns formed by the very low-grade components. The grade obtained after elutriation is 61-63 per cent TPL, giving a yield in weight of 65-66 per cent approximately.

(b) Calcination

The operation involves three phases:

- Drying and pre-heating of the ore;

- Calcination proper which is carried out in fluidized-bed calciners (the ore is heated to a temperature of 850-900°);

- Cooling.

The standard obtained after calcination is 69.5 per cent TPL, giving a yield in weight of 85-88 per cent.

(c) Washing

After decomposition of the carbonates and the release of carbon dioxide during the calcination, the ore is then washed so as to remove the alkaline salts, lime and magnesium either by dissolution or by suspension in water without adding any reagents. These operations are carried out in hydrocyclones, tanks and pulsed columns. The grade obtained after washing is 72-74 per cent TPL, giving a yield in weight of approximately 78 per cent.

(d) Drying

The washed and dried ore is then dried a second time in conventional recycling kilns, followed by dry dedusting to reduce the moisture content from 130 to 0.5 per cent.

The marketable phosphate is then taken to a covered depository with a capacity of 25,000 t. It is loaded into the 45.5 t - phosphate cars from seven hoppers each holding 400 t and equipped with compressed-air-operated shutes.

4. Wet process

This process which is known as "dedusting" involves the following operations:

(a) Drying of the screened ore in fluidized beds. The hot gases generated in the combustion chamber pass into a windbox and through the pipes of the windbox into the drying compartment where they ensure fluidization. The drying temperature varies from 300 to 1,000°, the minimum capacity of the kiln is 115 t/h and the moisture content of the product is 3 per cent;

(b) Prescreening at 2 + 4 mm;

(c) Crushing in a percussion mill;

(d) Pneumatic selection by bladed selectors;

(e) Post-screening with an 800-1,000 micron mesh. The material passing through the screen is the marketable product, which is taken by conveyor to storage hoppers each with a capacity of 4,000 t.

The cars are loaded in the same way as for the calcined, washed and dried product.

5. Processing capacity

The installed production capacities are:

- Dedusted phosphate: 160,000 t;
- Calcined phosphate 500,000 t.

6. Transport

The phosphates are transported 330 km by rail to their destination:

- ASMIDAL (Phosphatic Fertilizer Complex);
- The port where they are stored in facilities provided for products to be exported.

7. Future development

Concurrently with the construction of a phosphatic fertilizer complex near the Djebel Onk mine with a capacity of 360,000 t/y of TSP and 40,000 t/y of STPP, the National Iron and Phosphate Enterprise has plans to construct a supersimple plant and units for the formulation of natural phosphate-based fertilizers.

The first experiments carried out by FERPHOS open up good prospects for using phosphate as fertilizer in different forms:

- Spreading of the phosphate as such over acid soils;

- Slightly acidified phospate;

- NPK or PK formulated phosphate.

If the construction of large fertilizer complexes enable us to manufacture highly elaborate products, in certain cases, especially when phosphate with high formic and citric acid solubility is available, the use of it in simple and less costly forms will make it possible to obtain results of the same order.

LIPTAKO-GOURMA AUTHORITY

Project for the industrial production of phosphatic fertilizers in member States of the Liptako-Gourma Authority. Summary of the results of technological and feasibility studies*

Between November 1986 and August 1989, the Liptako-Gourma Authority carried out a study to find the technology best suited to the grade of the ores existing in its member countries (Burkina Faso, Mali and Niger) and to the prevailing economic conditions.

The study was made by the French research and development organization SOFRECO. It first discusses the geological, lithological and mineralogical characteristics of phosphates from the four main deposits (Kodjari in Burkina Faso, Tamaguilelt in Mali, Tahoua and Par Duw in Niger). Although their origins and ages are different, the ores have a very poor content, with high amounts of silica and iron-aluminium, especially in the case of the Kodjari and Par Duw ores.

Five procedures applied to different phosphates were compared in the study:

- Partial action by sulphuric acid or PNPA procedure;
- Action by nitric acid;
- Double action by nitric and sulphuric acid;
- Action by nitrous fumes on an organic matter support or the HUMIFERT process;
- Blending phosphates ground with urea or potash.

Fertilizer samples made in the laboratory by means of these processes were subjected to agronomic tests in plant pots by two different methods.

A technico-economic comparison of these processes took into account:

- The results of a market study and forecasts for phosphatic fertilizer consumption;
- The grade of the fertilizers made (content of fertilizing elements, solubility, dry matter production and level of phosphorus extracted);
- The level of investments required for implementing each of the processes studied;
- The problems arising in the spreading of the fertilizers.

The comparison of the processes suggested that two of them should be selected:

- Partial action by sulphuric acid;
- Action in nitrous fumes.

