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ROUND-TABLE DISCUSSIONS ON THE DEVELOPMENT
OF PHOSPHATES AND PHOSPHATE FERTILIZER
INDUSTRY IN DEVELOPING COUNTRIES
GAFSA, TUNISIA, 17-23 NOVEMBER 1985

REPORT OF THE MEETING*

(Development of phosphates).

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INTRODUCTION

1. The Fourth Consultation Meeting on the Fertilizer Industry convened by UNIDO at New Delhi on 23-27 January 1984, strongly recommended that co-operation among developing countries in the field of fertilizer industries should be strengthened through exchange of experience and information, and technical assistance, in order to help the developing countries to select and acquire appropriate technologies, as well as to improve the operation of their existing fertilizer plants.

2. Fertilizers play a fundamental role in the production of food needed for the survival of mankind. In addition to nitrogen and potash fertilizers, phosphates assume a great importance in this role because of their basic and complementary function as plant nutrients.

3. Many developing countries have natural phosphate resources but do not have appropriate technologies suiting the composition and/or quality of their which would suit the quality of indigenous raw materials and fulfil specific requirements of their agriculture.

4. On the other hand, many industrialized countries have developed optimum fertilizer production technologies, but are dependent on the developing countries' supply of high-grade phosphate rock.

5. With the depletion of high-grade phosphate resources world-wide, in both the developing and developed countries, demand is growing for the development of new beneficiation and conversion processes, in order to enhance the utilization of easier available medium and low-grade phosphate rock, and to assure that the up-graded raw materials would meet the requirements of existing phosphate fertilizer plants.

6. In addition, the developing countries' governments realize that for economic reasons phosphate fertilizer plants should be established near the source of raw materials. In doing so the countries would be in a position not only to meet their own fertilizer demand but also produce value added products for exporting and thus improve their national economies.

7. Efforts have been made in some of these countries to produce non-conventional/non-traditional phosphate fertilizer products based on low-grade phosphate minerals, which contain impurities beyond permissible limits prescribed by the traditional processing methods applied in the existing fertilizer plants.

8. In general, the developing countries' future prospects in this field are favourable. There is constant need for establishing new fertilizer plants to satisfy the growing local demand for fertilizer which for mainly economic reasons cannot be fulfilled through importing.

9. Thus, with a view to promoting the exchange of information on the subject, and with the intention of disseminating relevant knowledge which has accumulated in many countries, as well as for co-ordination of approaches, and identification of areas of further research, UNIDO in co-operation with the Tunisian Government, through the Compagnie des Phosphates de Gafsa decided to organize Round-Table Discussions on this extensive subject of interest to the developing and developed countries.

10. Tunisia ranks sixths among the major phosphate producing countries in the world. Her phosphate industry also faces the problem of decreasing quality (P_2O_5 content) of phosphate mineral resources. Considerable efforts have been made to improve the efficiency of mining and beneficiation, and to utilize medium-grade phosphates and off-grade materials to produce concentrates of P_2O_5 contents below conventional standards, by applying appropriate, specifically for this purpose developed technologies for the production of standard phosphate fertilizers.

11. In supporting the programme of the Round-Table Discussions the Tunisian phosphate mining and processing companies have offered to make their technological experience available to the participants through organizing plant visits and facilitating the exchange of views between their plant engineers and the foreign specialists attending the meeting.

12. In summary, for the purpose of arring at a consensus on important tasks and for defining constructive recommendations, the following objectives of the meeting have been proposed and pursued:

i) To exchange information and experience in planning, engineering design and operation of phosphate mines and fertilizer plants.

ii) To identify problem areas and to discuss possible solutions concerning proper exploitation of phosphate resources and the phosphate fertilizer industry.

iii) To promote contacts between specialists of the phosphate industry with a view to furthering co-operation among countries and companies through long term arrangements, such as joint ventures, technical assistance and raw materials supply agreements, and joint marketing accords.

GENERAL CONCLUSIONS AND RECOMMENDATIONS

13. Extensive conclusions have been drawn from the contents of papers presented to the meeting, and from the ensuing discussions. They reflect the views of participants, and highlight the problems faced by the developing countries' phosphate industries.

14. 49 detailed findings and 31 related recommendations have been formulated and grouped by subjects under common headings, in congruence with the programme of the meeting, in order to facilitate their correlation with the proceedings. Because of their comprehensiveness they are presented separately in Chapters II and III of this report.

15. In general, the consensus of the Round-Table Discussions was that close co-operation among the developing countries has become a determinant factor in their efforts to develop their phosphate industries on the basis of new technologies for appropriate utilization of indigenous low-grade phosphate resources.

16. Future development trends of phosphate fertilizer production and use call for new concepts and attitudes, backed by extensive industrial and agronomic research, in order to overcome the technological and commercial barriers presently posed by the traditional standardization of world-wide traded phosphate raw materials, intermediates and fertilizer products.

17. UNIDO, in co-operation with governments of the developing countries and appropriate international organizations should continue its catalytical role in strengthening the co-operation of all parties concerned, through initiating joint programmes and technical assistance projects. These programmes are expected to enhance the developing countries' awareness of each other's potential in fields of mutual interest, and to establish a firm basis for increasing their self-reliance in phosphate fertilizer supplies and technological progress.

18. In practical terms, as a matter of immediate attention UNIDO should assist the developing countries in ascertaining the feasibility of and developing methods for the exploitation of small deposits (isolated pockets) of medium and high-grade phosphate minerals, with the aim of utilizing them for the production of SSP or otherwise by applying simple processing methods, if local conditions would warrant favourable economic results of investment and appropriate agronomic efficiency of the various new products.

I. ORGANIZATION OF THE MEETING

19. The Round-Table Discussions and plant visits took place from 17 to 23 November 1985 at the GAFSA office of the Compagnie des Phosphates de Gafsa, the underground mines at SEHIB, the open-cast mines at KEF SCHEFAEIR, the adjacent rock washing/beneficiation plants of CPG, the

Research Centre of CPG at METLAOUI, and the fertilizer plants at GABES: Industries Chimiques Maghrèbines (ICM), Société d'Industrie d'Acide Phosphorique et Engrais (SIAPE) and Société Arabe des Engrais Phosphates et Azotes (SAEPA).

20. The meeting was attended by 117 participants from industries and government bodies of 21 developing countries, international organizations, professional institutions, fertilizer industry associations, universities and companies of the industrialized countries' fertilizer industry.

Opening of the Meeting

21. The Round-Table Discussions on the Development of Phosphates and Phosphate Fertilizer Industries were inaugurated by Mr. Mohamed El-Fadhel KHALIL, President Director General of the Compagnie des Phosphates de Gafsa.

22. In his opening statement he emphasized that the fertilizer industry, in general, and the phosphate industry, in particular, is of vital importance to the developing world which faces food shortages and famine, and strives for hither efficiency of agriculture. In reverting to the favourable example of Tunisia, the host country of the meeting, he drew the attention of the forum to the development policies of the Tunisian Government which strongly supports the growth of the phosphate mining and fertilizer sector of the national economy. He elaborated extensively on past achievements and future tasks and exhibited the extensive experience accrued by the Tunisian fertilizer companies and their success in transferring indigenous phosphate processing technologies to other developing countries. Furthermore, he emphasized the existing potential of Tunisia for becoming a substantial contributor to the technical development in this field, while ranking high among the major phosphate producers and exporters in the world.

23. In referring to the co-operation between CPG and UNIDO for organizing the meeting, he expressed his appreciation of the arrangements made jointly which strengthened its international character.

24. The welcome address on behalf of UNIDO was presented by Mr. Tariq AL KHUDAYRI, Chief of the Arab Unit, Policy Co ordination Division, in his capacity as special representative of the Director General of UNIDO, Mr. Domingo SIAZON.

25. He welcomed the participants and stressed UNIDO's appreciation for the generosity and efforts of the Government of the Republic of Tunisia and CPG in joining UNIDO to prepare for and convene the Round-Table Discussions. He gave a brief account of UNIDO's mandate and objectives as a specialized UN agency, with specific reference to its functions and activities. While referring to UNIDO's efforts in promoting industrial development of developing countries, he displayed the principles of UNIDO's programmes on technical assistance and promotion of co-operation among the developing countries themselves as well as between the developing and developed countries, with particular reference to projects supporting the progress of fertilizer industries.

Election of the Bureau

26. Mr. Mohsen ZERELLI, Director, Mines and Geology, Ministry of the National Economy of Tunisia, was elected as chairman of the meeting.

27. Further elected were to serve as Vice-Chairmen:

i) Mr. J.A.S. MATTOS, Planning Manager
PETROFERTIL, Brazil;

ii) Mr. Tariq Al KHUDAYRI, Chief of the Arab Unit,
Policy Co-ordination Division of UNIDO;

Mr. B.K. JAIN, Technical Director of the
Fertilizer Association of India
acted as Chief Rapporteur.

Programme of the Meeting

28. The programme of the Round-Table Discussions announced by the chairman comprised seven working sessions: The introductory session for presentation of country papers, five technical sessions dealing with technical and economic issues proposed for the deliberations of the meeting, in accordance with the agenda delineated in the Aide Mèmoire, and the closing session for presentation of conclusions of the discussions and formulation of recommendations. In detail, the five technical sessions covered the following subjects:

i) Phosphate rock mining and its current and future technical problems;

ii) Problems related to phosphate beneficiation and up-grading of low-grade phosphates as well as their use for the production of phosphoric acid and phosphate fertilizer;

iii) Research on improving the production of phosphoric acid, - new types of phosphate fertilizers to be produced on a small scale, and the production of liquid fertilizers;

iv) Economics, pricing policies and marketing of phosphate fertilizers, and review of the world supply/demand situation, and future development trends;

v) Management of maintenance services and utilities supplies, and environmental problems of phosphate fertilizer plants.

29. Each session was followed by discussions from which the findings and recommendations presented in Chapter II and III of this report have been collected or deduced and compiled by the drafting team of the report.

Introductory Session

30. At the outset of the working sessions of the meeting an introductory address was presented on behalf of Mr. Anatoly VASSILIEV, Director of the Division of Industrial Operations of UNIDO.

31. The Director's message highlighted UNIDO's views on the economic constraints which world-wide impede the development of the fertilizer industry, slow down the growth-rate of consumption of phosphate fertilizer, and deteriorate the developing countries' national economies. He indicated that at present the fertilizer industries face many adverse factors instead of fully utilizing their technological potential to satisfy the world-wide increasing real need for fertilizer.

32. In dwelling on UNIDO's role and activities for promoting fertilizer industries in developing countries the presentation summarized UNIDO's experience in this field, drawn in particular from the implementation of technical assistance projects requested by governments. In this connection, as a guide to the deliberations of the meeting, the introductory message indicated major problem areas which call for involvement of international organizations and assistance supported by international, regional and bilateral aid programmes.

33. Participants from developing countries who wished to elaborate on the status and future outlook of development of phosphate mining as well as fertilizer production and use in their countries presented summaries of their experience and views. Concise abstracts of country papers submitted to the meeting are given in ANNEX A of the report.

34. Presentations were made by the invitees from Bangladesh, Benin, Brazil, Chile, China, India, Niger, Pakistan, Poland, Senegal (oral only), Tanzania, Turkey and Viet Nam.

Technical Sessions

35. The First Technical Session was inaugurated by H.E. Abdel Azis BEN DHIA, Minister of Higher Education and Scientific Research of the Government of Tunisia. In his speech, the Honourable Minister stressed the importance of fertilizer in agriculture and the need for assuring low costs of fertilization to reduce the constant threat of famine in the world. He drew the attention of the participants to the historical development of the phosphate industry of Tunisia, dating back almost one hundred years, which consequently has reached a high level of technological development and is now ranking sixth among the largest phosphate producing countries of the world. While indicating that rock processing technologies developed in Tunisia are now being applied in many developing countries, the Minister confirmed the Government's commitment in supporting the research and development work of the industry and continuation of co-operation with other developing countries.

36. Comprehensive abstracts of the technical papers delivered to the meeting have been prepared by UNIDO and included in ANNEX B of the report.

Closing of the Meeting

37. The plenary sessions of the Round-Table Discussions were completed on 20 November 1985. The conclusions and recommendations prepared by the drafting team in provisional form were announced at the closing session, without having been discussed or formally endorsed, however, with the understanding of the forum that the edited final version will appear in the report and proceedings of the meeting.

38. The closing session was given a high standing by the host authorities of the meeting who invited high ranking persons to preside over the closing ceremony.

39. The session was chaired by the Minister of the National Economy, Government of the Republic of Tunisia; the Vice-President of the General Assembly; the Governor of GAFSA; the Secretary General of the Co-ordination Committee of the "Parti Socialiste Destourien" in GAFSA; the President Director General of the Tunisia Emirate Development Bank; the Ambassador of the Socialist People's Republic of Romania; the President Director General of CPG; the Director of Mines and Geology, Ministry of the National Economy of Tunisia (Chairman of the Meeting); and the Representative of UNIDO.

40. Closing statements were presented by the Chairman of the Meeting, the President Director General of CPG, the Representative of UNIDO, and H.E. Rachid SFAR, Minister of the National Economy, Government of the Republic of Tunisia.

41. The Chairman, Mr. Mohsen ZERELLI expressed on behalf of the participants as well as the co-operating and host organizations, their appreciation of the great importance given to the Meeting by the Minister of the National Economy who demonstrated the Government's particular interest in the development of the phosphate and fertilizer sector of the Tunisian economy. He underlined its fundamental linkage with industrialization and promotion of agricultural development towards enhancing the food security of the country.

42. In summarizing the deliberations of the Meeting he indicated that among the large number of issues discussed during the very compressed two days' programme of technical sessions, the participants gave priority to the presently pressing crucial problems relating to:

- Beneficiation of low-grade phosphates to make them suitable for the widest possible and most straightforward utilization;

- Improvement of phosphate up-grading and conversion methods; and

- Improvement of energy consumption and maintenance of plants.

Solutions to these problems are expected to serve the common aim of reducing the production cost of fertilizers and thus make them easier accessible to all those in need all over the world.

43. The President Director General of CPG Mr. Mohamed El-Fadhel KHALIL introduced the conclusions arrived at by the Round-Table Meeting, and the recommendations proposed for consideration and follow-up by the parties concerned. In his closing address he emphasized the ultimate goal of rock phosphate and phosphate fertilizer production which, as a source of indispensable agricultural input materials, substantially helps the developing countries in reducing their food supply problems. He reiterated his conviction that persisting food shortages, malnutrition of the growing population, and recurrent famine encountered in many places of the developing world are the most basic and crucial problems which cause economic backwardness.

44. The representative of UNIDO, Mr. Tariq Al KHUDAYRI, presented an overall résumé f the concept, contents and outcome of the Meeting. He appreciated the participants' keen interest in continued learning about the potential of knowledge existing in the developing countries' phosphate industries, and made particular reference to the high level of competence of the Tunisian engineers who have extensively contributed to the discussions by displaying their experience.

45. With respect to the draft report prepared for the closing session, and the presentation of conclusions and recommendations which covered a large number of subjects despite the short time available for their extraction from the discussions and formulation owing to the extremely compressed time schedule of the meeting, he intimated that the report needs to be expanded and edited in accordance with UNIDO's standard practice. It shall thus become fully representative of the emerging new trends and common problem areas, and form a valuable background information for all the organizations and companies concerned when initiating pertinent follow-up work and co-operation on the major issues raised and substantiated by the meeting.

46. In concluding, he thanked for the excellent hospitality accorded by the Tunisian Government, CPG, the phosphate industry in general, and all the contributing organizations and companies, in particular. While assuring the forum of the improved new role of UNIDO as a self-reliant Specialized Agency of the United Nations system, he reiterated UNIDO's preparedness and readiness to provide technical assistance and organize or participate in co-operative programmes in all the areas of interest, if and when requested by governments of the developing countries.

47. The closing speech was held by H.E. Rachid SFAR, Minister of the National Economy, Government of the Republic of Tunisia. He conveyed to all the participants of the Round-Table Discussions his best wishes of welcome to Tunisia, and thanked UNIDO for the choice of the subject and designation of Tunisia as venue of the meeting.

48. He stressed the important role which phosphates and phosphate fertilizers can play in the national economies of developing countries, in general, and in Tunisia in particular. He pointed at the wide range of possibilities offered by this sector for the development of technical and commercial co-operation among the developing countries, which in his opinion could surely successfully be pursued between countries possessing large resources of raw materials an having their own manufacturing technologies, while on the other hand, their demand for fertilizer is constantly growing at an accelerated rate because their consumption of fertilizer is presently still very low and their growth rate of population remains high.

49. The co-operation should cover such areas as studies and research on the utilization or low-grade phosphates; strengthening of vertical integration in the phosphate producing countries; co-ordination of industrialization programmes; maintenance of and training in fertilizer plants.

50. The extensive experience in exploiting phosphate resources of medium-grade quality, gained in Tunisia over a long time, has resulted in mastering the phosphate extraction, beneficiation and conversion techniques, and in developing appropriate technologies, which are now openly available to all the developing countries and thus modestly contribute to their food security goals.

51. The Minister underlined the comprehensiveness of recommendations made by the Round-Table Meeting, the necessity of following-up on them in a consistent way, and the important role to be played by UNIDO in connection with the follow-up action. He reiterated his congratulations on the success of the Meeting addressed to UNIDO and the Compagnie des Phosphates de Gafsa, and wished all its participants a pleasant completion of their stay in Tunisia.

52. The Chairman of the Meeting Mr. Mohsen ZERELLI closed the session. In his Votes of Thanks he conveyed the feelings of gratitude to H.E. Rachid SFAR, for the valuable recommendations given in his speech relating to the present and future work, and the development targets of the Tunisian phosphate industry.

53. Furthermore, he thanked the Vice-Chairmen Messrs. AL KHUDAYRI and MATTOS, the Rapporteur Mr. JAIN and the UNIDO staff, as well as all the persons involved on part of CPG and the contributing organizations, institutions and companies, for the efficient and smooth co-operation which led to the successful completion of the Round-Table Discussions.

II. RESUME OF FINDINGS

54. The following list of conclusions represent a rèsumè of views expressed and comments made by the participants of the Round-Table Discussions during their deliberations on the main topics, and reflect the highlights of papers presented to the meeting.

Mining of Phosphates (Current and Future Problems)

55. The cost of underground mining operations and the depth of mines is increasing. A study carried out in TUNISIA shows the economic benefits derived from changing the traditional methods to mechanical mining by using the following techniques: Longwall Face Cutting (LFC: employing armoured chain conveyors, cutter loaders and powered roof supports), or Sub-Level Stoping (SLS: using scrapers and Load-Haul-Dump machines).

56. The exploitation of phosphate ore by open-pit mining can be increased at larger depth with a higher ratio of overburden to ore. This can be achieved by mechanizing the work and equipping the open-pit mines with suitable machines, such as drag lines, whereever feasible. This will make possible to increase the depth of exploitation at bearable costs and lead to higher recovery of phosphate ores from the deposits.

Beneficiation and Upgrading of Low-grade Phosphates

57. Beneficiation of low grade phosphate ore of metaphoric origin, containing 16-17% P_2O_5 and 12-15% MgO, with impurities calcite, dolomite and silica, from the Jhamarkotra Phosphate Deposit in the State Rajastan/INDIA, has successfully been carried out. The rock has been upgraded to 32% P_2O_5 with a MgO content of less than 1.5%. A pilot plant set up at the mine has confirmed the beneficiation process which has indigenously been developed in INDIA. The reserves in this deposit are 60 million tons of low-grade ore. The concentrates are suitable for the production of SSP and phosphoric acid.

58. A low-grade complex ore from Mussoorie in the State Uttar Pradesh/INDIA, of sedimentary origin, containing 15-18% P_2O_5 and pyrites, organic matter and silica as impurities, could not successfully be beneficiated to the intended level of 28-30% P_2O_5, although several trials have been conducted in INDIA and abroad. The tests, however, showed that this material can be pre-concentrated to 22-24% P_2O_5 by the heavy media method using the Dyna Whirl Pool equipment. P_2O_5 recovery of 88% has been attained. The reserves of the Mussoorie deposit amount to 45 million tons.

59. BRAZIL disposes of huge reserves of low grade phosphate ore in the range of 3.8 billion tons, containing only approximately 10% P_2O_5. The ore has been beneficiated by using indigenously developed processing methods which can successfully be applied to ores of a P_2O_5 content down to 5.5%. The ore is igneous by origin, whereas the main impurity is silica. The concentrates obtained are suitable for making SSP and phosphoric acid.

60. CHILE has low-grade phosphate ore of 6% P_2O_5. It contains silica and carbonates as main impurities, which are present both as exo-gangue and endo-gangue. This ore could be beneficiated only up to 24% P_2O_5 as it is highly substituted with carbonates. The concentrates are not suitable for producing SSP or TSP. They are, however, suitable for direct application to the soil. On acidic soils their agronomic efficiency is the same as TSP (or even better).

61. VIET NAM is endowed with large deposits of phosphate rock. A new technology has been developed indigenously for converting it into SSP.

62. The phosphate ore reserves of ARGENTINA are only those connected with iron ore mining and beneficiation. Tailings of magnatite contain 7.1% P_2O_5 and 27.5% Fe. They have successfully been beneficiated, yielding concentrates of 34% P_2O_5, with a recovery ratio of 55%.

63. In CHINA studies are being conducted for developing suitable methods of beneficiation of indigenous phosphate ores.

64. TANZANIA is using indigenous low grade phosphates. Through beneficiation they are made suitable for the production of TSP in the existing fertilizer plant which had been designed to use high-grade imported raw materials.

65. There are vast reserves of low-grade phosphate ore in TURKEY. Sedimentary deposits contain 320 million tons (11-12% P_2O_5). There are also large reserves of magmatic ores (100 million tons) but of very low grade (4-6% P_2O_5). The quality of concentrates attained so far is not high enough for producing TSP. Therefore, the Turkish phosphate fertilizer industry still uses imported rock for its phosphoric acid plants.

66. TUNISIA has succeeded in developing beneficiation methods for the utilization of low-grade materials containing 16-22% P_2O_5. The concentrates obtained contain 28% P_2O_5 at a recovery yield of 90%. The ores treated are taken from various sources and hence contain different impurities as exo-gangue in form of (a) carbonates, (b) silicio-carbonates, (c) silicious minerals. The quantities of amines and phosphoric esters used in the beneficiation process depend on the nature of impurities. As examples, quantities in the order of 200 g/ton of amines and 100-200 g of phosphoric esters per ton of the rock treated are being applied in the flotation circuit.

67. In TUNISIA it has also been found feasible to recover phosphates from fines rejected by the phosphate ore washing plants. The fines treated are above 40 microns granulometric size, which constitute 8.8% by weight of the run-of-mine material fed to the washing operation. They contain 22-24% P_2O_5 and can be upgraded to 27-29% P_2O_5 at 90% yield of recovery. Concentrates thus obtained have been tested and found suitable for the production of phosphoric acid in the existing fertilizer plants.

68. Low-grade phosphate ores containing agglomerates of dolomite as exo-gangue which is closely attached to the phosphate mineral have also successfully been beneficiated in TUNISIA. A two-step flotation method

has been applied: the first step under normal pH to remove the carbonates, the second step under acidic conditions which increase the reactivity of the flotation collectors and thus effectively separate the agglomerated gangue material.

Use of Low-grade Ore as Phosphate Fertilizer

69. Some low grade phosphate ores originating from Northern and Western African countries and Madagascar have been evaluated for establishing their phosphate solubility and availability co-efficients, and then applied to the soil as phosphate fertilizers. Agronomic studies extending over several years have shown that the behaviour of the phosphate rock depends on a number of factors such as: (a) characteristics of the phosphate rock, e.g., substitution of carbonate in the crystal lattice; crystallography; solubility in various chemical substances; (b) reactions with soil components, in particular its acidity; (c) utilization conditions; water regime; phosphate particle size; mode of application.

70. Further studies have shown that the application of phosphate rock together with fertilizer of 10-20% water solubility improves the availability of the phosphate nutrient component to the crops.

71. Investigations have been conducted on partially acidulated rock which showed that partial acidulation improves the physical and handling properties of the product. Agronomic test further confirmed the improvement of phosphate nutrient (P_2O_5) availability to plants, which reached almost that of 100% water-soluble phosphate fertilizer, even if acidulation was carried out to the extent of 29% only.

72. Extensive experiments and agronomic field trials have been carried out on direct application of Mussoorie phosphate rock as phosphate fertilizer to acid soils. It has been demonstrated that this type of rock when ground to 100 mesh powder is agronomically as effective as 100% water-soluble phosphate fertilizer, for all crops and plants. It has further been shown that a mixture containing Mussoorie phosphate rock and water-soluble fertilizer of 1:1 ratio (nutrient basis) applied to neutral or alkaline soils agronomically equals the effect of all the 100% water-soluble phosphate fertilizers.

73. In order to overcome the disadvantages of handling and use, and to reduce losses of ground rock, the effect of mini-granulation of Mussoorie rock powder with water-soluble binders has been studied. The agronomic efficiency of mini-granules has been tested in the same way as testing of ground rock by the International Fertilizer Development Centre (IFDC), under a UNDP/UNIDO sponsored project.

74. Studies have been conducted on the application of Mussoorie phosphate rock to neutral and alkaline soils in the area near the deposits, in order to enhance the value of the low-grade ore. For this purpose a Partially Acidulated Phosphate Rock (PAPR) has been prepared by using sulphuric and/or phosphoric acid. The products had acceptable physical and chemical properties. Agronomic tests and field trials revealed that a 50% acidulated rock (PAPR) is equal in effect to TSP, whereas a 25% acidulated PAPR proved only 2% less effective than TSP. These studies have also been conducted by the International Fertilizer Development Centre (IFDC) in USA under the UNDP/UNIDO project.

75. Agronomic studies have shown that dissolution of the phosphate rock, through which the nutrient component (P_2O_5) becomes available to plants, improves when the soil is acidic, low in phosphorus, and contains organic matter

76. Further research also showed that acidic soils rich in Fe and Al are very inefficient in utilizing water-soluble phosphate fertilizers, as in presence of water the phosphatic components react with Fe and Al-ions and are converted into Fe and Al phosphates which are unavailable to plants as nutrients. Under these conditions water-soluble phosphate fertilizers should not be applied.

77. Applied research has been conducted on using the low-grade Mussoorie phosphates for producing liquid NP fertilizers. For this purpose renewable sources of energy have been applied, namely mini-hydro-electric generators, or windmill-driven electric power generators, or photo-voltaic cells as source of electricity to provide electric energy to an Electric-Arc Generator of nitric oxides, developed by the Battelle Kettering Research Institute, USA. The pilot unit required an input of 5 kW electric power and phosphate rock chips (11 mm size). It can produce a quantity of liquid NP fertilizer per year satisfying the needs of a farm area of 2 hectars.

78. In NIGER the utilization of low grade phosphate rock from two deposits has been studied. (TALHUA rock of 22-26% P_2O_5, and PARC DU W rock, 20-30% P_2O_5 in Aluminum Phosphate). The minerals have been applied directly to the soil. The Government has encouraged their use by subsidizing the price. However, owing to low agronomic response the fertilizer has not become popular. Research of IFDC provided an indication that partial acidulation would improve the agronomic response of the rock.

Production of Phosphate Fertilizers

79. The nature of impurities of the phosphate rock plays a very critical role in the hemi-hydrate process of manufacturing phosphoric acid. Impurities such as carbonates, silica, fluorides, organic matter and metallic compounds should not exceed certain limits, because processing conditions of the hemi-hydrate technology lead to high viscosities and densities. This is not the case when applying the di-hydrate process for the production of phosphoric acid. However, the grade of P_2O_5 content in the phosphate rock does not pose a limitation on the application of the hemi-hydrate processing method.

80. Proper testing of phosphate rock and evaluation of the quality of the "green" phosphoric acid produced is necessary in order to decide on the suitability of the hemi-hydrate method for processing. Phosphate rock of high content of impurities should normally be processed only in plants using the di-hydrate method for production of phosphoric acid.

81. In FRANCE a new type of phosphate fertilizer has been developed (by tradename called HEMIFERT). Low grade phosphate rock mixed with organic matter is digested by reaction with nitric acid. The acid is obtained on a small scale by oxidation of ammonia in a traditional way. Tree leaves,

cane trashes, straw, peat, etc., can be used as organic matter. The nutrient content of the fertilizer product in terms of N:P:K is 5:7:0 when using phosphate rock of 25% P_2O_5. The production cost appears to be attractive, but the fertilizer should be consumed in the area near the plant, as it is a low-analysis product entailing an unfavourable transportation to production cost ratio per ton of nutrient components.

82. In ARGENTINA considerations focus on the development of a new type of nitro-phosphate fertilizer of low water-solubility but high solubility in weak acids for use on acidic soils. For its manufacture phosphate concentrates rich in Fe, available from beneficiation of iron ore tailings, shall be utilized. The concentrates have been found not suitable for the production of SSP, TSP, MAP or DAP.

83. Research continues on ways of increasing the availability and/or solubility co-efficients of un-reactive phosphate rock by using as reagents gaseous SO3 or microbiological means.

84. CHINA is producing fused magnesium phosphate. Many scattered small plants make up for the total production capacity of 70 000 tpy. Locally available phosphate rock, serpentine and coal is fused in small shaft furnaces built by own means of the farming communes. This product represents approximately 30% of the country's total consumption of phosphate fertilizer.

85. A new compound fertilizer product is being developed in CHINA. It shall contain 10-12% N and 40-42% P_2O_5. A new phosphoric acid production method is being tested. It will be suitable for processing phosphate ores of MgO and R_2O_3 contents up to 10%. The innovative neutralization/concentration process has been tested in a pilot plant, and a number of small plants based on this technology are under construction.

86. Studies on processing of low-grade phosphate rock of the LAGARBAR deposit for the production of phosphoric acid have been carried out in PAKISTAN. It is proposed to set up a pilot plant based on Tunisian phosphoric acid technology for low-grade ore processing.

87. A new method has been developed in TUNISIA for production of liquid phosphate fertilizers using ammonia solution and super-phosphoric acid as feedstock. The two liquids are mixed in a tubular reactor yielding poly-phosphates which form stable liquids. The nutrient analysis of the product is 10.8:37.0.

88. SIAPE of TUNISIA has developed a process for producing super-phosphoric acid containing 70-74% P_2O_5. The "green" acid is processed in two steps, first from 28 to 54% P_2O_5 then in the second step from 54 to 70-74% P_2O_5. In this way the concentration of impurities is reduced, and the final product, the super-phosphoric acid (SPA), is less corrosive. SPA of good quality must be low in metallic impurities, in particular magnesium. The conventional method of removal/recovery of metallic impurities applies controlled cooling of the SPA at the outlet of the evaporator. Under controlled temperature conditions the metallic impurities crystallize and precipitate, and can be removed by filtration. High losses of P_2O_5 in the filter-cake render this method

uneconomical. A new method of removing the metallic impurities has been developed which offers favourable economic results. It uses the ion-exchange operation. Diluted phosphoric acid is passed through a column filled with ion-exchange resins which retain the impurities and can periodically be re-generated.

Economics and Marketing of Phosphate Products

89. In order to maximize the economic advantage of a country's fertilizer raw materials endowment the most favourable type of fertilizer to be produced must be chosen. E.g.: A study has shown that if both P and K nutrient materials are indigenously available, but importing of sulphur needs to be avoided, the best among the various technically viable options is to produce nitro-phosphate NPK compound fertilizer (using locally available K2SO4), whereas the second option would be urea based NPK (also using K2SO4). The study has further shown that the recommendable type of fertilizer to be produced very much depends on the indigenous availability of raw materials.

90. An economic study has been conducted by STAMICARBON on the production of nitro-phosphate fertilizer vis-à-vis phosphoric acid based products. The general conclusion shows that the economics of the Nitro-phosphate process are independent of sulphur and phosphoric acid prices, and secondly, Nitro-phosphate fertilizers are cheaper to produce than P.A. based products. The new process yielding a NPK formulation of 28:14:0 is reportedly more favourable than that of 22.5:22.5:0 ratio.

91. The economics of exploitation of phosphate rock by underground mining vs. open-cast mining have been studied in TUNISIA. The study concluded that if the underground mined, obviously more expensive, raw material could directly be used for conversion into phosphoric acid, its cost would become attractive. Treatment of mixed ores, from underground and open-cast mining, cause unjustifiable losses of phosphates in the washing plants.

92. Laboratory and pilot plant tests have been carried out on the run-of-mine phosphate ores of the M'DILLA and MFTLAOUI underground deposits in TUNISIA, for producing phosphoric acid by the SIAPE technology which is suitable for low-grade ores. It has been found possible to obtain acceptable conversion parameters such as: reaction temperature and time; losses of P_2O_5 in phospho-gypsum; consumption of sulphuric acid, etc.. Further research is, however, necessary for solving foaming problems, scaling of equipment, and controlling the level of impurities content in the phosphoric acid.

93. Fertilizer prices in BRAZIL are controlled by the Government. Through this measure the consumption of fertilizer and agricultural production has improved in the country to the benefit of the national economy. It has also resulted in maximizing the use of indigenous phosphate rock and attainment of self-sufficiency in this field.

94. In TURKEY phosphate fertilizers are sold to farmers at subsidized prices. The difference between the ex-factory prices and the retail prices is reimbursed to the producer as subsidy. The ex-factory prices

are determined on the basis of the import substitution effect by providing the producer with a bonus in relation to the savings of foreign exchange attained through indigenous production.

95. In INDIA phosphate fertilizers are sold at prices fixed by the Government, which are identical throughout the country. The ex-factory prices of phosphate fertilizers produced is determined on the basis of a normative costing method established by the Government. The cost of transportation from the factory to the field is reimbursed through an allocation made by the Government for distribution costs. The difference between the established sales price and the actual production cost (ex-factory plus equated freight cost) is reimbursed to the producer as subsidy. This measure has stimulated the growth of phosphate fertilizer consumption by the Indian farmers.

96. In PAKISTAN the sales prices of fertilizers are fixed by the Government which thus has encouraged the use of phosphatic products.

97. The review of world phosphate fertilizer production and consumption over the past years shows a favourable constant growth. In 1984 the production reached 34 million tons (in terms of P_2O_5), while consumption lagged behind at a level of 31.8 million tons. USA and TUNISIA are the largest exporters of phosphate fertilizers. The major importing countries are CHINA, FRANCE, IRELAND, F.R. GERMANY. Price trends reveal a decline of both TSP and DAP prices, down to US$ 110 and 158 per metric ton of material, respectively. Projections for the next 5 years indicate that production may reach 42.6 million tons P_2O_5, while consumption will follow at a lower growth rate, attaining an estimated level of 40.2 million tons only, thus leaving a surplus of at least 2.4 million tons P_2O_5 per year in the crop year 1989/90.

98. The International Fertilizer Industry Association (IFA) made a survey of the supply/demand situation for the coming 3 years up to 1987/88, taking into account data produced by the UNIDO/FAO/World Bank Working Group on Fertilizer, and information furnished by IFA member countries. The survey reveals a potential surplus of about 2.44 million tons P_2O_5 in form of phosphoric acid production capacity. Further, North America, and Northern and Western African countries will be suppliers of surplus P.A.. Major importers will be Asian countries, Europe and Latin America. IFA has nevertheless observed that the oversupply situation should not be alarming as it amounts to only 10% of the demand projections, which may be narrowed down by many factors. In particular, there are optimistic prospects of improvement of the developing countries' economies which is bound to stimulate the growth of phosphate fertilizer consumption in view of their large potential needs. At present the consumption of phosphates in the developing countries is far below levels reached in the industrialized world.

Energy, Maintenance and Environmental Problems

99. Proper maintenance of chemical fertilizer plants plays a vital role in controlling their technical performance and economic efficiency. Various systems of maintenance management have been evaluated (e.g., breakdown maintenance, causing sudden unexpected shut down and high

maintenance cost, as well as high consequential losses; shut down caused by deterioration of equipment owing to lack of systematic maintenance procedures; preventive and predictive maintenance systems). The need for applying proper maintenance management methods has been highlighted. Measures to be taken should focus attention on the organization of inspection services, control of mechanical operating parameters of equipment, adequate inventory of spare parts, use of computers for spare parts inventory control, and consistency in following established maintenance procedures and techniques under control of the maintenance management system. It has been assessed that the cost of spare parts needed for maintenance amounts to approximately 5% of the total up-dated capital cost of a phosphate fertilizer plant.

100. The specific consumption of utilities should constantly be reviewed and compared with the engineering design data of the plants, and those attained under normal operating conditions. Through consistent monitoring it will be possible to identify areas in which savings of steam, water, electric power, natural gas (fuel), and instrument/service air can be made by taking corrective measures in time.

In phosphate fertilizer plants improvements can be made in:

- The waste heat recovery system of the sulphuric acid plant (in order to save electric energy);

- The consumption of steam for concentrating the phosphoric acid (through precise control of specific consumption and operating parameters);

- Recycling of steam condensate (utilization of all potential sources);

- The consumption of electric energy (through improving the power factor and co-ordination of planned shut downs of the units).

101. In order to optimize the consumption of utilities it has been found necessary to review periodically:

- The energy balance of each unit of the plant,

- The influence of operating conditions on energy consumption,

- The production cost of the utilities,

- Progress in technologies which tend to become more energy efficient.

102. Efficient recovery of fluorine is necessary both from SSP and TSP plants. Improvement of the absorption efficiency has been achieved in POLAND. The recovered fluosilicic acid can then be processed into various fluorine compounds, inclusive of synthetic fluorspar needed in other industries. In particular, countries which have no sources of natural fluorspar may benefit from the application of such fluorine recovery and processing operations.

103. The Phospho-gypsum by-product of the TSP plant which hitherto was disposed in BANGLADESH as waste material is now being used in agriculture by direct application to the soil for reducing its sulphur-deficiency.