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* By Mr. Philippe Ouedraogo, Mining Engineer of Liptako-Gourma Authority.

A detailed feasibility study showed that it would be possible, from 1992 onwards, to set up plants for manufacturing fertilizers by the following processes:

- Action in nitrous fumes, capacity 3,000 t/y of P_2O_5, to be established at Ouagadougou and Légon. The two towns could have a second plant five or six years later;

- PNPA, in a plant turning out 2,000-3,000 t/y of P_2O_5, set up at Say in Niger.

The economic study points out the numerous financial and socio-economic advantages of such construction plans, which would lead to highly competitive cost prices for fertilizers produced or delivered.

However, the newness of the nitrous fume process will make it necessary to study the relevant technical proposal very thoroughly.

BURKINA FASO

Survey of the use of phosphates in the crude state and prospects for setting up mini-plants for fertilizers in Burkina Faso*

In Burkina Faso agricultural problems involving the fertility of the soil are at the heart of the difficulties experienced by peasants. In most cases the soils show a lack of phosphorus of the order of 40-50 kg/ha of P_2O_5; following the discovery of phosphatic deposits in the south-east of the country (Kodjari, Arly, Aloub and Djonana), an ambitious programme of experiments has been launched to bring to light the conditions necessary for using these phosphates in the crude state.

Having ascertained all the constraints on direct application due to the mediocre grade of those phosphates (too much iron-aluminium and siliceous gangue), Burkina Faso has shown keen interest in looking for ways to improve them using non-conventional solubilization processes.

The partial acidulation process seems to suit best the Kodjari phosphates, and research and development offices of IFDC, ATFER, CIRAD/TIMAC and SOFRECO have been invited successively to make feasibility studies on that basis. The CIRAD/TIMAC process of a complex reaction in the presence of soluble phosphate compounds such as MAP appears the most promising for Burkina Faso. The World Bank and FAC have also been approached for funds to support the second phase of the CIRAD/TIMAC study.

It should be noted that Burkina Faso has the political will and favourable conditions for setting up a fertilizer mini-plant. However, in addition to the conditions, there is need for financial and technical assistance to translate those initiatives into reality. Burkina Faso is expecting a great deal from the Dakar meeting which, it is hoped, will be a springboard for developing initiatives immediately applicable for the encouragement and promotion of the industrial capacities of countries requiring such.

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* By Mr. Grégoire Kaboré, Directorate for Inputs and Agricultural Mechanization, Ministry of Agriculture and Stock-Breeding.

INTERNATIONAL FERTILIZER DEVELOPMENT CENTRE (Togo)

Options for supplying Sub-Saharan Africa with fertilizers*

In Sub-Saharan Africa, where a speeded-up growth rate of the population is foreseen and, as a result, an increased demand for foodstuffs, fertilizers are one of the principal means of improving agricultural production; hence it is more and more important to supply the farmers of that region with fertilizers. According to estimates, intensification of crop growing (increased yield) should make it possible to cover 70 per cent of the additional food requirements during the next 10 years. Thus it will be necessary to produce various fertilizers on the spot (as far as possible), first and foremost phosphates, on the basis of local resources. Given the cramped nature of the fertilizer market in most of the countries, a plant turning out conventional products has difficulty in competing with imported products normally coming from larger factories.

The countries of Sub-Saharan Africa therefore have a choice between:

- Importing bagged fertilizers - which is the commonest method of supplying fertilizers in the region;

- Streamlining and perfecting methods of forecasting and procurement in order to improve the efficiency in importing fertilizers, which would make it possible as a whole to reduce costs;

- Co-operating at regional level in supplying the smaller consumer States with fertilizers so as to improve their position as regards invitation to tender and shipment;

- Importing bulk products and local bagging - a method which has shown its value in Kenya, in the United Republic of Tanzania and the Sudan;

- Importing in bulk the fertilizer components and blending and bagging them locally - an approach which is all the more worth while if some of the raw materials are available locally, as in the case of Nigeria;

- When conditions lend themselves, manufacturing conventional and other fertilizer products from raw materials available on the spot;

- Streamlining of smaller-scale invitations to tender so as to permit greater competition among suppliers and increase the number of products coming up to specification (bulk blending or nitrate-derived products).

Further studies should be undertaken to determine which of these options best suits the given situation. An attempt should also be made to induce governments to accord greater priority to supplying the agricultural sector with fertilizers and other means of production.

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* By Mr. M. Jeandrain, FAO fertilizer programme.

FAO

The choice of fertilizer: the user's point of view*

The FAO fertilizer programmes are aimed at assisting governments to increase agricultural production by judicious use of fertilizers. On this account FAO officials are in close contact with the peasants and are learning to understand their problems. Hence it is the point of view of the users and their advisers that the author reproduces in these short notes.