III. RECOMMENDATIONS

Mining

104. With a view to the necessity of containing the costs of phosphate rock mining which increase when exploitation proceeds towards depth, it is recommended that mining operations be modernized through employing new methods and machines of the latest generation.

Feasibility considerations on choices should take into account:

(a) The geological disposition of the phosphate deposit over the useful life span of the machines.

(b) The different phosphate dilution factors which will be introduced by using the new methods and new types of machines. Not only the decrease of P_2O_5 content but also the addition of previously not present impurities needs to be taken into account.

(c) Training of workers who are expected to operate and maintain the machines properly.

105. It is recommended to develop special mining methods for exploiting very small phosphate rock deposits which have been discovered in many countries, while opening of mining operations had so far been considered not profitable. Phosphate companies and governments should be encouraged to undertake the necessary development work with the aim of making possible the utilization of suitable phosphate minerals trapped in small pockets in various locations.

Beneficiation

106. Under the premise that low-grade (or "poor") phosphate ores of any level of phosphate content can suitably be upgraded for use as fertilizer raw materials provided appropriate beneficiation technologies are chosen, it is recommended to undertake the following investigations:

(a) Mineralogical and phosphate liberation studies to better understand the nature and behaviour of gangue materials;

(b) Laboratory and bench scale research on the separation of mineral impurities present as endo-gangue, by applying various available technologies;

(c) Pilot plant trials to confirm the results of the bench scale tests, and to obtain adequate quantities of concentrates of acceptable grades (P_2O_5 content) and permissible levels of impurities, and to establish firm parameters and design data for engineering of large scale beneficiation plants.

(d) Chemical application studies for determining the suitability of the concentrates for the production of SSP and phosphoric acid. Further, the composition of SSP and PA should be analyzed to define acceptable limits of their quality parameters, and to identify impurities which might cause difficulties in the end use of these products and hence would need to be eliminated.

107. Low-grade phosphate ores which contain impurities in form of endo-gangue should marginally be improved by removing or decreasing the exo-gangue content only. The beneficiation method chosen to this end should be tested as indicated in paragraphs (b), (c), (d) above, with the aim of maximizing the recovery of P_2O_5, even if not obtaining standard high-grade concentrates.

108. Agronomic studies should be carried out on direct application of concentrates obtained through beneficiation of-low grade ores. The studies should take into account the following recommendations.

Direct Use of Low-grade Phosphate Rock

109. The usefulness of ground phosphate rock for direct application to soils as fertilizer should thoroughly be assessed by investigating:

(a) Rock characteristics, origin, age, substitution (compounding of the P-component);

(b) Soil factors, pH, phosphorus content, organic matter;

(c) Utilization conditions, water regimes of soils, particle size, etc.

Once these parameters are known, it is recommended to conduct agromonic tests in laboratories, green houses and in the field in order to evaluate and compare the agronomic effectiveness of the fertilizer under different soil conditions and for various crops.

110. It is strongly recommended that the use of phosphate rock and rock concentrates for direct application be encouraged or permitted only for those materials which have successfully passed the afore-mentioned tests and trials.

111. Phosphate rock and concentrates which have been found not responsive under given conditions of direct application on the proposed soils and crops can be made reactive through partial acidulation with sulphuric or phosphoric acid. In such cases it is recommended to conduct detailed studies on the physical and chemical properties of the various types of Partially Acidulated Phosphate Rock (PAPR) produced, followed by agronomic tests and field trials along the lines indicated above in paragraph 109 for establishing their agronomic effectiveness.

112. Phosphates of high water-solubility are not recommended for application on soils of high Iron and Aluminum content becuase of their high Phosphorus-fixing capacity which deteriorates the fertilization effect. However, the use of non-conventional fertilizers, such as: ground phosphate rock, PAPR products and Nitrophosphate fertilizers is recommendable, provided the fertilizer materials are low in water-soluble P_2O_5 but highly soluble in acids.

Production of Phosphate Fertilizers

113. Care should be exercized in choosing a suitable process for the manufacture of phosphoric acid. The phosphate rock or concentrate must thoroughly be analyzed for impurities. It is recommended to apply the hemi-hydrate process for conversion of raw materials which are free from interfering impurities. For processing of phosphate rock or concentrates containing such impurities the di-hydrate technology would normally be recommendable, particularly in countries which do not possess the prerequisite higher developed technical infrastructure and experience.

114. Phosphate rock/concentrates which contain impurities above the normally acceptable limits, but having P_2O_5 contents not below 25%, should thoroughly be investigated through bench scale testing followed by pilot plant trials. It is recommended to take a consistent approach so as to assure that the results obtained are representative for the material used and really prove its suitability for the manufacture of phosphoric acid. The use of phosphate rock containing vaguely defined impurities, without conducting all the afore-mentioned tests and trials, and without determining all the critical operating parameters has led in the past to disastrous plant failures.

115. The choice of appropriate phosphates and phosphate fertilizers to be produced in a country should be based on comprehensive surveys of all the influential factors and evaluation of the economics involved. The surveys should take into consideration the quantity, quality and technological suitability of indigenously available raw materials, the level of existing infrastructure and the cost of its expansion, and the potential market demand. It is further recommended, for proper assessment of the potential domestic fertilizer demand, to take into account the agronomic requirements such as crops, soils, climatic conditions, etc., of the areas where the fertilizer products are proposed to be used.

116. In developing countries, where technical infrastructural support is limited, manufacture and application of simple fertilizer products should be chosen. It is recommended to select a manageable number of types, avoid confusing multiple grades, and chose less sophisticated production methods. Quality standards should be specified in compliance with local requirements and conditions. Particular attention in this regard is to be paid to the useful example of many developing countries, which have developed their phosphate fertilizer consumption and industry starting with the manufacture of SSP.

117. When considering the production and application of liquid fertilizers, it is recommended to investigate the technical and economic parameters of manufacture, transportation, storage, distribution to end-users, and handling by the farmers. Field trials need to be carried out in order to determine the cheapest and easiest distribution and application methods which would offer the highest economic benefits to the farmers.

118. The conversion of phosphoric acid, obtained from processing of medium grade phosphate rock, into super-phosphoric acid has been investigated and found feasible. It is recommended, however, to continue

research on determining proper quality parameters of the phosphoric acid used and on improving the purification methods through pilot plant trials in order to establish fully reliable data on operating conditions and cost of chemicals for transferring the results to the industrial scale.

119. The new low-analysis NP fertilizer product "HEMIFERT" deserves attention. It is recommended to continue research on its chemical, physical and handling properties, and to determine the agronomic response to crops under soil conditions in locations where it is proposed to be used.

120. It is further recommended to pursue investigations on small scale manufacture of a low-analysis NP fertilizer by using renewable sources of energy, such as: mini-hydroelectric generators, windmills or photovoltaic cells. The new technology utilizing low grade phosphate chips and nitric oxides generated in an electric arc may prove useful in remote areas and provide farmers with a selfreliant source of fertilizer.

121. The production of Fused Magnesium Phosphate in mini-shaft-furnace plants using low grade phosphate rock, dolomite/serpentine and coal may offer a recommendable source of phosphate fertilizer in locations where raw materials availability would render such plants feasible. The suitability of the product should be investigated for crops and soils in countries in which the prerequisite raw materials and technological conditions can be fulfilled.

Economics and Marketing

122. Each country should make its own choice of the type and grade of fertilizer to be produced, in particular for domestic consumption, taking into account the indigenous endowment with basic raw materials (P, K, S, and energy) needed, and the appropriateness of their quality.

123. Countries which do not possess local resources of sulphur should consider the Nitro-phosphate route for producing NP or NPK compound fertilizers, which may offer a favourable option, in particular if new energy saving technologies could be applied. It is recommended, however, to complete the agronomic research before a firm decision is taken on the type and grade of fertilizer to be produced.

124. The experience of many countries has demonstrated that subsidizing of sales prices of fertilizers has stimulated their consumption, and has increased the agricultural production. It is recommended that other developing countries which strive for self-sufficiency in food supplies should take advantage of this experience and follow a similar policy, or adopt one of these viable systems, adjusted to suit their local production cost and pricing conditions.

Energy, Maintenance and Environment

125. Preventive and predictive maintenance management systems should be applied in phosphate fertilizer plants. Maintenance work should be organized in a systematic manner covering sufficient details, and be aided by a computer for keeping record of schedules, procurement and inventory of spare parts, maintenance cost, etc.. The system facilitates keeping track of maintenance timing and cost saving measures and has a direct positive bearing on plant productivity and overall economic performance of a company.

126. It is recommended to conduct regularly surveys of energy balances and consumption of utilities and evaluate them in order to identify viable measures to reduce production costs. Attention should be focussed on improving the waste heat recovery, decreasing the consumption of utilities, and updating of the chemical process technologies through plant modification and replacement of inefficient equipment.

127. Recovery of fluorine from rock processing operations should be applied with the substantive aim of improving environmental conditions at and around plants. The recovered fluorine may then be utilized for manufacturing salable fluorine compounds.

128. Reconversion of Phospho-gypsum for sulphuric acid recovery and production of cement should further be investigated. The process may be feasible in situations where the disposal of the waste-product of phosphoric acid production entails expensive technical and environmental pollution problems, and where there is a potential market demand for cement. Countries in which this is the case should take up pertinent research and related economic feasible studies as a matter of priority.

129. The Phospho-gypsum which is being used as soil conditioner and nutrient on sulphur-deficient soils should not contain free fluosilisic acid. Fluorine compounds have been identified as poisons affecting the vegetation of plants and health of animals. As the effect of fluosilisic acid is cumulative, even small residual proportions in the Phospho-gypsum may be detrimental in the long run if it is regularly applied.

General Recommendations

130. Developing countries dependent on imported sulphur should search for indigenous resources of sulphur-bearing minerals in order to become more self-reliant in raw materials supplies. It has been demonstrated in a developing country that these minerals can profitably be processed to produce sulphuric acid or elemental sulphur. Proven alternative technologies are available.

131. There is growing need for improving and/or strengthening the co-operation between the developing and developed countries and among the developing countries' themselves, in the field of phosphate and phosphate fertilizer industries, for the benefit of the developing countries' producers, exporters and users derived from maximizing the exploitation of local raw material resources. It is recommended to establish appropriate co-operative arrangements among the countries concerned to induce or facilitate:

(a) Exchange of experience and information;

(b) Joint considerations on economic aspects of phosphate fertilizer production and use;

(c) Development of production and application of non-conventional fertilizers, by types and grades of nutrient content, in countries which do not possess phosphate rock of the traditionally standard high-grade quality, but are endowed with large or small quantities of medium and low-grade phosphate ores.

132. It is further recommended to establish a standing Co-operative Phosphate Fertilizer Development Group, composed of specialists of the developing countries' phosphate industries. The Group should be expected to meet at regular intervals, review the pertinent research and development programmes and take initiatives on co-operation along the lines indicated in the preceeding paragraph. UNIDO should take measures towards organizing this Group and enlist the necessary support of interested governments and fertilizer companies with the aim of successfully initiating the work of the co-operative programme.

133. While emphasizing the mandate and role of UNIDO in providing technical assistance and promoting co-operation among the developing countries, the Round-Table Meeting recommended in general that interested governments and companies/institutions should take advantage of the services offered by UNIDO such as: The Industrial and Technological Information Bank of UNIDO (INTIB), Advisory Services on technical and economic issues, Technical Assistance Projects, Training Programmes, and Technical Meetings on all relevant industry related topics.

134. The Meeting further recommended with a view to UNIDO's function as the proper international specialized agency of the UN system and its involvement in promoting and expediting the development of the developing countries' phosphate fertilizer industries, that UNIDO should convene seminars on specific topics to assist phosphate fertilizer producers in finding solutions to their technical problems. The seminars may separately deal with such issues as: technological progress and development targets, surveying results of pertinent laboratory research and pilot plant work, maintenance management and spare parts inventory control, investment planning for plant modernization, safety, corrosion in phosphate fertilizer plants, environmental aspects, etc.. It was further suggested that fertilizer producing companies (through their proper government channels) may officially request UNIDO's technical assistance in form of expert services and UNDP funded country programme development projects, for solving specific problems, e.g., establishment of pilot plants, updating of technologies, plant de-bottlenecking, energy saving and other specific measures aiming at improvement of plant operation and economy.

ANNEX A

ABSTRACTS OF COUNTRY PAPERS
Submitted and presented to the Meeting by UNIDO Invitees

CRP No. 1
ABSTRACT

Achievements of the Polish Phosphate Fertilizer Industry
by Pawel Rozwadowski

The present production of phosphate fertilizers in Poland is 0.9 million tonnes P_2O_5 per year. In the second half of the eighties it will increase to 1.0 million mt P_2O_5 per year, thereafter from 1990 onwards it will further rise to 1.2 million mt P_2O_5 per year. Poland produces various grades of NPK's and TSP.

Poland has no phosphate rock deposits and imports 3.5 million mt/year. Phosphoric acid production capacity amounts to 450,000 mt/year of P_2O_5, based on the dihydrate wet process. The Polish phosphate fertilizer industry has the capability to set up single stream phosphoric acid plants of capacities up to 200,000 mt/year of P_2O_5.

Poland is one of the world's leading countries in the production of sulphur. Presently sulphur production is 5 million mt/year, out of which 4 million mt/year are exported.

Research, design and construction specialists who are experienced in setting up phosphoric acid, sulphuric acid and fertilizer plants are available. The largest single stream sulphuric acid plant designed and built by Polish enterprises has a capacity of 500,000 mt/year.

Environmental protection is being given high importance by the Polish phosphate industry. Emission levels of fluorine and SO2 gases have been considerably reduced. However, the problem of proper disposal of Phospho-gypsum is still engaging attention. This problem may possibly be solved by applying a new originally in Poland developed method of non-waste conversion of phosphoric acid into complex fertilizers in a nitrogen-phosphate fertilizer plant.

CRP No. 2
ABSTRACT

The Development of Phosphate Fertilizer Industry in Vietnam
by Vu Ta Hai

Vietnam is rich in phosphorite deposits but until 1962 had no phosphate fertilizer plant. The principal raw materials for the presently operating fertilizer plant are local phosphorites and imported pyrites. The plant has been constructed with aid received from the USSR. The plant produces single super phosphate by a new technology using sulphuric acid of 100% concentration, based on fluidized bed roasting of pyrites. Future plans have been drawn to change the product to TSP and to construct a large scale Nitro-phosphate plant.

CRP No. 3

ABSTRACT

The Brazilian Phosphate Industry
by Jorge A.S. Mattos

Brazil has met her demand for fertilizers by importing large quantities until 1970. The international price increase of agricultural commodities in 1971 stimulated the development of agriculture and the growth of its export potential. However, in view of the increasing price of imported fertilizers, the Government was urged to draw up a National Fertilizer and Agricultural Limestone Plan with the aim of modernizing the fertilizer industry and developing its export capability. Thus, new capacities for phosphate rock beneficiation, phosphoric acid and phosphate fertilizer production had to be set up.

Phosphate Rock

Reserves have been estimated at 3.8 billion mt equivalent to 380 million mt P_2O_5, which are about 2.5% of the world reserves. The phosphate ore is of igneous origin with a P_2O_5 content of about 10%.

Brazil has developed a special technology for beneficiating / upgrading their-low grade ore of P_2O_5 content as low as 5.5%. The total installed capacity of the beneficiation plants is 4.9 million mt/year.

The installed phosphoric acid capacity, after some improvements have been made, is 715,000 mt of P_2O_5 per year.

The installed phosphate fertilizer capacity is 2.5 million mt of P_2O_5 per year. This consists of SSP 4.8, TSP 4.4, MAP 1.7, DAP 0.86 and PAPR 0.50 million mt/year, respectively.

Phosphate rock production has reached a level of 1.5 million tons of P_2O_5 in 1985, leading to self-sufficiency.

Phosphoric acid production will reach a level of 680,000 mt P_2O_5 in 1985 and there will be no imports.

Phosphate fertilizer production will reach 1.157 mt of P_2O_5 in 1985, reaching the level of self-sufficiency.

Future prospects of the fertilizer industry in Brazil show a favourable picture. New capacities will be added to phosphate rock beneficiation plants amounting to 540,000 mt/year of P_2O_5, phosphoric acid: 300,000 mt/year of P_2O_5, Ammonia: 300,000 mt/year, Urea: 360,000 mt/year.

Further, there is increasing need for boosting food production in the country in which the population reaches a level of 130 million.

The Brazilian industry is taking steps to improve its productivity and utilization of inputs, and promotes technological research with the aim of attaining higher production levels in future years.

CRP No. 4
ABSTRACT

Phosphate Fertilizer Market in Chile
by Pedro Pavlovic Zuvic

Domestic production of phosphate fertilizers is limited at present in Chile. "Compania Sudamericana de Fosfatos S.A., COSAF" is the only company manufacturing 15,000 mt/year of SSP (22.5% P_2O_5) in a plant originally designed for TSP of 100,000 mt/year capacity (it did not work owing to technological problems).

The consumption of phosphate fertilizers in Chile was approximately 82,000 mt of P_2O_5 in 1984. On top of the small indigenous production of SSP (approx. 3,200 mt P_2O_5), the balance was entirely imported at a foreign exchange expenditure of about US$ 30 million. TSP and DAP account for 70% and 26% of the domestic consumption, respectively.

The price of phosphate fertilizers on the domestic market follows closely the trend of international FOB prices.

A recent study has estimated the potential demand for phosphate fertilizer during the period 1985-87 at 180,000 mt P_2O_5 per year.

Indigenous rock phosphate deposits at Mejillones and Bahia Inglesa are being investigated and evaluated for establishing a domestic source of P_2O_5. Studies are being conducted on direct application of phosphate concentrates as fertilizer or alternatively to use them for manufacture of partially acidulated phosphate rock, at an annual rate of 20,000 mt P_2O_5 equivalent. A feasibility study is under evaluation in this regard on the exploitation of the Mejillones deposit. Ways of utilizing the Bahia Inglesa deposit are also being investigated. It is intended to produce TSP from this source.

CRP No. 5
ABSTRACT

Phosphate Industry in Bangladesh
by Mesba Uddin Ahmed Chowdhury

Bangladesh has one TSP factory, situated at the sea port of Chittagong (160 miles from Dhaka). It has a production capacity of 152,000 mt/year, but has been producing only at the rate of 50-55% of its capacity, due to various factors like shortage of raw materials, breakdown of equipment, shortage of electric power and low market off-take, etc.. This plant is using only imported rock phosphate and sulphur as the country has no indigenous resources of these raw materials. Its output targeted for 1985, amounting to 100,000 mt TSP, is expected to be attained.

Recently completed studies show that the demand for phosphate fertilizers is 300,000 mt of TSP per year. Plans have been drawn to import concentrated phosphoric acid and thus further increase the indigenous TSP production capacity. A phosphoric acid storage tank of 10,000 mt capacity is under construction and shall be completed by June 1986. The balance of the requirement amounting to 200,000 mt/year will however be imported.