Phosphatic fertilizer may be composed of two different inputs: a rectifying fertilizer and a production fertilizer. What follows relates especially to the production fertilizer.

We should keep in mind the financial difficulties to which the peasants are more and more exposed in purchasing their fertilizers; furthermore, the tendency to supply fertilizers at actual market prices and privatization of the distribution routes are becoming more widespread.

Without calling into question the agronomic value of low-concentration fertilizers, the highly concentrated ones are often fairly cost-effective at actual market prices, which is not the case with fertilizer that is concentrated to only a slight or medium extent.

The growing costs of agricultural inputs induces the peasants, aided by their advisers, to make a more rational and restrictive choice when purchasing their inputs. For example, in the case of fertilizers:

- A more rational choice: we would speak of the cost of a "root return" fertilizing unit and no longer just the cost of a bag of fertilizer;

- A more restrictive choice: should not the peasants limit the external application of nutrients to only those elements essential for plant nutrition and to maintenance of soil fertility by the addition of an organic fertilizer? Let us note that this protects the soluble phosphates against their decline in the soil. Hence from the point of view of the producers it is better to continue efforts to improve the grade of the fertilizer: for example, to avoid as far as possible making the peasants pay for nutrients which it is not essential to apply externally.

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* By Mr. M. Jeandrain, FAO fertilizer programme.

FRANCE

An example of natural fine phosphate from Senegal*

This sedimentary phosphate which comes from the Lam-Lam deposit near Thiès is mined by the Senegalese Thiès Phosphate Company at Dakar.

It has a high P_2O_5 content (34 per cent) with a guaranteed minimum of 74 per cent BPL and a small amount of iron-aluminium, which permits different industrial applications.

It is therefore suitable for manufacturing phosphoric acid, by itself or as a mixture, from single superphosphate, of which there are various examples in the world, and also from triple superphosphate.

The phosphate can be used directly as fertilizer for acidic soils (pH < 6), preferably wet soils, so that it can be more rapidly taken up.

Basic tests in Senegal have officially shown its value as a fertilizer for groundnuts.

Substantial increases in yield have been found over a period of eight years, which broadly offset the cost of the initial fertilizer.

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* By Mr. Robert Faure, Senegalese Thiès Phosphate Company.

KUWAIT

The phosphate industry in the Arab region*

The industry has been in existence since the nineteenth century and eight Arab countries are now making phosphatic fertilizers. The production of natural phosphates rose from 31 million tons in 1980 to 42 million tons in 1988. The proportion of natural phosphates in the consumption of phosphatic fertilizers varies with the country of the region from 10 to 100 per cent of the total quantity. Phosphates obtained in the region amount to between 65 and 77 per cent, or represent an increase from 1.9 million tons of P_2O_5 in 1980 to about 5.7 million tons in 1990. The region provides single superphosphate, triple superphosphate, ammonium phosphate and several NPK fertilizers. In 1988, 1.2 million tons of single superphosphate intended solely for local consumption were produced; in 1988 the production of triple superphosphate was 2.2 million tons, of which a small proportion is used on the spot, the bulk being exported. The production of ammonium phosphate rose in 1988 to 2.7 million tons, as against only 400,000 tons in 1980. The ammonium phosphate is mostly intended for export.

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* By Mr. Wadié S. Abboud, Head of the Department of Information and Publications, AFCFP.

MALAWI

Group I mineral deposits - apatite*

Apatite is a phosphatic mineral frequently used for making fertilizer (superphosphate) and which when ground can be applied directly to the soil under certain conditions.

Apatite is present in pyroxenites at Malindi and Chingale, two localities in the southern region. At Malindi the eluvial soils overlying the pyroxenite contains an average of 7.8 per cent chlorapatite. Deep pitting and core drilling have shown that the pyroxenes at Chingale contain about 8.7 per cent apatite over the areas explored. Despite the extensive nature of it, the Chingale apatite deposit compares unfavourably with the Tundulu deposit, which is outlined below.

The principal apatite deposit is to be found at Nathace Hill in the District of Mulanie. The apatitic rocks form an arcuate zone (30-100 m in width) around the eastern side of the hill. The apatite occurs as pale pink grains with an average diameter of 0.1 mm in a matrix of calcite. It contains approximately 2.09 per cent fluorine. In 1970 exploratory drilling was carried out in a selected area to determine the tonnage.

According to the results of the drilling, 1,250,000 tons of apatite-rich rock containing an average grade of 15 per cent P_2O_5 could be mined by the open-cast method. An area of about 900,000 tons containing an average of 22 per cent P_2O_5 has been detected within this mass. The Nathace Hill deposit is an important phosphate reserve, but its utilization is dependent on the manufacture of sulphuric acid in Malawi.

Mineral deposits containing sulphur (pyrite and pyrrhotite) are found to occur at Malingunde Hill, 25 km to the south-west of Lilongwe, and close to Chisepo, 50 km north-west of Lilongwe. The Geological Survey has examined the two deposits and carried out drilling showing the presence at Malingunde Hill of 2.5 million of pyritiferous gneiss tons with an average of 10 per cent sulphur. Mineral dressing tests indicated that gravitational separation methods would produce concentrates covering the needs of a sulphuric acid plant. In the Chisepo area, the best deposit is located at Nkhanya Hill, where one drill-hole has revealed a mineral averaging 11.9 per cent sulphur; it is assumed that several million tons of pyritiferous gneiss exist in that locality above plain level.

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* Mr. Ibrahim A.G. Panjwani, Managing Director, Royal Chemical Enterprises Ltd.

UNIDO

Test programme for solubilization of phosphates using the fungus PB-50*

The paper examines the potential of micro-organisms, in particular, the fungus PB-50 for increasing the solubility of phosphatic fertilizers. It ensues from a number of recent studies that up to 70 per cent of the phosphate applied by farmers can be absorbed by soil clays and organic matter and is not therefore readily available to the plant. Some naturally-occurring micro-organisms have the ability to solubilize phosphates in the soil, thereby reducing the requirement for the nutrient by as much as 50 per cent. The paper summarizes the results of field experiments with the local production of micro-organisms and their application. The conclusions reached are as follows:

1. The potential uptake of P_2O_5 by the crops during the growth period does not exceed 30 per cent due to the rapid absorption by soil components;

2. When added in the right quantity, the fungus Penicilium Bilaji, which occurs naturally in the soil in very small concentrations, may greatly improve the P_2O_5 availability to crops throughout the growth period;

3. The field test carried out in the province of Saskatchewan in Canada has shown that the application of the fungus can reduce the amount of fertilizer needed by 50 per cent, given the same crop yield;

4. The greenhouse test shows that the fungus is capable of solubilizing the P_2O_5 in natural phosphates;

5. Dissemination of the PB-50 fungus technique, if it is successful, will make for savings of hundreds of millions of dollars in the investments required to develop the phosphatic fertilizer industry.

Study of the use of phosphatic ores

The paper investigates possible uses of phosphate ores of low- or medium-grade containing between 10 and 25 per cent P_2O_5, including after they have undergone enrichment, utilization directly as phosphatic fertilizers, calcined, partly acidulated products, liquid nitro-phosphates and single superphosphates. The author concludes that phosphatic ores containing more than 30 per cent P_2O_5 are of direct interest in making water-soluble phosphatic fertilizers, whereas the beneficiation of an ore containing less than 10 per cent is of no economic interest.

Low-grade phosphates that are sufficiently reactive can be used directly as a source of phosphorus, depending on such factors as type of rock, grain size, mode of application and so forth. However, some technologies such as heat treatment by treating the crystalline structure into the amorphous state enhance the effectiveness of ground phosphates.

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* By an interregional consultant, Chemical Industries Branch, Department of Industrial Operations (UNIDO).

Generally speaking, the technologies used to produce fertilizers from ground natural phosphates suitable for direct application are relatively simple and cheap; they only require a minimum of technical skill and are not really suited to economies of scale. Low- or medium-grade natural phosphates therefore provide a cheap source of phosphorus for fertilizers. These deposits occur in many of the countries of Sub-Saharan Africa. Tests carried out in the field or on plantations under different agro-climatic and soil conditions show the agronomic value of natural phosphates when directly applied.

Production of fertilizers from poor phosphates onwards

The study deals with the possibility of using low-grade or medium-grade phosphates for making fertilizers and the problems involved. It indicates that small-scale plants set up in rural areas and using locally available phosphatic rock may compete with the larger export-oriented plants in terms of delivered cost to the African peasant. After a brief introduction to the geology and prospecting for phosphate deposits, the study goes on to make a thorough analysis of the processes for dressing and enriching medium-grade phosphates, with due regard for traditional and modern techniques for non-conventional products. It concludes convincingly that depending on a number of variables such as type of soil, soil crop system, rock characteristics, irrigation and so forth, fertilizers with a low P_2O_5 content may play a significant role in meeting fertilizer demands for agriculture in Sub-Saharan Africa.