By-product Phospho-gypsum is being disposed by sales to the farmers as a source of sulphur for sulphur-deficient soils. Reprocessing of Phospho-gypsum and manufacture of cement clinker is under consideration.

CRP No. 6

ABSTRACT

Phosphate Fertilizer Industry in Turkey
by Bahattin Aygün

Turkey has a number of phosphate rock deposits. The deposits at Tasit, Kasrik and Akras are of sedimentary origins. The deposit at Bitlis-Unaldi-Bingöl-Avnik is of magmatic type. The sedimentary deposits represent a compounded reserve of over 320 million tons but are low-grade (11-22% P_2O_5), and appear to be economically exploitable to a limited extent only. The magmatic deposits contain over 100 million tons and are also low-grade (4-6% P_2O_5).

Present production of phosphate rock is 45,000 mt/year. A beneficiation plant will be put into operation in 1986 and shall produce 750,000 mt of concentrate per year. The use of indigenous phosphate rock is hampered by difficulties owing to insufficient quantities or quality, improper prices and also untimely supply.

Turkey started the use of chemical fertilizers in 1928. First production facilities were set up in 1944. The product was NSP (Normal Super Phosphate). The facilities were expanded in 1954 and 1961. Later, these plants were converted to TSP, reaching a capacity of 185,000 mt/per year in 1970.

Since 1980, a major expansion programme on fertilizer production was taken up, and in 1984 production reached a level of 655,000 mt of P_2O_5.

The consumption of phosphate fertilizers also grew simultaneously and reached a level of 684,000 mt P_2O_5 in 1984. The gap in the demand/supply balance was met through imports.

The phosphate industry is undertaking several development projects. A joint venture fertilizer complex is under construction, financed jointly by Turkey, Tunisia, Kuwait, Saudi Arabia and USA. It will produce 450,000 mt of ammonium nitrate (33,5% N) and 420,000 mt of DAP per year. Further, the capacities of sulphuric acid and phosphoric acid plants are being increased to improve the overall capacity utilization of the existing fertilizer plants to 85%.

The pricing policy adopted by the Turkish Government is to sell fertilizers to the farmers at subsidized rates. The difference between the selling price and the cost price plus 10% profit is subsidized by the Government.

Since 1980, the Government is determining the ex-factory prices of fertilizers on the basis of providing a bonus for savings in foreign currencies resulting from indigenous production.

CRP No. 7

ABSTRACT

The Development of the Phosphate and Phosphate Fertilizer Industry in China

by Zhang Kaiyan

There was no phosphate fertilizer production in China before the founding of the Republic of China (1949).. The first SSP production started in 1955 using indigenous phosphate rock. Later, in 1960 China developed a shaft furnace process to manufacture Fused Magnesium Phosphate. The production has reached a level of 700,000 mt of P_2O_5 annually which represents approx. 30% of the total production of phosphate fertilizers in China. At present the Chinese phosphate fertilizer production totals 2.5 million mt P_2O_5 per year. There are about 500 phosphate fertilizer plants in China today.

China has large phosphate rock reserves amounting to 12 billion tons. The present production is 14.2 million mt/year. Further, the Chinese chemical industry is developing indigenous technologies for beneficiating low-grade phosphate rock close to its source.

China is developing a process to use high-impurity phosphate rock for manufacturing phosphoric acid. A neutralizing-concentration process has been tested in a pilot plant. The phosphate rock used contains MgO and R_2O_3 up to 10%. The product obtained contains N 10-12%, P_2O_5 40-42%.

China negotiated a joint venture project with Tunisia and Kuwait to construct a plant of 1,500 mt/day capacity. For future years it is planned to:

(1) Beneficiate all the phosphate rock. A new large beneficiation plant project is under consideration.

(2) One 3,000 mt/day Nitro-phosphate project is under construction. Two more Nitro-phosphate plant projects based on Chinese technology are also being implemented.

(3) A number of phosphate fertilizer plants using domestic raw materials or imported phosphoric acid to produce Ammonium Phosphate, TSP and DAP are being considered. Some of them are already under construction.

(4) A feasibility study is also being undertaken on the production of elemental phosphorus or phosphoric acid utilizing local rock.

CRP No. 8

ABSTRACT

Status of the Development of Phosphates and Phosphate Fertilizers in Tanzania

by K.L. Haule

Phosphate rock deposits have been discovered in 1960 and tried out for direct application. A number of feasibility studies were carried out, and in 1984 a phosphate mine was commissioned at Minjingu in the Arusha region by the Minjingu Rock Phosphate Company.

There is only one fertilizer manufacturing company in Tanzania which is located in Tanga, a port town in the North-Eastern part of the country. The plant was built in 1970 and produces Ammonium Sulphate, TSP and NPK compound fertilizers using only imported raw materials. The new phosphate mine will now supply the phosphate rock to this plant.

The supply/demand balance of phosphate fertilizers in Tanzania shows that the existing fertilizer plant will not be able to meet the growing demand. Imports of fertilizers are therefore increasing.

The major problem facing the fertilizer industry is lack of foreign exchange in particular for importing spare parts and materials required for repairs and maintenance of the plants.

The Minjingu Rock Phosphate has opened a good prospect for Tanzania. It can meet the phosphate rock requirements of the existing fertilizer plants and also supply rock for direct application. For this purpose some small additional processing plants (granulation and bagging) may need to be set up close to the mining area.

In the future, Tanzania may also exploit another phosphate rock deposit reported to exist in the South-Western part of the country, in the Mbeya region. A second fertilizer plant at Kilwa in the South-Eastern part, in the Lindi region is expected to be established. It will utilize indigenous resources of natural gas for the production of nitrogen fertilizer (Urea). Through successful exploitation of indigenous mineral resources and their local processing the country may be able to alleviate its foreign currency problems and thus enhance agricultural development.

CRP No. 9
ABSTRACT

The Development of the Phosphate and Phosphate Fertilizer Industry of Benin
by Jean-Marie Houssou

The phosphate and phosphate fertilizer industry of Benin is in its early stage of development.

Investigations are being conducted in the Southern region of the country (MONO Province), where the geological structure of Togolese deposits continues.

Investigations conducted in 1976 and 1980 resulted in the discovery of a deposit in the region of MEKROU, bordering with Burkina Faso and Niger. The P_2O_5 content of the ore is around 26%, whereas the reserves are estimated at 5.5 million tons.

The possibility of establishing a SSP plant of 33,000 mt/year capacity has been considered, which would favourably be located in the most important agricultural zone of the country. However, the local consumption would only be approximately 15,000 mt/year, while the production cost would exceed the cost of imported products by 15%. This recognition has halted the implementation of a project. The utilization of these phosphates needs further to be studied.

A fertilizer plant project has been initiated in 1978, when various difficulties connected with the importation of fertilizers had been encountered. It appeared necessary to establish a bulk blending plant, because the quantities of fertilizer needed have increased considerably. The plant should have become operational in 1980. By then the demand had been estimated at 90,000 mt/year. The capacity of the plant is 50 t/h or 240,000 mt/year in 3 lines of 80,000 mt/year per line. Some delay occured, but by the end of 1984 the equipment was installed. The start-up and guarantee test shall take place in December 1985. The investment cost is high (1.720 billion F CFA). The recommended composition of the blended product is NPKSB 14-23-14-5-1. It shall be produced from imported DAP, AS, KCl and Boracine, or other single nutrient fertilizers available on the market at favourable prices.

The delay in starting plant operation experienced since 1984 has mainly been caused by lack of foreign currency to purchase the input materials and bags.

In connection with the intention to use the plant it will be necessary to renegotiate the financing conditions with the World Bank and other lenders.

Present demand for phosphate fertilizer in Mali is 13,000 mt/year. This represents only 5% of the capacity of the plant. However, it is necessary to increase food production. It might then be possible to attain a consumption of at least 90,000 tons as had been forecast in 1978 on the basis of the planned local demand.

In order to increase the consumption of fertilizer in the country, the following requirements should be fulfilled:

- The price of the product must be subsidized by the Government;
- Funds should be available for awarding credit facilities to the farmers if and when needed;
- Continuation of providing the farmers with technical advice and guidance on advanced cropping patterns and fertilization.

<u>CRP No. 10</u>
<u>ABSTRACT</u>

<u>Optimizing Resources for the Development of Indian Phosphate Fertilizer Industry</u>
by B.K. Jain

Agriculture is the mainstay of the Indian economy, and within this context fertilizers hold the key position. Various technologies are being applied using various raw materials and producing a variety of products.

India has set up a phosphate fertilizer production capacity of 1.722 million mt of P_2O_5 per year and ranks 5th/6th in the world. Compound growth rates of capacities are 10.9% per year.

Phosphate fertilizer products are in the form of SSP and TSP at 0.308 million mt, NP at 0.634 million mt, and NPK at 0.375 million mt/year.

Productivity of the industry varies. SSP and Nitrophosphate production has achieved a capacity utilization of 75%, NPK-complexes run at 100%, but Phosphoric Acid and TSP is at only 31%, owing to various equipment problems, such as corrosion and failure of rubber lining.

Under the Government's Resource Optimization Programme it has been attempted to use indigenous raw materials. Rock Phosphate from Jhamarkotra with over 30% P_2O_5 and 7-11% silica has been used although it has poor reactivity. However, reserves are limited to 18 million tons only.

Low-grade rock from Jhamarkotra, where reserves amount to over 60 million tons has been successfully beneficiated from 18-20% P_2O_5 to over 32% P_2O_5 and MgO levels below 1.5%. A pilot plant for beneficiation of 200 mt/day has confirmed the viability of the process, and a commercial size plant of 0.30-0.35 million mt/year will be set up. About 0.70 million tons/year of indigenous rock are being utilized by the industry.

Sulphur is entirely imported, except for a small quantity from petroleum refining and sulphur recovery from fuel oils. Huge reserves of pyrites, containing 300 million tons of sulphur are proposed to be exploited by applying a proven technology which has been developed in India. Smelter gases also contribute to the balance of sulphuric acid production to the extent of 70,000 mt/year of sulphur equivalent.

Through consistent pursuance of growth strategies India has achieved a compound growth rate of consumption of 15.6% per year. In order to meet the growing demand, a mixed strategy of indigenous production supplemented by imports of finished fertilizers has been adopted. The import component is maintained at around 0.50 million mt of P_2O_5 per year.

In order to meet the needs for sulphur and other secondary nutrient requirements of crops and soils, substantial new capacities have been planned for manufacture of SSP, which will increase to 0.80 million mt of P_2O_5 per year by 1989/90.

Further new capacities are being planned to reduce the dependence on sulphur. To this end Nitro-phosphates shall be produced by applying a new process which consumes less energy than the conventional methods.

For the future the production of DAP is being encouraged. DAP has advantages in production, handling and storage. Capacities will be increased from 3.68 million tons to 11.30 million tons per year.

Direct use of phosphate rock is being increased from the present level of 80,000 mt/year to 120,000 - 150,000 mt/year.

In view of the constantly increasing prices of sulphur, production of sulphur from pyrites and/or phospho-gypsum is being considered.

The tasks ahead of the Indian Fertilizer Industry are various. Many fertilizer technologies and capabilities in engineering design are available. Latest technologies like pipe reactors, pressure neutralizers and fuidized bed granulation methods are being adopted.

For pollution abatement, total recycle of effluents needs to be considered, with particular attention focussed on fluorine recovery and utilization of by-product gypsum.

Schemes for improving the capacity utilization, especially that of phosphoric acid plants, along with improvement of energy efficiency and overall plant productivity need to be implemented.

Since the comfortable availability of phosphate fertilizers is expected to end by 1994/95, efforts need to be intensified to optimize the use of indigenous raw materials.

For achieving food production targets of 185 million mt of grain per year by 1989/90, a fertilizer consumption of 14.0 million tons of nutrients has to be aimed at. Keeping in view the soil and crop requirements, suitable production patterns must be evolved to achieve balanced fertilization in terms of nutrient ratios.

In order to encourage the farmers to use more fertilizers for achieving higher food production targets, it is necessary to evaluate the cost/benefit ratios of fertilizer use and to take measures well in advance towards improving the efficiency of fertilizer production, distribution, and utilization, and to adjust the pricing policies accordingly.

CRP No. 11

ABSTRACT

Production of Phosphate Fertilizers in Pakistan
by S. Shaukar Kazmi

Pakistan is producing at present 90,000 mt P_2O_5 per year in phosphate fertilizers, whereas the consumption is more than 250,000 mt P_2O_5 per year. The balance is met by imports.

Assessment by the National Fertilizer Development Cell of the Pakistan Planning Commission has estimated that by 1989-90, the demand will increase to 396,000 nutrient tons, while production will not exceed 92,000 nutrient tons. The gap will continuously have to be met through imports.

Fertilizers are distributed to farmers through public sector organizations. The distribution cost is borne by the Government.

The National Fertilizer Corporation (Government Company) is exploring the possibility of using the newly discovered phosphate rock deposit for production of phosphatic fertilizers. In this regard in May 1985, a contract has been signed with SIAPE, a Tunisian fertilizer company, for supply of a phosphoric acid pilot plant. The plant will have a capacity of 100 kg of P_2O_5 per day usin LAGARBAN phosphate rock.

Feasibility studies have shown that with a new project for the manufacture of phosphate fertilizers, the sales price would range between US$ 310 to 330 per mt, when a 20% return on investment is assumed. This does not make new investment attractive at present because the prices of phosphate fertilizers are quite low on the international market. In the particular case of Pakistan it should be kept in mind that large quantities of phosphate rock and sulphur have to be imported.

CRP No. 12
ABSTRACT

The Situation of Natural Phosphate Resources of Niger
by Issa Harouna

The policy of Niger is to become self-sufficient in food production. The prerequisite importation of fertilizers in order to increase the output of agriculture represents a financial burden on the economy. However, the country is endowed with modest indigenous resources of phosphates.

So far two small deposits have been discovered in regions located North-East and South of the capital Niamey.

Exploitation of phosphates at Tahoua has just begun, but the size of the deposit has not yet been estimated. The P_2O_5 content of the ore varies between 22 and 36%.

The second deposit located at Parc du W is composed of aluminum phosphate of 23-30% P_2O_5 content. The reserves are estimated at 208,106 mt and are considered more important than the Tahoua deposit.

The Government decided to establish a grinding plant in order to make the phosphate suitable for direct application.

Mining is being conducted in a rather simple way, partly mechanized and partly manually. The grinding mill has a capacity of 6000 mt/year. At present the plant is not operating because of commercial problems.

Two obstacles have been identified, which have caused the shut-down of operations:

(1) The high cost of production at 52 F CFA/kg. The Government is subsidizing the sales of ground rock to the farmers who pay only 29 F CFA/kg.

(2) Although the price of the product is low, it does not sell well. Its solubility is low and application of the powder is difficult since it is carried away by the wind. The effects of fertilization become visible only after two years.

It appeared advisable to establish a plant for partial acidulation of the phosphate. To this end a pre-feasibility study has been carried out by the International Fertilizer Development Centre (IFDC), USA.

ANNEX B

ABSTRACTS OF TECHNICAL PAPERS
Presented at the Meeting

ID/WG.453/1
ABSTRACT
Original: English

The Role of Impurities in Determining the Performance of Phospheric Acid Manufacture by the Hemihydrate Process
by Norman Robinson

Phosphate rock is usually associated with impurities such as silica carbonate, minor and trace mineral elements. These impurities affect the process characteristics of manufacture of phosphoric acid. In addition to the enrichment of P_2O_5 content the beneficiation process chosen must give due consideration to impurity levels in the various beneficiation routes.

The impurities of phosphate rock have a particular effect on the Hemihydrate process of manufacture of phosphoric acid owing to reaction conditions. The effects of the more important impurities are:

(a) Carbonates - These produce CO_2 off-gases which get more entrained in the process acid owing to high density and viscosity of the acid as compared to the acid produced in the Dihydrate process. High gassing of the acid affects crystal growth.

Presence of organic matter reduces the de-entrainment of gases and affects the effectiveness of the defoamers.

(b) Silica - The reactive silica determines the extent of fluorine evolution whose ionic reaction involving aluminum affects hemihydrate crystal properties. The unreactive silica if present in fine particles reduces the filterability especially with the viscous hemihydrate acid.

(c) Fluorine - As compared to the Dihydrate process in the Hemihydrate process a larger proportion of fluorine evolves in form of SiF_4 because of the higher reaction temperature and P_2O_5 concentration. This also favours the decomposition of SiF_6^{--} to F^- which reacts with Ca and Al ions forming complexes which are removed with the hemihydrate and thus influences its crystal properties and filterability.

(d) Metallic Impurities - Apart from aluminum, iron and magnesium they have little effect on crystal growth but they affect the viscosity of the acid. The impurities precipitate and form a sludge which affects filtration and storage of the acid.

Alkali metals combined with SiF_6^{--} ions produce compounds which can form scale. In the Hemihydrate process, the solubility of Na_2SiF_6 is very low. It reduces the tendency of scaling which occurs in reaction vessels and pipework. The degree of scaling depends on the concentrations of alkali metals present in the rock.

Test procedures for evaluating the phosphate rock for the manufacture of phosphoric acid have been elaborated. They comprise the determination of physical and chemical properties of phosphate rock, its reactivity, foaming properties, and crystallization tests. Pilot plant trials are performed for comparing the behaviour of different types of rock under a given set of defined operating conditions.

In order to obtain further essential data required for plant design a number of other tests are carried out, such as settling tests, corrosion tests, and determination of physical properties of the acid (density, viscosity and vapour pressure).

ID/WG.453/2
ABSTRACT
Original: English

Maximizing the Share of Domestic Raw Materials in Developing the Phosphate Fertilizer Industry
by Matti Sinnemaa

The raw materials required for phosphate and compound fertilizer production are very seldom found all in one country. Careful planning is thus needed to identify for each country the most suitable production scheme for utilizing its natural resources. This is necessary, as the international prices of raw materials for fertilizers vary quite independently of the final product prices. Thus the increased use of domestic raw materials will not only decrease foreign currency expenditures, but will also guarantee an economical fertilizer production irrespective of the fluctuations of international prices of raw materials.

The raw material cost-components of various fertilizer products: TSP, DAP, NPK based on KCl/K_2SO_4 have been evaluated. If phosphate rock is the only domestic raw material, it forms 51% of the raw materials cost of TSP, 31% of the raw materials cost of DAP and 11-14% in the case of NPK.

Similarly, if P and K raw materials are both available domestically, they constitute 58% of the cost of the raw materials needed for phospho-nitric (KEMIRA) NPK using K_2SO_4, or 44% if using KCl followed by 54% in NPK-urea based with K_2SO_4, and 39% with KCl.

If sulphur imports are to be avoided, then the best option is the Odda CAN process, which will however require an input of ammonia at a share of 66% and 51% respectively of the raw materials costs (with K in form of K_2SO_4 or KCl). Therefore a good source of ammonia must be available close to the phosphate fertilizer plant.

If sulphur imports shall be reduced, the phospho-nitric (KEMIRA) NPK (using K_2SO_4) appears to be the most attractive process followed by urea-based NPK (using K_2SO_4), although in both cases the use of sulphur is not completely eliminated.

ID/WG.453/3
ABSTRACT
Original: English

Production Cost Comparison between Nitrophosphate and Phosphoric Acid Based Fertilizers
by Marcel A. Tanke

Stamicarbon has developed an improved version of the Nitrophosphate process based on crystallization of calcium nitrate. A production cost comparison has been made between each of the two grades of NP products (a) 28:14:0, (b) 22.5:22.5:0, both obtained by using the new process, and the phosphoric acid route using phosphoric and nitric acid, and ammonia.

With the production of grade 28:14:0, all of the NH_4NO_3 produced in the $Ca(NO_3)_2$ conversion plant is recycled to the Nitrophosphate plant. No additional (Calcium-) Ammonium Nitrate CAN is produced. During the production of grade 22.5:22.5:0, a proportion of the NH4NO3 solution (80% concentration) produced is recycled to the NP plant while the remainder is concentrated to 99% and prilled.

The following assumptions have been made for the cost comparison:

	Products	
	(a) 28:14:0	(b) 22.5:22.5:0
Phosphate nutrient capacity (tons P_2O_5 per year)	70,000	70,000
Fertilizer product capacity (tons material per year)	500,000	311,000
Investment cost		
Phosphoric acid	$ 22 million	$ 16 million
Nitrophosphate	$ 37 million	$ 32.3 million
NH_4NO_3 (80% solution)	-	$ 6 million

Prices of Inputs

Phosphoric acid: US$ 375 per ton of P_2O_5 (purchased from external sources)
Sulphur : US$ 125 per ton
NH_4NO_3 (operating cost credit) : US$ 119 per ton

The annual fixed cost has been assumed at 35% of investment. Phosphate rock composition has been assumed at 32% P_2O_5 + 50% CaO.

The cost comparison showed that the production cost of the nitrophosphate based product 28:14:0 is $ 110 less than that of the phosphoric acid based product.

In the case of grade 22.5:22.5:0 the nitrophosphate based product is cheaper by almost $ 80 per ton, after giving credit for the NH_4NO_3 by-product of the process. Further in both cases the variable cost of P_2O_5 of the Nitrophosphate process is about $ 250 per ton lower than that of the phosphoric acid based route.

ID/WG.453/4
ABSTRACT
Original: English

World Phosphate Fertilizer Supply/Demand Trends
by Gene Harris

World phosphate production, consumption, trading prices, trends over the past decade have been reviewed, and the future outlook of the supply/demand situation over the next five year period ending 1989/90 has been assessed. (All annual figures are given in terms of P_2O_5.)

Production: World phosphate fertilizer production amounted to 34 million mt in 1984 as compared to 25 million mt in 1973/74. In the USA production increased from 6.9 million mt to 9.2 million mt, while in the USSR the production increased from 3.0 to 6.1 million mt. Further, the analysis showed that developed countries increased their production meagerly from 21.5 million mt to 25.6 million mt (annual compound growth rate 1.8%), the developing countries increased their production considerably from 3.5 to 8.4 million mt (annual compound growth rate of 9.0%). USA, USSR, China, France and India are the five major producers of phosphate fertilizers in the world.

Consumption: The review showed an increase from 24.2 in 1973/74 to 31.8 million tons in 1984, giving an annual compound growth rate of 2.8%. In the developed countries the consumption increased from 19.4 to 21.5 million tons as compared to the developing countries where it increased considerably from 4.8 to 10.2 million mt, giving an annual compound growth rate of 9.8%. The consumption in the developed countries suffered a set-back caused by over-production, fall in prices of the farm outputs, whereas the prices of inputs increased. The developing countries on the other hand encouraged the consumption by giving subsidies and taking other measures towards attaining self-sufficiency in food production.

World average use of phosphate fertilizer was 21 kg P_2O_5/ha while the average in the developed countries amounted to 31 kg P_2O_5/ha. The level of consumption in many developing countries is low, e.g., in India it was 7.1 kg P_2O_5/ha, in Africa 6 kg P_2O_5/ha.

Trade: USA continues to be the leader in exporting finished fertilizers (3.95 million mt), followed by Tunisia (0.485 million mt). The total world exports were approx. 8.12 million mt.

The major importing countries in 1983/84 were China (1.0 million mt), France (0.56 million mt), followed by Iran, West-Germany and Italy. The total of imports amounted to 6.7 million mt.

Prices: TSP and DAP prices declined during the last 2 to 3 years. However, the review over the past decade showed that TSP prices increased from 1970 to 1981, reaching a peak of $ 206/mt in February 1981. In July 1985 the price dropped to its lowest level $ 110/mt. DAP prices followed a similar trend. A peak of $ 206/mt was reached in January 1980, thereafter the prices started declining, reaching their lowest level of $ 158/mt in July 1985.

Supply and Demand: The FAO/UNIDO/World Bank Working Group on Fertilizer has made a supply and demand forecast for the next five year period ending 1989/90. The capacity of phosphoric acid is expected to increase from 33.5 to 36.9 million mt from 1985 to 1990, representing an increase of 10%. This increase will mainly take place in the USSR from 5.4 to 6.2 million mt, in Africa from 4.1 to 6.2 million mt, and in Latin America from 1.2 to 1.9 million mt. The phosphate fertilizer supply capability has been projected to increase from 37.5 million tons in 1984/85 to 42.6 million tons in 1989/90.

The Working Group's estimate of consumption has shown an increase from 34.0 to 40.2 million mt P_2O_5 for the period 1984/85 to 1989/90. This constitutes a growth rate of about 3.5% annually.

The above projections reflect a potentially large surplus of phosphate fertilizer availability throughout the next 5 years.

ID/WG.453/5
ABSTRACT
Original: English

Research and Development for Phosphate Recovery and Phosphate Fertilizer Production from Iron Ore Concentration Tails at Sierra Grande, Argentina
by Makoto Kuwabara and Hector F. Pastorino

Agriculture is the key sector of the Argentinian economy. It contributes about 13% to the gross domestic product and about 75% to the total of exports of the country. Consumption of phosphate fertilizers in 1984 was 47,000 tons of P_2O_5 and is projected to increase to 100,000/150,000 tons of P_2O_5 per year by 1990/95.

Phosphate fertilizers with high water solubility like SSP, TSP, MAP/DAP are preferred. The use of other fertilizers like ground phosphate rock, fused Ca, Mg phosphates is limited to acidic soil areas of the Mescpotamic area in the North-East. Compound fertilizers are generally used. The use of nitrophosphates has not been widely accepted by the farmers.

In Argentina, tails of iron ore concentrates produced in the Sierra Grande, Rio Negro area are the only source of phosphatic raw materials. The use of this material is being promoted.

Sierra Grande iron ore is a sedimentary magnetite, containing 54.8% Fe and 3.5% P_2O_5. Beneficiation of this ore by crushing, grinding, magnetic separation, and floatation gives an iron ore concentrate containing 68% Fe. The tails from the above beneficiation process have a P_2O_5 content of 7.1% with 27.5% of Fe. The tails are finely ground to

85% under 400 mesh, from which phosphate concentrates are recovered by floatation. These concentrates contain 36.0% P_2O_5, 6.0% Fe, 44.3% Cal and 1.5% Fe. The recovery of P_2O_5 in this process is 56%. Based on the results of concentration tests a plant of an annual production capacity of 100,000 of phosphate concentrate with a P_2O_5 content of 36,000 tons is considered feasible.

The possibility of manufacturing phosphatic fertilizers by using this concentrate has been assessed. It showed that the P_2O_5 content in the concentrate is satisfactory, Fe content is high, which is mostly in the ferrous form, reactivity with acids is very low, organic matter and carbonates are low, producing no foam during digestion with nitric and sulphuric acids.

An evaluation of different fertilizer products has also been made from the physical, chemical and end use point of view. MAP/DAP and NP are most favourable alternatives.

Studies on the optimization of the fertilizer product mix are being carried out, in order to assess the economic feasibility of production of fertilizers with low water solubility, but with high solubility in weak acids for application in acid soils and pastures. The application of new technologies (e.g., reaction with gaseous SO_3 and microbiological methods) is being considered for economic use of indigenous phosphate resources of Argentina.

ID/WG.453/6
ABSTRACT
Original: English

Optimizing Resources for the Development of Indian Phosphate Fertilizer Industry

(refer to ABSTRACTS of Country Papers)

ID/WG.453/7
ABSTRACT
Original: French

Maintenance of Fertilizer Plants
by Fehti Abdelkefi (ICM)

The comprehensive account of functions of the maintenance and repair services of the fertilizer plants belonging to the Groupe Chimique de Gabes (GCG) presents a practical example of a successfully operating maintenance system, which serves a number of large plants and production units. The system has been developed indigenously and is capable of coping with a wide variety of maintenance problems encountered in the plants, which apply many different technologies, machinery and corrosive media.

On the basis of this experience general conclusions have been drawn and presented in form of listings of topics which should be taken into account when intending to improve an existing or to establish a new viable and cost efficient maintenance management system for a phosphate fertilizer plant or complex.

I. Activities of GCG

The general presentation of activities of the co-operating four companies of GCG, namely:

Industries Chimiques Maghrébines (ICM),
Société Arabe des Engrais Phosphatés et Azotes (SAEPA),
Engrais de Gabès, and
Société el Kimia

provides an account of the large size of manufacturing operations and the extent of maintenance and repair services required.

The plants of the Group produce: finished fertilizer products: AN, TSP, DCP, MAP, DAP and NPK (as alternative to DAP); fertilizer intermediates (sulphuric, nitric and phosphoric acid); and other related technical products (STPP, explosive grade AN).

The listings of production capacities of the plants belonging to the Group, and data on the throughput capacities of the raw material processing units and technologies applied give to understand that the Group represents a highly developed complex of the Tunisian minerals processing and fertilizer industry, which is of great importance to the country's national economy.

II. The Organization of Maintenance

On the basis of ICM's experience an outline of principles of functioning of a well organized maintenance system has been presented.

The issues of particular importance derived from this experience may by summarized as follows:

(a) The functions of the maintenance system

There are a number of prerequisites to attaining an appropriate level of effectiveness of the system. However, the assurance of proper functioning of the plants and their safety are the most important factors.

The level of effectiveness of the system and of the particular tasks performed must be known. To this end the ratio of maintenance cost to the quantified function of the plants or services rendered should be calculated and kept under control. The ratio should be as low as possible.

Other important contributing factors for consideration are: the age of construction materials used, availability of spare parts, proper lubrication of machines and surveillance of their performance, plant modifications aiming at simplification of maintenance procedures, evaluation of direct maintenance costs in order to decide in time on necessary replacement of equipment, etc..

As regards the age factor, the engineering concepts of plants play a major role, because they must ensure the maximum operational readiness of the equipment, the cost of which must be compatible with the expected return on the capital investment made.

(b) Methods of maintenance

The description of the historical background of development of the various types and methods of maintenance organization showed the complexity of problems involved, in particular as regards the planning of work and costs.

The following classification of maintenance methods has been presented and discussed: accidental (break-down), preventive, diagnostic (on-line, non-destructive testing during plant operations), directed, and predictive maintenance, and the information system for maintenance planning (survey of life time of materials and arrangements for their repair). The new method of directed maintenance systems considers mainly the economic requirements and classifies the breakdowns in relation to indirect financial consequences: priority group causing complete shut-down of plant operations; important group, causing decrease of output; and secondary group, not affecting the production. Spare parts for the priority group must be on stock, for the important group they should be available, but for the secondary group only those spare parts are considered essential, for which the procurement time is long.

(c) The execution of maintenance work

An extensive list of issues to be considered for planning and execution of maintenance work has been provided. They follow the logic of implementing given tasks: basic knowledge and awareness of the technical problems involved, the physical means (tools, machines and administrative facilities), and the functional methods of implementation (human factors, distribution of responsibilities, organization and control), and the prerequisite qualifications of the maintenance personnel.

(d) Other important tasks of the system

The innovative nature of new methods of maintenance management and control has induced a number of specific functions and tasks. The proposed classification of these tasks covers the following areas: organizational methods, inspection, speed of implementation, engineering-design, and safety aspects. In this context the co-ordination among the different services/professions engaged from within and outside the company; codification, computerization of the entire system, studies on likelihood of accidents, legal aspect, and accident prevention call for particular attention.

III. Financial control of maintenance management

The elements of the system, which need to be considered in this regard, comprise the control of direct and indirect costs, inclusive of assessing the magnitude of consequential losses caused by plant breakdown, and their impact on the unit manufacturing costs of products of the plants concerned. The maintenance cost/service ratio should be calculated as a means of keeping the cost-related factors under control. The definition of the services rendered should be understood in broad technical terms as they may relate to working hours of the machines, plant output or product quantity as well as to other parameters, which are representative for expressing cost/effect relationships (e.g. cost of maintenance per unit production cost, or per ton of product, etc.).

IV. The maintenance system of ICM

The comprehensive description of the maintenance system of ICM provides an example of the practicalities of maintenance organization of a large phosphate fertilizer complex. Many of the details which have extensively been elaborated upon may serve as guidance on the functions to be performed and the physical facilities required to make a maintenance management system effective and cost efficient. All the functions of ICM's existing system, earlier indicated in this abstract, have been displayed with practice related comments, emphasizing the services required, the areas serviced, the facilities available, and the tasks performed (e.g. the Central Workshop and its equipment, the preparation of work, preventive maintenance procedures, sub-contracting of jobs, mechanographic control, and spare parts management).

ID/WG.453/8
ABSTRACT
Original: French

Upgrading of a Carbonated Phosphate: Problems faced by the Aggregate Structure: Solutions Adopted
by Lahmadi Kamel and L. Yakdhane (CPG)

The structure of aggregates of carbonated phosphates of the deposits of the Gafsa basin poses certain difficulties in separating the phosphatic components. Studies have been undertaken by CPG to recommend a viable beneficiation method for the top-seam phosphates of the Jellabia deposit.

As regards the structure of these phosphates, petrographic and mineralogical investigations have shown that the phosphatic components resemble those found in the principal series of phosphate minerals. However, the predominantly dolomitic carbonates differ and are present in form of aggregates of irregular surface. Elimination of these aggregates by flotation has not been as easy as it would have been for the separation of carbonates of regular structure.

The results of quantitative mineralogical assays led to the conclusion that the phosphate is of low grade type, which appears suitable for beneficiation by flotation. The average CaO/P_2O_5 ratio is 1.55 while the P_2O_5 content ranges between 30 and 31 percent. The silica content is relatively low.

Various ways of treatment have been considered and tried out. Pretreatment by abrasion in a neutral environment under different conditions did not lead to an improvement of the flotation behaviour of the aggregates. A proportion of the phosphatic components, however, is separated in a normal way. These have been named "free" carbonates. Abrasion of the remaining carbonates called "aggregates" in an acidic medium has led to encouraging results. This method has further been developed in order to increase their reactivity vis-à-vis the flotation collectors. The irregular surface structure of the aggregates impede the adsorption of the collector.

The finally recommended beneficiation method comprises two steps: first, flotation in a neutral environment for the separation of the so called "free" carbonates, and second, under acidic conditions for the recovery of "aggregates".

Only this method has been found suitable for producing a marketable concentrate from the top-seam phosphates of the investigated deposit.

ID/WG.453/9
ABSTRACT
Original: French

Phosphate Recovery from Washery Fines
by Hitiwech Ali (CPG)

The phosphates contained in the discarded washery fines of the various types of phosphates extracted from open cast and underground mines represent a valuable source of raw material for the manufacture of phosphoric acid.

The treatment of the mined crude minerals by washing for obtaining commercial grade phosphates of homogenous quality for the fertilizer industry leaves large quantities of off-grade material behind and causes considerable losses in terms of wasted phosphate mineral resources.

Investigations have successfully been carried out with the aim of recovering these valuable materials from the coarse and fine rejects of the separating operation.

The material balances and granulometric classification of the wastes suggest that the proportion of fines larger than 70 microns in size is an important source of phosphates, qualitatively and quantitatively. Through more precise control of operating conditions of the existing washing plants, wastage of this fraction could be reduced.

The proportion of fines larger than 50 microns amounts to 7.5% of the total tonnage of crude material processed. This amount is also not negligible. Research has therefore concentrated on the utilization of this material.

The material balances calculated for the throughput of phosphates of four washeries which process raw materials from four different sources, and the results of chemical analyses confirmed the feasibility of the reprocessing concept.

While the total amount of rejected materials contained rather a low average percentage of P_2O_5, the fines of over 50 microns size represented a valuable source of phosphates, with P_2O_5 contents ranging from 21.5 to 27.6%, and CaO/P_2O_5 ratios from 1.69 to 1.95.

Two possible beneficiation methods have been considered: abrasion by agitation (turbulence), and flotation. The first method provides a proper feedstock for the second method, which then has been pursued. Extrapolated results based on a series of tests reveal a hypothetical potential for recovering 204,500 tons of commercial phosphates, taking into account all the existing sources. A rough cost estimate arrived at a processing cost of 5 Tunesian Dinars per ton of the recovered phosphates and thus proves the feasibility of undertaking the reprocessing of fines.

Nevertheless, it has been recommended to carry out more precise operating and opportunity cost studies to arrive at fully representative results.

As regards the beneficiation of fines of granulometric size above 40 microns, which has been encouraged by the aforementioned favourable results, some trials have been carried out in order to quantitatively assess the difference of gains between the results achieved by beneficiation of the two types of waste materials (40 and 50 micron cuts).

The beneficiation of the 40 micron cut has also been found technically viable. Through optimizing the beneficiation method it might be possible to reduce the consumption of flotation agents (esters and amines) and thus reduce the production cost of the recovered concentrate.

In summary, the results of investigations led to the following conclusions:

- The losses of phosphates in the discarded fines are considerable;
- Recovery of a large proportion of phosphates contained therein is technically possible;
- The cost of reprocessing by flotation is acceptable;
- The infrastructure required is not complicated.

There are also other favourable technical factors which support the concept, such as: the potential for utilizing wastes of lower granulometric size; the reduction of slime content and saving of flocculants; improvement of the quality of recycled process water, and reduction of the erosion of piping and machinery.

The research work on converting the recovered phosphates into phosphoric acid has been completed with positive results. By determining the consumption of sulphuric acid, the yield and losses in terms of P_2O_5, the rate of filtration, and the quality of the phosphoric acid produced, it has become evident that the behaviour of the reprocessed fines does not differ from that of the regular material.

On the basis of nine tests the recovered concentrate has been found suitable for phosphoric acid production by the Dihydrate process. The concentration of the final acid attained in all the tests was close to the attempted level of 30% with an overall yield of 94-95% and filtrability of gypsum equivalent to 4.4 tons P_2O_5 per day per sq m. Foaming may be encountered without causing unresolvable problems. However, precautions against chloride corrosion will have to be considered.

The Tunesian phosphate industry processes presently on the average approximately 9 million tons of crude phosphates per year. While taking into account the potential for reprocessing all the fines of larger than 40 microns granulometric size the overall turnover of the company could increase by 11%.