The study is made up of the following sections:

- Fertilization and fertilizing material;
- Effect of impoverishment of phosphates on different fertilizer manufacturing cycles;
- Geology of phosphate mines;
- Enrichment of low-grade phosphates,
- Non-conventional fertilizers obtained from low-grade phosphates onwards:
  - Products for direct application;
  - Products after simple chemical transformation;
  - Products after biochemical transformation.

PAKISTAN

Use of phosphal as a phosphatic fertilizer and source of phosphorus for manufacturing fertilizer with multiple nutrients: Pakistani experience*

One hundred and eighty-one field tests spanning a period of more than 10 years were carried out at 90 different sites representing various types of soil and ecosystems in order to evaluate the efficiency of phosphal as a phosphatic fertilizer for rice, wheat and maize. On the basis of a content of equivalent P_2O_5, a comparision was made of the immediate and cumulative effects of phosphal and ordinary single superphosphate in the recommended amounts or in progressively varying quantities. The results show that phosphal had as an average the same agronomic efficiency as single superphosphate in the case of rice, and an efficiency of less than 15 and 27 per cent for wheat and maize, respectively.

By mixing phosphal with urea, calcium ammonium nitrate and ammonium sulphate by the tank granulation method, it was shown that compound fertilizers considerably varying in the N:P ratio as well in their physical and chemical properties could be obtained. Mixtures containing urea, however, had the most desirable properties. The urea-phosphal mixture proved to be superior from the agronomic standpoint since it behaves as a delayed-action fertilizer.

Hence phosphal can replace single superphosphate in the case of rice, whereas the amount applied has to be increased by 50-100 per cent in order to obtain immediate and identical effects for wheat and maize. Phosphal seems, though, to be better than single superphosphate as far as cumulative effects are concerned.

Processing and use of medium- and low-grade phosphates: the situation in Pakistan**

Technology options: use of local natural phosphate rock

The natural phosphates existing in Pakistan are usually found in the form of rock that is cherty, dolomitic, pelletal, hard, compact and medium to dark grey in colour. The rock is cherty in the region of Kakul, basically dolomitic in the Lagarban area and pyritic in the region of Dalola. Petrographic studies of natural phosphates from the Lagarban region, carried out at Albany (United States) have revealed a close association with apatite, quartz (in granular form), haematite (Fe_2O_3) and hydrated iron compounds in all the samples. The grade of the ore varies considerably within the different ore bodies.

The reserves are not very extensive; the MgO content is rather high, with the Fe_2O_3 and carbonate contents exceeding the prescribed limits. Use of these phosphates is therefore a challenge for all concerned. Various international agencies have made beneficiation studies on the siliceous and dolomitic phosphates of local origin.

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* Messrs. I. Bajwa, Zahid Aziz, M. Rashid and Raza Hussain, National Fertilizer Corporation of Pakistan.

** By Zahid Aziz, UNIDO Consultant, National Fertilizer Corporation of Pakistan.

Flotation experiments: tests with carbonates and silica, iron and phosphate have been made by the United States Bureau of Mines at Albany. The different experiments have shown that the flotation of phosphates yields better results than are obtained by carbonate, silica and iron flotation.

Because of the high cost of the complicated techniques used to bring down the nuisance impurity content to the proper level, the enrichment of these natural phosphates has not been found economical. Hence, to mine the local medium-grade phosphate deposits, other technical approaches are needed, i.e. ways of processing the natural phosphate rock that are independent of the grade of it.

With regard to the use and treatment of natural phosphates of medium grade, there are the following options:

- Production of phosphoric acid;
- Direct conversion into phosphatic fertilizers;
- Manufacture of nitrophosphates;
- Manufacture of single superphosphates.
- Other options:
- Blending;
- Direct use of natural phosphate rock.

The study then describes the technological capabilities of the Asiatic fertilizer industry with regard to the following points:

- Process design, basic and project engineering;
- Project management, procurement, construction and inspection services;
- Plant start-up, commissioning and operation;
- Market development, marketing and distribution;
- Maintenance, technical back-up and spare parts;
- Capability with regard to setting up services and facilities for research and development, testing, inspection, quality control etc.;
- Manpower training facilities;
- Joint venture;
- Barter and counter trade agreements;
- Market sharing;
- Balancing, modernization and rehabilitation of fertilizer plants.

SENEGAL

Description of the phosphate branch*

Phosphates are the basic product mined in Senegal, which is the second African producer after Morocco. Mining is an essential part of the economic and social life of the country. The mined products themselves make up an important part of the total revenue from foreign trade. Research has shown two large deposits which are being worked by the Senegalese Taïba Phosphate Company (CSPT) and the Senegalese Thiès Phosphate Company (SSPT), which are concerns with 50 per cent capital participation by the State. Apart from the deposits in operation, there are known resources at Matam in the north-east of Senegal (36 million tons with 28.7 per cent P_2O_5), in Casamance in the south, at Namel (Precambrian phosphate) and all along the eastern edge of the sedimentary basin. The phosphate reserves in Senegal are estimated at a total of more than 100,000,000 tons.

To exploit this potential more effectively, the State has set up the Senegal Chemical Industries (ICS), and this organization is converting part of the Taïba phosphates into phosphoric acid and fertilizers. The companies in the group aim at better exploitation of the resources by improving the flow sheets, maximizing yield by reducing costs, diversifying products and making use of by-products (non-floated phosphatic slime or pebbles). The relevant impact can be measured through its effect on the main sectors of the national economy (more than a quarter of the electricity consumption, almost 80 per cent of the railway traffic, more than 10 per cent of the consumption of petroleum products, about 40 per cent of the shipping from Dakar, about 23 per cent of the total exports of goods from Senegal and more than 2,300 permanent jobs).

Processing of the Taïba ore*

The enrichment process as applied to the Taïba ore covers mainly:

- Elimination of fractions greater than 25 mm that are sterile;
- Separation by screening of the fraction greater than 8 mm;
- Grinding of that fraction for purposes of flotation;
- Elimination of the finest sections which do not require the flotation technique;
- Anionic flotation in several separate cycles for phosphate minerals and elimination of siliceous gangue;
- Filtration and drying of the concentrate;
- Cyles for thickening the various effluents so as to maximize recovery of the water.

A marketable concentrate of high grade (79-80 BPL) and three types of rejects are thus obtained:

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* By Mr. Chérif El Waly Diop, Geological Engineer, Directorate for Mining and Geology.

- Completely sterile silex (17 per cent of the extracted tonnage);
- Slimes (24 per cent P_2O_5 and 36 per cent of the extracted tonnage);
- Flotation residues with 8 per cent P_2O_5 (7 per cent of the tonnage extracted).

The concentrate obtained is of high grade:

- It can be used directly, without crushing;
- The filtration capacity of the gypsum is very high;
- The P_2O_5 extraction yield is greater than 96 per cent;
- The consumption of sulphuric acid is low (2.5 t with 100 per cent/t of P_2O_5);
- Concentration of the phosphoric acid is easy and the liquid fertilizers obtained have satisfactory properties for storage.

Targets for improving the recovery of Taïba phosphate: slimes*

The concentration of crude phosphate from the mine produces three types of rejects:

- Completely sterile silex which is unfortunately almost unusable;
- Flotation residues which are now exhausted to the extent of 8 or 9 per cent of the P_2O_5; the older residues, which are less exhausted, are reprocessed and thereby provide almost 10 per cent of the mine's overall production;
- Slimes, which are very fine residues and represent more than a third of the run of the mill, having a content of 25 per cent P_2O_5; they are normally discharged into settling tanks.

The amount of these slime rejects has long justified the research done to develop their utilization.

The physical-chemical characteristics of the product were analysed by different methods and several methods of utilization have been envisaged: direct use as an enriching agent, concentration by agglomeration or by selective flaking, direct chemical action and, finally, cycloning of the coarsest fractions, a procedure which is practised nowadays by the ICS.

Utilization of phosphate slimes**

Crude slimes are extraction residues from the Taïba mines and consist of fine particles less than 40 microns in size. They take the form of a suspension with 60 g/l of solid matter, the P_2O_5 content of the slimes being of the order of

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* Mr. Babacar Diagne, Director for Mining, Senegalese Taïba Phosphate Company.

** By Mr. Doudou Fam, Engineer (ICS).

23-25 per cent. They are concentrated to 120 g/l in prethickeners before being discharged into irrigation tanks for ultimate recovery of the water. The untreated slimes account for 30 per cent of the tonnage extracted from the mine. In 1988, 2,900,000 t of slimes were produced.

The treatment process applied by the ICS for utilizing the slimes is to recover the particle fraction greater than 10 microns by hydrocycloning. This fraction is about 29 per cent of the total mass of crude slime.

Enriched slimes are mixed with marketable ore in a proportion of about 18 per cent weight. The addition of enriched slimes does not result in any measurable effect on the operation of the plant.

Eighty-six thousand one hundred and forty-seven tons of dry enriched slimes were produced in 1988, or 69,742 t of equivalent marketable phosphate.

The long-term objective is to raise this output to 300,000 t/y of equivalent phosphate, or almost 30 per cent of the consumption of the phosphoric acid plant.

An example of Senegalese tricalcium phosphate: its nature and applications*

The Lam-Lam phosphate deposit in lenticular form operated by the SSPT is located on the edge of the Thiès plateau quite near a huge alumino-calcium phosphate deposit.