ID/WG.453/10
ABSTRACT
Original: English

The Supply and Demand Outlook for Phosphoric Acid in Fertilizers
by K.F. Isherwood

The UNIDO/FAO/World Bank Working Group on Fertilizer makes forecasts of the supply/demand balance of fertilizers for five years ahead. The International Fertilizer Industry Association (IFA) concentrates on the supply/demand situation of phosphate fertilizers. The method applied by IFA differs from that of the Working Group. It aims at establishing the phosphoric acid supply/demand balance, which does not take into consideration the non-H_3PO_4 P_2O_5. However, the end result of the assessment is usually similar.

IFA has conducted the above surveys since 1973. The presented forecast relates to the three year period ahead, i.e., 1987/88 or 1988 with the base year of 1985. (Actual figures of 1982/83 or 1983 were taken as the base year for the forecast till 1985.)

The validity of the IFA method depends on the predominance of phosphoric acid P_2O_5 in the development of use of phosphate fertilizers. On the world basis (including centrally planned economies) the quantity of non-H3PO4P_2O_5 has increased only from 13.9 to 14.2 million tons P_2O_5 between 1974 to 1983, but has fallen as a proportion of the total of P_2O_5 produced from 53% to 45%.

The assessment of the development of phosphoric acid supplies shows that the potential production capacity will increase from 21.299 in 1983 to 27.388 million tons P_2O_5 by the year 1987/88. Further, it shows that the announced nameplate capacities of the plants will reach 36.690 million tons P_2O_5. The wide gap is explained by the fact that many plants work at low capacity levels due to various factors or are temporarily closed ("idle") but could restart as soon as the economic conditions would warrant profitability.

The demand forecast of phosphoric acid for fertilizer use shows that by the year 1987/88 it will reach approx. 24.946 million tons of P_2O_5.

The world supply/demand balance shows a surplus of 2.442 million tons of P_2O_5 which will be available in any form of phosphoric acid (e.g. liquid H3PO4 or ammonium phosphates). Further the analysis shows that North America and North West Africa will be the potential suppliers of surplus acid to the world market. The major importers will be Asia (both South Asia and Socialist Asia), East and West Europe and Latin America.

The critical assessment of results of the survey indicates that many uncertainty factors must be borne in mind when drawing final conclusions on the continuing surplus situation. These factors are:

(i) The surplus is marginal (10% only).

(ii) The output of the new plants in developing countries will take time to stabilize.

(iii) China, USSR and some other countries could import more P_2O_5 if application rates of P_2O_5 would be raised to the desired levels.

(iv) There are indications that some large plants may permanently close down.

(v) Present international prices of processed phosphates are low and thus not conducive to new investments.

(vi) An improvement of the economic situation of the developing countries could push up the demand for P_2O_5, while little additional capacity is due to come into operation in the major importing countries.

(vii) The demand estimates are optimistic, while unforeseen factors could possibly also increase the surplus.

(viii) If fertilizer prices increase, idle plants could be put again into operation and thus would increase the supply without new investment.

(ix) Some additional capacity of P_2O_5 could be constructed during the period, especially by producers wishing to add value to their rock resources.

However, in summary, IFA estimates that the situation towards the end of the 1980s may not be as bad for the producers as it seems at present especially if some improvement in the economy of developing countries takes place.

ID/WG.453/11
ABSTRACT
Original: French

New Process for Beneficiation by Floatation of the Phosphate Ores with Siliceous and/or Carbonated External Gangue
by Neffati Hedi and Lazhar Yakdhane (CPG)

It has become necessary to search for methods of utilizing phosphate ores (considered low-grade, if the P_2O_5 content is below 25%), because of the continuing depletion of high-grade resources. Methods of upgrading the higher grade materials have been found not suitable to this end. Moreover, physical methods are not selective enough to eliminate the impurities, which disturb later the conversion of phosphates into phosphoric acid (e.g. calcite, dolomite).

Beneficiation by floatation, though expensive, has been considered as providing the only useful option for processing those ores for which the other conventional methods (washing and air sweeping) prove inefficient.

No industrial plants seem to exist, which would process sedimental phosphates containing carbonated exogangue. However, a number of patents are available on the subject, which deal with laboratory scale beneficiation methods.

The known floatation methods, though representing a progress vis-à-vis the calcination of ore, do not solve all the problems encountered with the presence of siliceous and carbonated exogangues.

The research centre of CPG conducted extensive research on the development of a new floatation method (under patent application). The results indicate that there is no essential difference between samples of phosphates of different mineralogical and chemical compositions, taken from various sources in Tunisia, as regards their behaviour vis-à-vis the floatation collectors.

The method, which has successfuly been applied for the floatation of predominantly carbonated phosphates (in presence of phosphoric esters), has further been developed for the treatment of other phosphates, containing silico-carbonate and predominantly siliceous exogangue. Conclusions have been drawn from the summary of results of research, derived from 11 laboratory test series.

Tabulations of the composition of the processed materials, the percentage of P_2O_5 recovered, the quantities of floatation agents, their combinations and conditions of application, prove the viability of the various methods by which phosphate ores containing exogangue of different compositions can be beneficiated to a remarkable extent.

The favourably low quantities of collectors needed play a major role among the advantages of the finally proposed new method, in addition to the simplicity of its application, and adaptability to minerals of a range of proportions of exogangue components.

A particular advantage of the method is the avoidance of multi-stage treatment (such as anionic floatation, desorption by H_2SO_4, followed by washing). Two additional tests have been conducted to corroborate this statement by comparison between the multi-step and single-step floatation methods. The tabulations of results show that virtually identical results of concentration have been obtained by applying the two methods:

- Preconcentration by using anionic collectors in presence of hydrocarbons in an ammoniated environment, followed by a second floatation after having the preconcentrate heated with sulphuric acid and three times washed. The collector of the second step is an amine with kerosene.

- Single-step floatation of two minutes duration, by using a cationic collector and phosphoric esters.

Secondary advantages of the new method which deserve mentioning are:

- The floatation agents used (amines and esters) are not sensitive to the hardness of water. Identical results have been obtained when using wellwater of 210 deg TH or sea water of 700 deg TH.

- The method practically requires no control of pH of the medium in which the floatation is conducted, except for particularly different conditions (e.g. acid water).

- By combining the conditioning and floatation operations, recycling of the materials is reduced, the flowsheet is simplified and the output of operations increases. In consequence this leads to lower investment costs and more economical operations.

ID/WG.453/12
ABSTRACT
Original: French

Rehabilitation of Underground Mines of CPG and the Direct Utilization of the Crude Phosphate in the Manufacture of Phosphoric Acid
by Momamed Abbes (CPG)

Despite the efforts made to improve the operations and working conditions of the underground mines of CPG it has not been possible to reduce the mining costs and to make the product prices competitive to those attained by open-cast mining, although the P_2O_5 content of the underground mined phosphate, at approximately 27% is relatively high.

However, the upgrading operation by washing the underground mined rock is not cost efficient and hence hardly justifiable. This situation called for a new approach to utilizing the ROM (run-of-mine) phosphate in a more economical way.

The processing technology of SIAPE appears particularly suitable for the treatment of low-grade phosphates. Laboratory and pilot scale research has been conducted for studying attainable conversion parameters of two types of crude phosphates, mined at M'Dilla and Metlaoui, by using the dihydrate process.

Batchwise (discontinuous) trials have been carried out by treating the phosphate with sulphuric acid at 78°C, in presence of the phosphoric acid and phospho-gypsum recycled from the preceeding batch. After filtration under vacuum the filter cake is washed with increasingly diluted portions of phosphoric acid. The treatment time of each batch is 2.5 hours. The results recorded show a relatively large difference of filterability between the two types of phosphates (in favour of the material mined at Metlaoui). But in general they are low as compared to filterabilities of the upgraded materials obtained from the washing plants. Consequently the losses of P_2O_5 are high (0.19 and 0.18% of P_2O_5 in the gypsum vs. 0.1 and 0.15%).

Further trials concentrated on the relationship between the concentration of H_2SO_4 and losses in terms of P_2O_5 (i.e. the ratio of unreacted or syncrystallized P_2O_5 vs. acidity of the pulp). With the increase of acidity the proportion of unconverted P_2O_5 increases, and conversely, syncrystallized proportion of P_2O_5 decreases. By analysing the cause of this phenomenon and the influence of impurities on the behaviour of the phosphates in the presence of H2SO4, it has been found that the best results of the sulphuric acid treatment are attained when its concentration ranges between 12-15 and 16-18 g H2SO4 per liter for the M'Dilla and Metlaoui phosphates, respectively.

Trials have been conducted to improve the filterability of phospho-gypsum obtained when processing the M'Dilla crude phosphate. It has been concluded that the crystallization of phospho-gypsum of this particular material is very sensitive to the parameters of phosphoric acid production. It is necessary to maintain optimal conditions in order to attain an acceptable level of filterability.

In principle the crude phosphate produces very fine crystals. However, it is well known that the solubility of calcium sulphate under conditions of producing phospho-gypsum is influenced by many factors such as: temperature, concentration of the sulphuric acid and P_2O_5 compounds as well as the impurities which pass into the solution (fluosilicic acid, magnesium salts, iron and aluminum oxides, etc.). The relationships of some of these parameters have been studied and led to the following recognition:

- The increase of sulphuric acid concentration decreases the filtration time of phospho-gypsum.

- Contrary to this, with concentrations up to 30 g H_2SO_4/liter the losses of unconverted P_2O_5 increase. This problem may be overcome when using the SIAPE technology and its particular concept of the reaction vessel which allows processing of the material in two parts subsequently at concentrations of 30 and 13-15 g H_2SO_4 per liter.

- The concentration and hence the viscosity of phosphoric acid considerably reduces its filterability (in terms of output in tons P_2O_5 per day per sq. m vs. percentage of P_2O_5 in the phosphoric acid, or filtration velocity in cu.m per day per sq.m vs. viscosity of acid in cps.).

- The thickness of the filter cake decreases the filtration velocity, however, at 45 mm it still produces acceptable results (3.5 tons P_2O_5/day/sq.m). Flocculation of the pulp helps to considerably increase the filterability.

Continuous pilot plant tests of phosphates from both sources have been conducted by using a reactor of 5 kg capacity, at temperatures of 78-80^{o}C, reaction time 3.5 hours and 240 l/hr recycling of the pulp. The results demonstrated that:

- Losses of P_2O_5 are within acceptable limits. It appears possible to attain a conversion rate of 96-97%.

- The attained filterability 3.5-3.7 tons P_2O_5/day/sq.m is relatively good.

- Consumption of H_2SO_4 can be considered satisfactory (or very economical if taking into account that the processed materials had not been beneficiated).

- There is a remarkable difference between the viscosities of the phosphoric acids produced from the two crude phosphates, owing to largely differing contents of impurities (metallic compounds).

In summary the results of the research work confirm the feasibility of processing ROM phosphates from the two Tunisian sources. Remaining unsolved issues are: foaming, scaling of equipment and the high content of impurities in the final product.

Therefore, more precise research is needed to overcome possible difficulties. A pertinent project may also offer a solution to the problem of restructuring the economics of underground mining. Contributing positive factors would be:

- Reduction of transportation costs per ton of P_2O_5;

- Possibility of partly using the existing infrastructure;

- Utilization of the existing beneficiation capacities for upgrading of phosphates from the open-cast mines;

- Feeding of the existing chemical plants exclusively with the open-cast mined phosphates.

ID/WG.453/13
ABSTRACT
Original: English

Exploitation and Use of Low Grade Phosphate Rock, Indian Experience
by T.N. Jaggi

Phosphorus is an essential element in the balanced use of fertilizer nutrients. With presently attained food production levels of 150 million mt/year, there is a consumption of 1.87 million tons of P_2O_5 per year. This will increase to 3.23 million tons of P_2O_5 per year by the end of the crop year 1989/90. The Indian indigenous rock phosphate will provide only 0.41 million tons P_2O_5 per year for the production of phosphate fertilizers. Thus by the end of the present decade, India will import 2.80 million mt of P_2O_5 per year in form of rock phosphate, phosphoric acid or finished phosphate fertilizers. As Indian soils are low to medium in phosphorus, balanced fertilization of a N : P_2O_5 ratio 2 : 1 is necessary for maintaining the soil fertility and crop productivity.

India possesses only 18 million tons of high-grade phosphate rock (above 30% P_2O_5), and hence in order to attain self-reliance, low-grade rock must be utilized either through beneficiation or direct application to the soil in straight or modified form.

Various attempts have been made to beneficiate Indian low-grade phosphate ores. Singhbhum Apatite containing silica and magnetite impurities has been beneficiated to a concentrate of 41% P_2O_5 and above. Similarly Purlia phosphate ore has also been beneficiated, but the concentrate is not suitable for SSP production.

Jhamarkotra low-grade ore of 50 million tons reserves, have been successfully beneficiated from 16% P_2O_5 to 34-36% P_2O_5 with MgO below 1.5%. A pilot plant of 200 mt/day has confirmed the suitability of the process.

Maton rock containing silica as impurity has been beneficiated to a concentrate of higher than 36% P_2O_5 content, and a commercial size plant of 600 mt/day is in operation.

The Mussoorie rock phosphate deposit has a reserve of 45 million tons. The various gangue minerals present are calcite, dolomite, pyrite and organic matter. These impurities are evenly substituted in the crystal lattice. The ore is sedimentary, with 16% P_2O_5. Attempts to beneficiate the rock have not yielded favourable techno-economic results. However, pre-concentration of the ore to 22-23% P_2O_5 by applying the heavy media principle using Dyna Whirlpool and Hydrocyclone equipment has been found very attractive. A demonstration plant is being set up at Mussoorie to confirm the process on a large-scale using varieties of phosphate ores available at Mussoorie.

Direct application of rock phosphate which is dependent on the type of rock, its physical properties various soil and crop factors have been evaluated for some of the Indian phosphate minerals. Mussoorie phosphate rock has been found suitable, as it gives the same agronomic efficiency as water-soluble phosphate fertilizers in acid soils. In neutral and alkaline soils, a mixture of Mussoorie rock and SSP (1:1) has been found to compare well agronomically with SSP alone.

In order to overcome the difficulties in the use of Mussoorie phosphate rock powder, like transportation over long distances, difficulties in its use, and handling losses, certain development studies have been undertaken. The studies have been conducted by the International Fertilizer Development Centre, USA, under a UNDP/UNIDO sponsored project. The aims of the studies were:

(a) To improve the physical properties by mini-granulating the powder, using water-soluble binders;

(b) To develop a process for Partial Acidulation of Mussoorie rock to convert about 50% of the P_2O_5 content into a more soluble form of nutrient availability to plants;

(c) To identify the agronomic efficiency of developed products, i.e., mini-granulated phosphate rock powder and PAPR products in Laboratory Soil Incubation Studies, Green House Tests and Field Agronomic Trials in India.

Mini-granulation tests on the Mussoorie phosphate rock powder using KCl, H_2SO_4, H_3PO_4 binders have produced granules of the range between 300 microns and 106 microns. These have good physical and handling properties. There is no change in the available P_2O_5 as compared to the original Mussoorie phosphate rock powder (90% through 100 mesh).

Partial Acidulation tests done with Mussoorie phosphate rock powder, using H_2SO_4, H_3PO_4 to the extent of 50% or 25% of the normal acid requirement for complete digestion, have produced acceptable physical and handling properties. The product is in the form of either Run-of-Pile or granules having sizes between 3.35 to 0.212 mm. Chemical analyses of the products show that 50% / 25% of the P_2O_5 is in the water-soluble available form and the balance as phosphate rock P_2O_5.

Agronomic Tests, consisting of Soil Incubation studies, Green House studies, Field Trials in India for both mini-granule products and various Partially Acidulated Phosphate Rock (PAPR) products prepared from Mussoorie Phosphate Rock have been carried out.

Agronomic tests show that mini-granule products have the same agronomic efficiency as the powder.

Agronomic tests with PAPR products of Mussoorie rock powder show that these are able to provide the P_2O_5 requirements of the crops in neutral soils as efficienctly as the 100% water-soluble P_2O_5 fertilizers like TSP. It was also noted that even 25% acidulated products have an agronomic performance which compares well with that of TSP.

The economic evaluation of the PAPR products prepared with phosphoric acid shows that these products are most attractive as the extra cost of processing can be met from the additional sales proceeds of water-soluble P_2O_5 in the product. The cost of the phosphoric acid used is also met from the additional sales proceeds, as the use of this acid upgrades the P_2O_5 content of the PAPR product. Furthermore the marketability of the PAPR products becomes feasible if the products are sold near to the Mussoorie area, thereby providing a benefit to the national economy in cutting the cost of the fertilizer product at the farm gate.

Technical Paper No.14
ABSTRACT
Original: French

Management of Utilities in Phosphate Fertilizer Plants
by Mouldi Alouane (ICM)

Fertilizer plants are known as large consumers of energy. The consumption of utilities, such as steam, water, electric power, natural gas, instrument and service air, varies considerably with the different levels of plant output and the mutually interdependent operations of the units.

The specific features of the complexity of ICM plants, established in 1972, 74 and 82, pose many difficulties because of the multiplicity of types of equipment serving identical purposes, the complicated distribution network and the time differences in aging of the equipment.

Although in principle the energy balance of the complex is based on the self-sufficiency of steam and electric power supply of the sulphuric and phosphoric acid plants, supported by auxiliary boilers, in reality the daily requirements differ considerably in particular when all the plants of the scheme are not operating simultaneously at design capacity.

The fundamental concern of the utilities management is to assure steady supplies and optimization of costs, suiting all possible combinations of operating conditions. To this end a plan of action and procedures has been established, which enable the management to control the cost of utilities supply and to optimize its relation to the production costs of the final products.

A formula has been worked out for summarizing the positive or negative factors (in monetary terms) of all the essential parameters and external/internal production cost components (i.e.: specific consumptions, prices of raw materials and energy, personnel cost, depreciation, spare parts consumption, and other financial charges).

Practical examples taken from ICM's experience demonstrate the logic behind and use of the optimization programmes applied for reducing the consumption of natural gas for steam generation in the auxiliary boilers, while maximizing the output of heat recovery from the sulphuric acid plants and minimizing the consumption of steam by the various users.

In Tunisia the single absorption process is applied for sulphuric acid production. The steam/acid ratio is between 1.20 to 1.25%, which corresponds to a recuperation rate of 55%. Out of the unrecovered 45%, 40% goes into the cooling water, while 5% is the sum of radiation, stack and absorption tower losses. Studies conducted on this subject have revealed the possibility of recovering 90-95% of the energy produced by the sulphuric acid units existing in Tunisia and thus provide a source of 60 MW of additional energy, equivalent to savings of 0.3 million bbl crude oil per year. The return of capital required for making the necessary plant modifications has been estimated at max. 3 years.

The analysis of operating conditions of the auxiliary boilers which use natural gas has shown that there is a large potential for optimizing the specific consumption of gas per ton of vapour, if considering that the presently applied surplus of 30% of air can remarkably be reduced.