Extraction: this is done by conventional open-cast mining. There is a cover of a thickness varying between 13 and 20 m, made of laterite, which is broken up using explosives and then transported: the phosphate vein, averaging 6 m thick, is extracted after the swelling and undergoes simple mechanical processing.

Application in the fertilizer industry: the product obtained has three destinations as follows:

- Industrial manufacture of single superphosphate;
- Direct use as fertilizer after grinding down to 160 microns;
- Manufacture of acid in combination with other phosphates.

Agronomic applications: like all natural tricalcium phosphates, this phophate is characterized by poor solubility, hence the use of it is limited to highly acidic soils, with $pH < 6$, in which it permits gradual and long-term activity of the phosphate fertilizer. On this account it is used first and foremost as basic fertilizer.

Conclusion: Data received on a definite type of P_2O_5-rich tricalcium phosphate, the Lam-Lam phosphate of Senegal, confirm experimentally the possible use of it both in the fertilizer industry for making phosphoric acid and superphosphates and for direct application as basic fertilizer for highly acidic soils.

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* Senegalese Thiès Phosphate Company.

SENEGAL

Direct application of phosphal as a fertilizer - comparison with single superphosphate

Phosphal comes from an ore mined by the SSPT* in Thiès in Senegal, where large reserves of raw material with a homogeneous composition and a high P_2O_5 content have been discovered and exploited: more than 50 million tons over a concession of 30,000 ha. This ore is a double phosphate (lime and alumina).

After mechanical treatment and calcination in a rotary kiln, the ore undergoes basic changes in its initial structure:

- Physical changes: dissociation of the crystalline structures and conversion into an amorphous phase;

- Chemical changes: increase in the P_2O_5 concentration by nearly six points by the removal of the chemically bound water. Removal of the iron from the phosphate combination in the form of free ferric oxide.

The phosphal concentration - 34 units/100 kg - helps to reduce the cost of handling and spreading.

Phosphal meets the "EEC Fertilizer" standards laid down by the European Economic Community regulations. In the case of the alumino-calcium phosphates, the regulations stipulate an evaluation of the phosphorus as soluble P_2O_5 in Joulie alkaline ammonium citrate.

In the case of phosphal, the solubility is at least 80 per cent (weight) of its total P_2O_5. The solubility in the citrate, which appears at the same time as the fertilizing value, is in correlation with it. However, this is not an exact indication of the real efficiency of the phospal; studies have shown that when acted on by soil solutions all the phosphal units may be taken up by the plants.

The fertilizing value of phosphal is based on its use for crops going back more than 40 years, confirmed by studies and tests made under exact conditions.

Immediate effects comparable to those of single superphosphates are obtained in very poor soils, but greater after-effects by phosphal show its residual activity.

Calculation of the quantities of P_2O_5 exported after chemical analysis of each harvest confirm that all of the phosphal units have a fertilizing value. Phosphal is suitable for rectifying soils which show P_2O_5 deficiencies as well as keeping up their food potential, following the enrichment. It can be used for all types of agricultural and normal soils, covering a broad pH range (water pH 5.5 to more than 8.3).

Phosphal is a fertilizer that has been known for 40 years to have appreciable properties in economic terms:

- It does not affect the soil reaction;

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* Senegalese Thiès Phosphate Company.

- It is not sensitive to a decline in non-available compounds, frequent in certain water-soluble forms. Use of it covers the following spheres of application: all types of soils, both for rectifying fertilizer and supporting fertilizer; it is usable in the original state or mixed with other fertilizers as well as mixed together with calcium or magnesium enrichment agents.

All the potentialities offered by phosphal justify its marked development in numerous countries both with a temperate climate as well as tropical conditions.

Utilization of Matam phosphates*

The deposit of lime phosphate known as Matam phosphate is located 50 km as the crow flies from the locality of that name. It is to be found at 5 km from the Saint-Louis-Matam-Bakel roadway, 180 km from Tambacounda and 125 km from the main railway line Dakar-Bamako, and 590 km from Dakar by the route via Linguère.

The phosphate occurs at two places:

- South panel: Ouali-Diala: 300 ha

- North panel: Ndendory: 500 ha,

with a clear-cut rapid lateral transition towards the north, south and east.

Characteristics	P_2O_5	SiO_2	Fe-Al	CaO	Ca/P_2O_5	Millions of tons
	In percentage					
Ouali-Diala	27.6	9.9	3.4	44.1	1.60	12
Ndendory	29.1	11.1	4.1	43.5	1.49	27.5

The phosphate is pulverulent (80 microns) with an average of 5-10 parts of cadmium.

The layer-thickness is 4.9.