The dependence of steam consumption on the quality of the phosphates used is well known. The smaller the amount of impurities, the higher the concentration of P_2O_5 and consequently less steam is needed for evaporation. As free choice of high-grade raw materials is rather limited, energy saving programmes should concentrate on the design features (size) of the heat exchangers and control of parameters to avoid wastage of energy. Comparative studies and evaluation of operating conditions and outputs of various evaporation/distillation units should be carried out in order to identify the more energy efficient units as practical examples for improving the operating conditions of other units. This also applies to studies on possible savings through increased recycling of steam condensates, and reduced use of expensive distilled or demineralized water.

Specific measures have been recommended for optimizing the consumption of electric power. Better control of working parameters of the steam-turbine/power generator assembly may bring about considerable savings. Other recommendable measures are: control of the cosinus phi (power factor) of the entire plant; co-ordination of short and long term plant shut-downs and start-ups; maintaining continuity and high efficiency of operations (interrupted, irregular operations should be avoided).

In order to manage the economy of utilities production and consumption of fertilizer plants in the best applicable way, the following should be defined and pursued:

- Energy characteristics of each unit;

- Steam flow diagrams and energy balance of the entire plant;

- Influence of all operating parameters on the steam/energy balance;

- Energy balances of specific consumption;

- Realistic energy balances for all possible alternative operating conditions, in order to prevent limitation of production capacities;

- Review of the progress of technologies in order to propose economically justifiable modifications in time;

- Evaluation of the development of utility costs in order to implement projects, which earlier proved not profitable.

Technical Paper No.15
ABSTRACT
Original: French

Tunisian Phosphates and Sulphur
Future Prospects
by Ezzedine Jemaa (ICM)

The economics of phosphate fertilizer production depend heavily on the consumption of sulphur and its relation to the P_2O_5 content of the phosphate raw materials processed in the manufacture of phosphoric acid. The research team of ICM has become aware of the seriousness of problems faced by the Company, caused by two factors: decreasing quality of available phosphates (in terms of P_2O_5 content) and soaring sulphur prices.

Statistical data on unit consumption figures, yields and losses of P_2O_5 have been compiled and evaluated. They reflect the past history of utilizing GAFSA phosphates by the plants of the Chemical Complex of GABES. Extensive analytical surveys have been conducted and material balances prepared for identifying optimum relationships and recommendable ranges of P_2O_5 contents in the raw materials received from different sources. The objective of this work was to search for new ways and means

of economizing on the consumption of sulphur and to reduce losses of P_2O_5 in the phosphoric acid plants.

The phosphate processing plants of the Groupe Chimique Tunisien (ICM, SIAPE, SAEPA) use three types of phosphate rock supplied by the Compagnie des Phosphates de GAFSA (CPG) namely: "washed", "air swept", and a mixed grade MS60, composed of treated/dried crude phosphate and the "air swept" material.

The substantive aim of the very comprehensive research conducted by ICM was to define conditions and parameters for upgrading the phosphatic raw materials by fractionation (screening) and to chose a practically applicable borderline between fractions of higher and lower contents of P_2O_5 which would make possible to develop a raw material saving technology. To this end the work concentrated on separating the so called "higher fraction" or upper cut, i.e., the material of larger granulometric size but lower in P_2O_5 content than the remaining proportion of the raw material, and establishing an industrially viable upgrading method.

Tables 1 to 23 and A, B, C and flow charts (Fig. 1 to 4) of the report display all the details and provide the background data needed for understanding the concepts and considerations which led to the formulation of conclusions on the advantages of separate processing of the higher fraction of phosphates mined in the GAFSA area.

The conclusions indicate that:

(1) The consumption of sulphur could be reduced by 50,000 mt/year;

(2) 200,000 mt of phosphates could be saved;

(3) Losses of P_2O_5 could be reduced by recuperation of a proportion of the presently discarded clays (off-grade material or "solid rejects");

(4) The GAFSA phosphate rock processing capacities could be increased and surpass 3 million tons of phosphates annually.

The processing method proposed comprises the following consecutive steps:

- Fractionation of the crude rock phosphate delivered to GABES by screening and processing of the "higher fraction" of granulometric sizes above 1 mm ("washed" material), 0.5 mm ("air swept" material) and 0.315 mm for the mixed grade phosphate MS60. By definition the "higher fraction" has a P_2O_5 content of less than 27%. The average content is however much lower.;

- Stirring of the material with sea water and separation of clay by using hydrocyclones;

- Washing with industrial water;

- Second screening for removing large particles (grains of sand, limestone and phosphates);

- Calcination at 600°C.

The P_2O_5 content of the "higher fraction" can thus be increased from 20 to 30% or even to more than 31% (when applying recrystallization of apatitic structures after calcination). The chlorine content does not remarkably increase, while the content of alkaline components is reduced by calcination of the material. This favourably influences the fluorine balance during the production of phosphoric acid.

The off-grade material of the second screening operation are low-grade phosphates which could be used for direct application, or production of TSP along with the sludge separated from the concentrated phosphoric acid, or for the production of nitrophosphate NPK through treatment with nitric acid, or other combinations.

The upgrading and processing method developed by the team of engineers of the ICM laboratories promises to reduce the consumption of sulphur by 5% when using "washed" phosphates, 10% in the case of the "air swept" material, and 15% with grade MS60.

As a particular case of the results relating to upgrading of the REDEYEF air swept phosphate it has been found that after flotation of the clays from the higher fraction it is not necessary to apply a second screening before the washing operation with industrial water followed, if necessary, by calcination.

Some essential details presented in the tabulations of data which form the body of the report deserve highlighting.

The average unit cost of raw materials has been expressed by a formula, deduced from the actual costs incurred from 1980 to 1984 by ICM and SAEPA (phosphoric acid), and by SIAPE (TSP) as follows:

Phosphoric acid production: $d = 0.99\ S + 3.87\ P$
TSP : $d = 0.35\ S + 1.84\ P$
whereby d = total unit cost, S = price of sulphur in terms of 100% H_2SO_4, P = price of phosphate.

The consumption of sulphur and phosphates of various grades of Tunisian origin, in mt of material per mt of P_2O_5 in phosphoric acid (54%) and TSP range from 0.98 to 1.184 tons and 3.8 to 4.58 tons, respectively, the lowest being attained when using M'Dilla phosphates.

The consumption figures, when processing phosphate rock imported from various countries, (P_2O_5 : 31.75 to 34.13%) ranged 0.88 to 0.95 mt S per mt P_2O_5 and 3.00 to 3.25 t phosphate per ton P_2O_5, when producing phosphoric acid by the NISSAN process. With Tunisian rock 65/68 BPL (29% P_2O_5) S and Phosphate consumption was 0.93 and 3.54 tons, respectively.

The quantities of phosphates received and processed by ICM increased from 945,951 tons in 1980 to 1,402,120 tons in 1984. SAEPA received in the same period 1,052,074 to 1,176,003 mt per year, while the total consumption of sulphur of the three companies ICM, SAEPA and SIAPE increased from 718,453 tons to 831,799 tons per year.

The conclusions drawn on the results of the research, and the potential savings offered by the innovative approach are based on the assumption of processing by the companies under review 2,800,000 mt per year of phosphates and 700,000 mt S per year.

Thereof the total quantity of the "higher fraction" would represent 360,000 tons per year (75,000 mt P_2O_5) and yield 160,000 mt of high-grade phosphates (28% P_2O_5 = 44,800 mt P_2O_5 per year) leaving 200,000 mt of off-grade material containing 30,200 mt P_2O_5, which is considered a still useful raw material for other purposes as indicated above.

Technical Paper No.17
ABSTRACT
Original: English

Aspects of Natural Environment Protection through Fluorine Recovery in the Production of Phosphate Fertilizer
by P. Rozwadowski

Phosphate fertilizer industries using Apatites and Phosphorites as basic raw materials face the problem of fluorine generated during the process. It is estimated that 25-70% of the fluorine in the raw materials comes out in the gaseous, liquid and solid / phospho-gypsum / effluents and wastes, polluting the natural environment. It is necessary to protect the environment, as fluorine bearing compounds are harmful to people and animals.

The recovery of fluorine has the additional advantage that fluorine bearing compounds constitute valuable raw materials for the inorganic industry and provide a good substitute for natural fluorspar which indigenously is not available in Poland.

Fluorine recovery from single superphosphate production can be optimized by using the various types of absorbers either in series or in parallel and thus attaining a high absorption efficiency of over 99%.

When concentrating phosphoric acid, part of the fluorine compounds in the acid pass to the vapour phase. They are recovered in a scrubber by absorption in circulating solution of fluosilicic acid. The fluorine recovery system is quite simple and consists of unpacked sprayed absorbers to wash out silicon tetrafluoride and hydrogen fluoride to obtain commercial grade fluosilicic acid solution.

The Polish phosphate fertilizer industry recovers at present 12,000 mt per year of 100% H_2SiF_6, which represents a recovery of approx. 10% of the fluorine from the rock phosphate processed by this industry. In future years with the new wet phosphoric acid capacity coming into operation further fluosilicic acid production will be added.

The recovered Fluosilicic acid is processed into various fluorine compounds. The consumption of these compounds (like sodium of potassium

fluosilicates, sodium fluoride, synthetic cryolite, hydrogen fluoride, etc) is limited and thus the surplus fluosilicic acid can be converted into hydrofluoric acid for which demand is growing.

Based on the Polish process, a demonstration plant for production of 600 mt/year of anhydrous hydrogen fluoride from fluosilicic acid solution has been put into operation in Poland.

The advantage of the above process is that it can directly use the industrial fluosilicic acid and is suitable for large phosphate fertilizer plants.

The alternative to this method is the manufacture of hydrogen fluoride from synthetic fluorspar obtained through neutralization of fluosilicic acid. This opens the avenue of utilizing the surplus fluosilicic acid which can then be processed in other factories, remote from the source.

While it is necessary to maximize recovery of fluorine from phosphate rock processing in order to protect the environment, the products of this pollution abatement measure represent an important source of fluorine compounds in countries which are not endowed with natural deposits of fluorspar.

Technical Paper No.19
ABSTRACT
Original: French and English

HUMIFERT - Simplified Manufacturing of Binary Fertilizer with Humus
by F. Sternicha

For various technical and economic reasons some countries are unable to use their phosphate deposits. In some cases even the use of ground phosphate rock does not give efficient results. Countries which essentially depend on agriculture can develop only if they increase the output of their agricultural production. Many of these countries lack foreign currency and are unable to import fertilizers, and consequently have to depend on products made from local resources though poor in grade as classified by standards of the industrialized countries.

For dissolving the phosphates acids are needed. Countries which do not dispose of resources of sulphur or pyrites may use nitric acid or oxides which usually are obtained by oxidation of ammonia.

The simplified method proposed comprises two essential steps. First: to manufacture nitric acid on the spot, but without using a conventional nitric acid plant and absorption towers, and second: to add organic matter to the rock phosphate as intermediate absorbent in the reaction mixture. The organic matter on one hand accelerates the absorption of nitrogen oxides, and on the other hand fixes the slurry resulting from their reaction with the phosphate rock. The fertilizer product thus obtained has an appearance of a humid compost.

Agricultural wastes such as tree tops, cane-trashes, straws, peat or brown coal may be used as organic matter.

The average fertilizer nutrient composition of the HUMIFERT product will be 5:7:0 when rock phosphate containing 25% P_2O_5 is used. This product, however contains nitrogen as well, although being low in total nutrients like SSP. Further it provides the soil with organic matter and the nitrogen in assimilable nitric or nitrous state.

The process is simple and consists of mixing the ground phosphate rock with crushed organic matter. These components are moistened and transferred to a reactor where they react with nitrogen oxides obtained by oxidation of ammonia with air on a platinum gauze. The exothermic reaction is controlled by addition of condensates resulting from ammonia oxidation and if necessary by addition of water. No environmental pollution occurs since excess NOx gases are absorbed by the organic matter.

The investment of a plant varies according to its capacity which may range from 10 to 250 TPD. The estimated cost of a 50 mt per day plant is US$ 900,000 whereas for a 250 mt plant it comes to US$ 3.25 million.

The plant consumes less energy and is simple. It does not require highly qualified manpower for operation and maintenance.

The cost of the product of a 50 mt/day plant is about US$ 34.2 per ton (i.e. US$ 285 per mt of nutrient). This cost decreases with increasing capacities. In the case of a 250 mt/day plant it will be approx. US$ 31.5 per ton (i.e. US$ 225.3 per mt of nutrient).

The process and product appear to be attractive for developing countries. It will enable them to use their local sources of low-grade rock phosphates and thus save foreign currency.

Technical Paper No.20
ABSTRACT
Original: French

Concentration, Superconcentration and Purification of Phosphoric Acid Produced from Gafsa Phosphates by Using the Technology of SIAPE
by Noureddine Turki (SIAPE)

SIAPE (Société d'Industrie d'Acide Phosphorique et Engrais) has accumulated extensive experience in processing of phosphates of different qualities. The dihydrate technology developed by SIAPE is particularly suitable for low grade phosphates. Its positive features comprise: simple concept of the reactor vessel and simple construction of the agitators; easy venting and cooling of the pulp and easy maintainability of the plant; elimination of foaming without using auxiliary chemicals; and low consumption of electric power (approximately 100 kWh/ton P_2O_5).

The fertilizer industry has shown interest in using phosphoric acid of higher concentration. It is possible to concentrate the acid in two steps from 28% P_2O_5, first to 54% and then to 70-74%. The advantages expected to result from this operation would be:

- Reduced concentration of impurities (some would precipitate, others would evaporate during the operation);

- Decrease of transportation costs;

- Considerable improvement of corrosive properties of the acid.

The metallic impurities which cause scaling would be eliminated owing to the specific power of the superphosphoric acid (SPA) to prevent their precipitation by dissolving them under certain conditions.

SIAPE has established a pilot plant for producing SPA from concentrated PA. The plant is composed of an evaporator and tubular heat exchanger, through which the concentrated acid is recycled by a pump. The PA feed is led into the recycling stream and thus does not cause corrosion of the equipment. The corrosive components (F and Cl) of the impurities are extracted in the evaporator, under vacuum generated by a steam jet pump (ejector). The vapours are condensed by quenching with cooling water and drained into the sewage.

The ratio of polymerized P_2O_5 vs. the total content of P_2O_5 of the concentrated acid determines its stability. If the conversion ratio is below 20% crystallization occurs. Low concentrations of the acid reduces also its potential for keeping the impurities in suspension. However, for using the SPA, it is necessary to reduce the content of metallic impurities, in particular magnesium, which tends to precipitate in form of magnesium pyrophosphate. Magnesium impurities are also responsible for deferred precipitation of slurry, after days or months of storage.

Problems caused by the presence of magnesium become evident also when the phosphoric acid is ammoniated in connection with the production of liquid fertilizers. Methods for reducing the Mg content have therefore been studied. It has been found, however, that good results are not easily attainable.

Two methods have been experimented

- Precipitation of the Mg-Pyrophosphate in the SPA solution followed by filtration,

- Passing diluted PA through columns packed with ion exchange resins.

When cooling down the concentrated SPA solution from the outlet temperature of the evaporator, the Mg-Phosphates precipitate and can be removed by filtration. The growth of crystals needs to be controlled. The temperature regime of the cooling procedure must be maintained in narrow limits. Periodic agitation of the slurry is necessary. At 132°C it takes 20-21 hours to grow crystals of proper size, suitable for filtration. In order to facilitate the filtration, the temperature is kept at 100-120°C. A pre-coat filter must be used (a layer of 60 mm of diatomaceous earth serves as filter aid on the cloth).

By applying this method approximately 89% of the MgO is removed. However, a large proportion of P_2O_5 is retained in the filter cake (25%).

The second method of purifying the phosphoric acid is based on ion exchange technology. For the purpose of reducing the magnesium and calcium content diluted phosphoric acid is used and passed through columns filled with granules of the resin. Sulphuric acid is used for regenerating the resin. Since only the cations are retained by the resin, while the anions remain in the solution, there are no losses of P_2O_5.

The reduction of impurities attained by this method amounted to: 95% calcium, 88% magnesium, 27% iron, 99% potassium, whereas the silicium and aluminum content remained unchanged. These results have been obtained in a pilot plant by treatment of 7 liters per batch of PA solution in cycles of 7 minute duration (60 l/hr).

Technical Paper No.21
ABSTRACT
Original: French

The Manufacture of Liquid Fertilizers
by B. Damak (SIAPE)

Liquid fertilizers play an increasingly important role in the manufacture of chemical fertilizers. They offer a number of techno-economic advantages especially if considering their application for fertilizing large areas of agricultural land.

The properties of these liquids should fulfil the following conditions: high content of nutrients, good stability of storage properties, low solidifying temperature, low viscosity and low corrosiveness.

The expansion project SIAPE II will provide a source of purified phosphoric acid and a possibility of using ammonia for neutralizing the acid in order to obtain a liquid fertilizer of the NPK formula (10 - 34 - 0).

A laboratory scale pilot plant has been established by SIAPE. It is composed of a neutralizer and tubular reactor made of glass, and a countercurrent mixer of the phosphoric acid and ammonia. The receiver of the product is made of stainless steel and is equipped with a jacket for cooling the product.

Phosphoric acid of 54% concentration was preheated up to 95°C and pumped into the reactor, whereas the ammonia was taken from a steel cylinder under pressure of 10 bar, and applied in gaseous form. Although the acid contained some quantities of MgO and a remarkable content of iron and aluminum it has been possible to produce liquids of a high content of nutrients. The stability of the various liquids produced has been attributed mainly to the presence of non-cyclic polyphosphoric acid.

The molar ratios of N/P and the final concentration of nutrients in the liquids characterize the effectiveness of the pilot tests and determine the stability of the products.

For establishing the relationship between the N/P ratio and the properties of the liquid products various neutralization trials have been carried out by using purified superphosphoric acid (SPA) and Aqua Ammonia of PA quality (26.2% NH_3). Portions of 100 g of the SPA have been heated and treated with a calculated quantity of ammonia under constant stirring. The products have been analyzed and stored for two weeks.

The results obtained show that only the product of N/P ratio = 1.5 is a stable liquid. Products of N/P = 1.4 have an optimum viscosity. Liquids of N/P ratios 1 to 1.2 solidify even if their P_2O_5 content is only 32%.

Thereafter the relationship between the concentration of nutrients and stability of the liquids has been studied under controlled operating conditions of the trials. Phosphoric acid of 54% P_2O_5 has been used. Densities and P_2O_5 contents have been adjusted by controlling the proportions of water, ammonia and acid introduced into the reactor vessel.

The results show that it is possible to attain a concentration of liquid fertilizer (10.8 - 37 - 0) without affecting its stability. However, the N/P ratio should be maintained at 1.5 or slightly below.

For drawing conclusions on the behaviour of the liquids, stable samples of liquids have been acidulated by adding phosphoric acid of 54% P_2O_5, and the changes of physical properties have been observed.

The final conclusions derived from the tests confirm that it is possible to produce stable liquid NP fertilizers when using phosphoric acid containing impurities: MgO in small quantities, but Al_2O_3 and Fe_2O_3 in remarkably higher proportions. The presence of acyclic polyphosphoric acids in the SPA is deemed responsible for the stability of the products.

Reaction conditions considered optimal are:

N/P ratio in the reactor 1.4 to 1.5 at pH 5.7 to 6.1
in the product 1.45 to 1.5 at pH 5.9 to 6.1

The maximum concentration of nutrients of a stable liquid product was (10.8 - 37 - 0).

Technical Paper No.22
ABSTRACT
Original: French

The Prospects of Mechanization of Open Cast Mines
by Tahar Mahari (CPG)

Data on the development of CPG's mining operations since 1977 and the forecast till the year 2000 indicate that the total output increased from 5.1 million tons to 8.1 million tons in 1984 and is posed to reach 11.3 million tons in 2000. The respective proportions of underground vs. open cast mining are 80/20 (1977), 39/61 (1984) and 9/91 percent (2000).

Over the past years the mining methods applied in the underground mines have changed. The most significant change is the decreasing share of classical (traditional) methods recorded between 1976 and 1984, from 55.9 to 10.2%, while the LHD method (Load-Haul-Dump) has increased from 7.6 to 41.3%. The share of other methods applied such as scrapage, long wall face cutting, SLS (Sub-Level-Stoping) changed slightly only by few percentage points, whereas that of preparation mining ranged from 13.1 to 13.7, with its lowest level of 10.3% in 1980.

The productivity of underground mining in terms of t/HP has been evaluated. As compared to the traditional methods, which yield 3.5 to 5 t/HP, the improved up-to-date methods LHD, SLS and Long Wall Face Cutting provide much more favourable outputs with ranges attained: LHD 8-15, SLS 10 t/HP.

Mechanization of mining has been introduced at all the 7 mining sites of CPG in Tunisia starting with Long Wall Face Cutting in one mine in 1970, Scrapage between 1972 and 1976 at three sites, LHD between 1975 and 1980 at 6 sites, and SLS in 1973 in one mine.

The mechanization of mining faces the following problems:

- Small size and variety of geological conditions of the deposits,
- Introduction of mechanization at too late stages,
- Too quickly implemented mechanization,
- Large diversification of new mining methods.

CPG did not acquire new mining technologies.

The mining conditions at the open cast mines are similar to those existing in the underground mines in the early seventies. The conventional methods applied are 10 years old, the geological conditions of the deposits vary considerably, and the reserves of mineable phosphates are small and scattered.

At present a number of measures are taken of have been proposed and are being studied with the aim of increasing the mining efficiency at the various sites, such as increasing the range of machines for limestone quarrying, installing of a dragline at DJELLABIA, using payloaders plus belt conveyors for sands at Ras Draa, etc..

In order to improve the mining conditions the following recommendations have been proposed:

- CPG should study the various mining methods available and select the smallest possible number for application;

- Trials should be carried out at locations which provide the most favourable operating conditions;

- The new methods selected should be taken as a basis for improving all the mining techniques applied by CPG.

Technical Paper No.24
ABSTRACT
Original: English

Brazil, Phosphate Fertilizer Industry, Price Aspects

by Jorge A.S. Mattos

Prices of fertilizers in Brazil declined during the period 1965 to 1971. Thereafter they increased and doubled in 1974. This increase was due to higher cost of imported raw materials. In order to exercise control over fertilizer prices for the benefit of the farmers, the Government established in 1975 a price control system for NPK products. It was expanded in 1979 to cover also basic fertilizers and their raw materials.

The method of Government price control consists of determining a standard structure of production cost to which an allowance is added which takes into account the repayment of fixed assets and working capital. In view of the heavy inflation prevailing in Brazil, which is of the order of 200% per year, price adjustments are made on a quarterly basis.

The Government's efforts to curb inflation and to decrease the prices of food resulted in reducing the prices of fertilizer raw materials and fertilizers since 1978.

Phosphate Rock: The price (FOB Mine) was US$ 54 per ton in 1978. It increased to US$ 67 per ton in 1981 and in 1985 it has fallen to US$ 32 per ton.

Phosphoric Acid: The FOB price in 1978 was US$ 430 per ton (P_2O_5 basis). It increased to US$ 615 per ton and dropped to its present level of US$ 326 per ton.

Phosphate Fertilizers: In 1978 and 1979 prices remained at the same level because they were controlled by the Government. Later, when the control was discontinued, the prices increased significantly. The control was, however, re-imposed in 1983 and then the prices declined virtually to their prior levels, as shown below.

	1987	1980	1985
TSP	190	280	190
MAP/DAP	260	370	265

After start-up all projects implemented in Brazil have technically been improved in order to increase their efficiency. Market conditions were favourable and thus it was possible to operate the raw materials producing units above design capacity. Both state and private companies have joined in the national effort to provide fertilizers to the farmers at low cost through regionalizing the production and distribution of appropriate types of fertilizer based on the nearest source of raw materials. These measures are expected to bring about a significant reduction of transportation costs.

While considering the market demand and availability of mineral resources the Brazilian phosphate industry has a good potential for increasing the supply of raw materials, provided remunerative prices are determined by the Government. The presently offered prices hardly cover the production costs.

Technical Paper No.25
ABSTRACT
Original: English

Characterization and Beneficiation Studies of Low Grade Phosphate Ores from Chile
by Pedro Pavlovic Zuvic

CORFO, an agency of the Government of Chile, has conducted a development programme to evaluate the potential of indigenous phosphate rock resources. Two deposits, namely Mejillones and Bahia Inglesa have been identified. Evaluation has been carried out by the International Fertilizer Development Centre (IFDC), USA, and Brazilian Companies Serrana and Natron.

The Mejillones Deposit was located in 1978 and is situated 37 km north of Antofagasta city. The deposit extends over an area of 15 km^2 and has a thickness of 3 meters. The ore reserves are 56 million tons with a content of 6% P_2O_5. The overburden is soft and has a waste/ore ratio of 3.5 to 1.

The Bahia Inglesa deposit was discovered in 1982 and is situated 876 km north of Santiago. Two beds are present, which are of conglomerate type. One bed has an average content of 18% P_2O_5.

Minerological analyses of Mejillones samples show phosphate as carbonate-fluorapatite amounting to less than 30% by weight. The gangue minerals present are plagioclase feldspar (30%), quartz (20%), actinolite (8%) and biotite plus chlorite (6%). The apatite is in both organic and inorganic form, which has an analysis of 28% P_2O_5 owing to the presence of quartz and feldspar as endogangue.

Beneficiation studies including pilot plant investigations have been carried out. By flotation the material was upgraded to 22% P_2O_5 with a recovery of 72% as the best result achieved. The estimated overall recovery proposed for beneficiation is in the range of 50-55% of P_2O_5. This can be achieved in two steps. The first step by hydrocyclone, which yields the coarse fraction (minus 65 mesh plus 200 mesh) with a P_2O_5 content of 11.6% and SiO2 at 36.1%. The second step is to be performed by flotation using cationic or anionic silica flotation.

A number of studies have been conducted to evaluate the suitability of these concentrates for production of SSP or wet phosphoric acid. The results obtained were not encouraging because of serious technical problems encountered. Therefore, investigations have been undertaken to identify the suitability of these concentrates for direct application to the soil. Green house agronomic studies show that this material can directly used as fertilizer, particularly in acid soils in South Chile.

CORFO is considering to set up a commercial plant to produce for the domestic market a direct application concentrate or alternatively a partially acidulated phosphate rock, at the rate of 20,000 tons P_2O_5 per year. A similar development programme for the Bahia Inglesa phosphate deposit for manufacturing a potential product is progressing.

Technical Paper No.26
ABSTRACT
Original: French and English

Attempt for a Rational Approach of Roch Phosphates Utilization in Agriculture
by Truong Binh

Rock phosphates have different degrees of solubility and availability. Their behaviour depends on

- Rock characteristics, minerology, crystallography, solubility in various reagents;

- Reactions with soil types, particularly with their acidity;

- Utilization conditions: water regime, phosphate particle size, application mode.

Generally two parameters are used to evaluate the efficiency of rock phosphate. One is the solubility co-efficient in comparison with 100% water soluble P_2O_5 as in industrial grade TSP and the second is the availability co-efficient in comparison with TSP.

Studies have been conducted on West African phosphate rock taken from deposits of ARLI, KODJARI, TAHOUA, TAIBA, TILEMSI, TOGO, RENO. Both solubility and availability co-efficients vary between deposits with the type of rock and also between layers of the same deposit. RENO phosphate from GAFSA in Tunisia, followed by TILEMSI in Mali have given highest results. Studies on MADAGASCAR phosphates show that they have rapid reactivity, equivalent or superior to TSP.

The types of soil have a considerable influence on the agronomic efficiency of rock phosphate. Phosphate rock has a higher solubility index in acid soils than in neutral or near-neutral soils.

Soil humidity studies on the effect of soil humidity on phosphorus up-take, carried out on West African phosphates show that the effect varies with the type of rock. For soluble phosphates such as TSP or RENO the maximum efficiency is reached already with 25% Water Retention Capacity (WRC), with less soluble phosphates the efficiency increases significantly when the WRC increases from 25 to 50%.

Particle size studies carried out on West African phosphate rock show that rock ground to particle size of 0.1 mm gives a significantly higher efficiency than that of 0.5 mm particle size. If the particle size is above 0.5 mm generally there is no effect. Between 0.5 and 0.1 mm the gain of efficiency is around 17%. It is, however, not useful to

grind finer than 0.1 mm as the geometric surface of particles represents then only 5% of the total reactive surface owing to opening of the porous structure of the phosphates.

Farmers face constraints in the direct use of phosphate rock powder owing to its dustiness, difficult and hazardous spreading, and high initial investment for high rate of application because there is only a little perceptible immediate effect of fertilization.

Trials done by mixing the phosphate rock with small quantities of soluble phosphates (TSP) show some very positive improvement even with hard phosphate rocks like ARLI, KODJARI, TAIBA and TOGO. The effects depend on soil types. Gains range between 10 and 70%.

Partially acidulated phosphate rock with sulphuric acid gives the following advantages:

- Improvement of the availability of the phosphate nutrient component of the rock with immediate effect;

- Possibility of granulation without losing efficiency;

- Maintaining the fertilizer cost at an acceptable level.

Studies conducted in green houses and field trials with KODJARI and TOGO phosphate rock confirm these advantages. Field studies on TOGO rock extended over two years (1983/84) on crop cultures such as cotton (1983 - 47 blocks, 1984 - 38 blocks), maize (1983 - 21 blocks, 1984 - 22 blocks), sorghum (1983 - 13 blocks, 1984 - 11 blocks), groundnut (1984 - 44 blocks). In general the availability co-efficient with 29% acidulation was 90% and only in a few cases it was 70% or less.

ANNEX C

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UNIDO Consultant	PANFIL Sylwester R. UNIDO Vienna (DIO/CHEM) (address as above)
UNIDO Consultant	JAGGI Trebhawan Nath 507 Hemkunt Tower Nehru Place New Delhi-110019 (Office)

ANNEX D

LIST OF DOCUMENTS

I. TECHNICAL PAPERS REPRODUCED BY UNIDO

SYMBOL	TITLE (Original English or French)	AUTHOR(S), ORGANIZATION, COUNTRY
ID/WG.453/1	The role of impurities in determining the performance of phosphoric acid manufacture by the hemihydrate process	Norman Robinson Norsk Hydro Fertilizers Ltd. United Kingdom
ID/WG.453/2	Maximizing the share of domestic raw materials in developing the phosphate fertilizer industry	Matti Sinnemaa Kemira Engineering Finland
ID/WG.453/3	Production cost comparison between nitrophosphate and phosphoric acid based fertilizers	Marcel A. Tanke Stamicarbon BV Netherlands
ID/WG.453/4	World phosphate fertilizer supply/demand trends	Gene Harris International Fertilizer Development Centre USA
ID/WG.453/5	Research and development for phosphate recovery and phosphate fertilizer production from iron ore concentration tails at Sierra Grande, Argentina	Makoto Kuwabara UNICO International Corp. Japan, and Hector F. Pastorino HIPASAM, Argentina
ID/WG.453/6*	Optimizing resources for the development of Indian phosphate fertilizer industry	B.K. Jain Fertilizer Association of India, India
ID/WG.453/7	La maintenance dans les usines d'engrais	Abdelkefi Fethi Industries Chimiques Maghrèbines, Tunisie

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Note * : Presented as Country Paper on India

ID/WG.453/8	Valorisation d'un phosphate carbonaté. Problèmes posés par la structure en agrégats. Solutions adoptées.	Lahmadi Kamel and L. Yakdhane Compagnie des Phosphates de Gafsa, Tunisie
ID/WG.453/9	Récupération de phosphate dans les rejets fins des laveries	Htiwech Ali Compagnie des Phosphates de Gafsa, Tunisie
ID/WG.453/10	The supply and demand outlook for phosphoric acid in fertilizers	K.F. Isherwood International Fertilizer Industry Assoc., France
ID/WG.453/11	Nouveau procédé de valorisation par flottation de minerais de phosphate à exogangue siliceuse et/ou carbonatée	Neffati Hédi, Yakdhane Lazhar Compagnie des Phosphates de Gafsa, Tunisie
ID/WG.453/12	Redressement des mines souterraines de la CPG par l'utilisation directe du brut dans la fabrication d'acide phosphorique	Mohamed Abbes Compagnie des Phosphates de Gafsa, Tunisie
ID/WG.453/13	Exploitation and use of low grade phosphate rock - Indian experience	T.N. Jaggi (for UNIDO) Pyrites, Phosphates and Chemicals Ltd., India

II. TECHNICAL PAPERS SUBMITTED BY PARTICIPANTS

(REPRODUCED AT THE MEETING BY CPG)

NUMBER **	TITLE (Original English or French)	AUTHOR(S), ORGANIZATION, COUNTRY
14	La gestion des utilitès dans les usines d'engrais	Mouldi Alouane Industries Chimiques Maghrèbines, Tunisie
15	Phosphates tunisiens et souffre: prospections pour l'avenir	Ezzedine Jemaa Industries Chimiques Maghrèbines, Tunisie
17	Aspects of natural environment protection through fluorine recovery in the production of phosphate fertilizer	P. Rozwadowski NIEORGANIKA Association of the Inorganic Chemicals Industries, Warsaw Poland
19 ***	HUMIFERT - Simplified manufacturing of binany fertilizer with humus HUMIFERT - Fabrication simplifiée d'engrais binaire à l'humus	F. Sternicha SOFRECHIM Paris France
20	Concentration, superconcentration et purification de l'acide phosphorique obtenu à partir du phosphate de Gafsa selon le procédé SIAPE (Société d'Industrie d'Acide Phosphorique et Engrais)	Noureddine Turki, Ben Mansour SIAPE Tunisie
21	Fabrication d'engrais liquide	Mohamed Sabbah, B. Damak SIAPE, Tunisie
22	Mécanisation des mines à ciel ouvert	Tahar Mahari Compagnie des Phosphates de Gafsa, Tunisie

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Note: ** Papers numbered 16, 18 and 23, included in the provisional list have not been submitted.

*** Both English and French versions are available.

24	Brazil, Phosphate fertilizer industry, price aspects	Jorge A.S. Mattos IBRAFOS (Instituto Brasileiro do Fosfato), Brazil
25	Characterization and beneficiation studies on low grade phosphate ores from Chile	Pedro Pavlovic Zuvic Comitè de Sales Mixtas CORFO, Santiago, Chile
26 ***	Essai d'une approche raisonnèe de l'utilisation des phosphates naturels en agriculture Attempt for a rational approach of rock phosphate utilization in agriculture	Binh Truong IRAT-CIRAD Montpellier, France

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Note: *** Both English and French versions are available.

III. COUNTRY PAPERS (CONFERENCE ROOM PAPERS)

PRESENTED TO THE MEETING BY UNIDO INVITEES

NUMBER	TITLE (Original English or French)	AUTHOR, ORGANIZATION, COUNTRY
CRP No.1	Achievements of the Polish phosphate industry	P. Rozwadowski NIEORGANIKA Warsaw, Poland
CRP No.2	The development of the phosphate industry in Vietnam	Vu Tai Hai Fertilizer Industry General Department of Chemistry Hanoi, Vietnam
CRP No.3	The Brazilian phosphate industry	Jorge A.S. Mattos IBRAFOS (Instituto Brasileiro do Fosfato), Brazil
CRP No.4	Phosphate fertilizer market in Chile	Pedro Pavlovic Zuvic Comité de Sales Mixtas CORFO, Santiago, Chile
CRP No.5	Phosphate industry in Bangladesh	M.U.A. Chowdhury TSP Complex Ltd. North Patenga, Chittagong, Bangladesh
CRP No.6	Phosphate fertilizer industry in Turkey	Bahattin Aygun UNICO Int. Corp. Ankara, Turkey
CRP No.7	The development of phosphates and phosphate fertilizer industry in China	Zhang Kaiyan Chemical Planning Institute of China
CRP No.8	Status of the development of phosphates and phosphate fertilizer industry in Tanzania	K.L. Haule Tanzania Agricultural Research Organization (TARO)

CRP No.9	Développement de l'industrie des phosphates et des engrais phosphatés	Jean-Marie Houssou Société des Engrais du Bénin
CRP No.10 ***	The Fertilizer Association of India (FAI)	B.K. Jain The Fertilizer Association of India, India
CRP No.11	Production of phosphatic fertilizer in Pakistan	S. Shaukat Kazmi Ministry of Industries Islamabad, Pakistan
CRP No.12	Situation sur les phosphates naturels au Niger	Issa Harouna Ministère de l'Agriculture Niamey, Niger

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Note: **** See also paper No. ID/WG.453/6

IV. OTHER PAPERS FROM VARIOUS SOURCES MADE AVAILABLE TO THE PARTICIPANTS

SYMBOL LANGUAGE	TITLE	AUTHOR(S), ORGANIZATION, COUNTRY
UNIDO ID/209 No.8 E + F	Process Technologies for Phosphate Fertilizers (Development and Transfer of Technology Series) Procèdès de Fabrication des Engrais Sèrie "Mise au point et transfert des techniques"	UNIDO, Vienna, Austria
E only	Granular Fertilizers and their Production Engrais granulès et leur fabrication	The British Sulphur Corp. Ltd London, United Kingdom
UNIDO/IS.533 E only	Utilization of the Phosphogypsum produced in the Fertilizer Industry Valorisation du phosphogypse fabriquè dans l'industrie d'engrais	UNIDO, Division of Industrial Studies Vienna, Austria
UNIDO IDO/INF/75 E + F	UNIDO Facts and Figures UNIDO Faits et Chiffres	UNIDO, Vienna, Austria
	The Recovery of the Lanthanides from Phosphate Rock	Fathi Habashi Department of Mining and Metallurgy, Laval University Quebec City, Canada
	Trends in Fertilizer Technology and its Impact on the Environment	Fathi Habashi Department of Mining and Metallurgy, Laval University Quebec City, Canada