Beneficiation tests have been carried out on the Taïba phosphate. There have been tests with a heavy sample conducted by the BRGM using the dry process, and agronomic tests at the stations conducted by ISRA, SODEFITEX and SODAGRI (popularization in the rural environment).

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* By Mr. Chérif El Waly Diop, Geological Engineer, DMG.

Conclusions

During the rural popularization campaign the tests related to maize, rice and cotton. The results were satisfactory.

The State plans open-cast workings in order to make direct use of the phosphates as part of the development of the river basin.

Phosphate resources in West Africa

As far as the extraction and treatment are concerned, the profitability of such workings in terms of economic geology usually requires a high annual production of the ore - at least 1.5 million tons. The deposit reserves must be adequate for such production and be reckoned in tens or hundreds of millions of tons.

Open-cast mining is usually preferred.

A major advantage of the uncovering operations within this context is to be able to work several mineralized layers at the same time by setting aside the intervening sterile levels and the fact that advanced mechanization can be used. High-capacity equipment is therefore used for the mining operations: bucket drag-lines, bucket excavators, dredging shovels and, for conveying inside the mine, large trucks holding 100-225 tons of useful load.

Depending on their mineralogy, the phosphatic ores mined in this way often create a maximum number of different hypothetical cases which are difficult to deal with and the factor of suitability for enrichment then becomes highly important. After the mine the ores undergo the initial physical processes before the last test operation.

The solubilization of the phosphates preceding manufacture of the fertilizers usually takes the form of the following two main routes:

- The sulphur route (the main one): the basic products are phosphates and sulphur;

- The nitric route based on energy and phosphate.

The sulphuric solubilization route depends, for its part, on the sulphur resources as well as their cost. Experts are very pessimistic on the subject of the long-term resources of this material and it is probable that sulphur prices will tend to go up on this account.

Nevertheless, the processes permitting recycling of the gypsum formed during this reaction (phosphogypsum stemming from the filtration of phosphoric acid) for regenerating SO_2, an intermediate compound in the manufacture of sulphuric acid. This recycling, however, requires a lot of energy. Problems of the cost of energy and sulphur resources are therefore basic problems for the future. They will determine the trends in the manufacture of the fertilizers.

Now being tried out on an experimental basis, the techniques for making fertilizers that are economical in terms of energy and raw material (sulphur) will therefore acquire ever-greater importance in the future.

The paper investigates mainly the four following areas:

- Phosphate prospecting in West Africa;

- Processing of phosphate ores;

- Phosphatic fertilizers;

- Use of phosphates in agriculture.

Prospecting for phosphates in West Africa, which began just after the Second World War, was carried out by the French Overseas Mining Office between 1948 and 1959, then by the Office for Geological and Mining Research from 1959 onwards in collaboration with the Mining and Geology Directorates and the mining development companies of the countries involved.

From this standpoint the knowledge acquired all over the world on the geology of sedimentary phosphates of marine origin, on the palaeo-geographic and sedimentological environments - especially the association of phosphates and chemical sediments, serial condensation, weakness of the terrigenic component, radioactive characteristics of the phosphates etc. - has naturally served both to guide the study of the concentrations and has made it possible to proceed more quickly. In practice this type of exploration usually involves three successive phases:

- An inventory of the periods favourable for phosphatic sedimentation in a given basin;

- Delimitation of zones favourable for the accumulation of phosphate deposits;

- A detailed study of these favourable zones.

Studies are then mainly conducted by sinking wells and drilling, occasionally accompanied by logging, and they are generally brought nearer and nearer towards known indications and by potential sectors.

Finally, what are the uses of phosphates in agriculture?

On an African scale, and even on a world scale, it is quite clear that it is the fertilizers produced by the sulphuric, phosphoric and nitric reaction route that are the most used and which are being tested and tried out in agriculture in the most diversified forms, depending on the climates, countries and crops. Since the subject is an extremely broad one, the author confines himself to the case of natural phosphates in the light of work done in Africa during the last few years by the international agricultural development institutions and the African research organizations. Although they are geared to natural phosphates, the procedures discussed here are still fairly similar to those practised for fertilizers.

The natural phosphates, usually the apatitic type, may have very different degrees of solubility and assimilability. Their behaviour depends first on their intrinsic characteristics and then on their reactions with the environment.

In conclusion, the present stage, much more than the previous one, should be geared towards satisfying African agricultural requirements and self-sufficiency in food, which is still very unequal. The present stage is one of transition from the traditional use of a high-grade fertilizer (with a few exceptions such as single superphosphate; certain cases of direct application) to the use of products better adapted to the diversity of regional and local and economic situations. This adaptation will more than ever before have to be the subject of dialogue between all the persons concerned in the phosphate branch and it is indeed in that sense that this paper has been derived.