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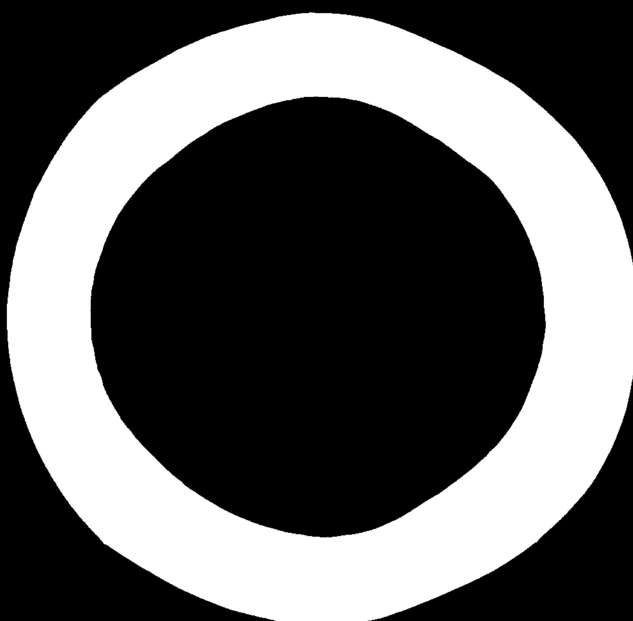
FACTORS INHIBITING THE INDIGENOUS GROWTH OF THE FERTILIZER INDUSTRY IN DEVELOPING COUNTRIES

UNITED NATIONS



UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
VIENNA

FACTORS INHIBITING THE INDIGENOUS GROWTH OF THE FERTILIZER INDUSTRY IN DEVELOPING COUNTRIES

Report of the Ad Hoc Group of Experts from Fertilizer-Deficit Countries

UNIDO Headquarters, Vienna
6–10 May 1968

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EXPLANATORY NOTES

Reference to tons is to metric tons unless otherwise stated.

Reference to dollars ($) is to United States dollars unless otherwise indicated. One mill equals $0.001.

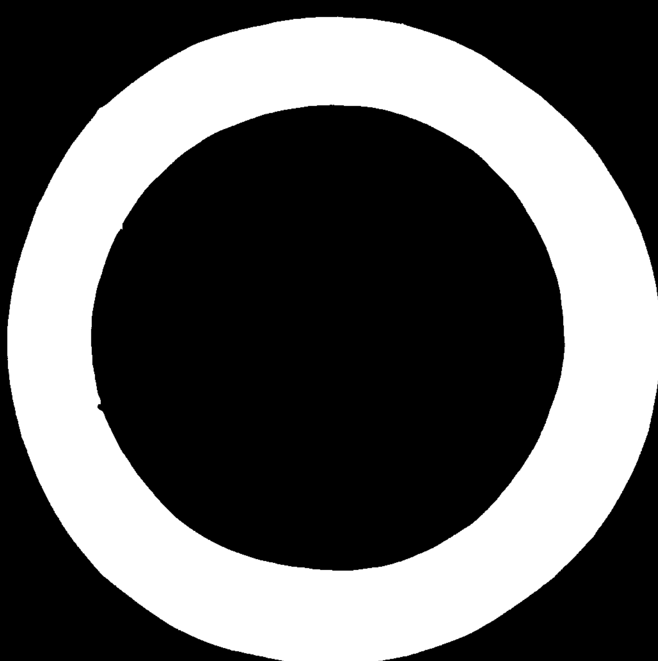
A one-year period that is not a calendar year is indicated as follows: 1965/1966.

A period of two years or more is indicated as follows: 1965–1966, 1965–1968 etc.

Details and percentages in tables do not necessarily add up to totals because of the use of round figures.

The following abbreviations have been used:

AN	=	ammonium nitrate (or diluted as calcium ammonium nitrate)
c. i. f.	=	cost, insurance and freight
DAP	=	diammonium phosphate
E£	=	Egyptian pound ($1 = E£0.348)
f. o. b.	=	free on board
kg	=	kilogram
km	=	kilometre
km^2	=	square kilometre
kVA	=	kilovolt ampere
LNG	=	liquefied natural gas
m	=	metre
m^3	=	cubic metre
MAP	=	monoammonium phosphate
MAP/DAP	=	monoammonium phosphate, diammonium phosphate or mixtures of the two
MF	=	mixed fertilizers (N-P mixtures in MAP/DAP)
MW	=	megawatt
NPF	=	nitrophosphate fertilizers
psig	=	pounds per square inch gauge
S£	=	Sudanese pound ($1 = S£0.348)
SSP	=	single superphosphate (normal superphosphate)
t/d	=	tons per day
TSP	=	triple superphosphate (concentrated superphosphate)



Preface

A meeting of an *ad hoc* group of experts from five fertilizer-deficit countries and consultants from five fertilizer-surplus countries was held at the headquarters of the United Nations Industrial Development Organization (UNIDO) in Vienna from 6 to 10 May 1968. The meeting, organized by UNIDO, reviewed the factors inhibiting the indigenous growth of the fertilizer industry in developing countries. The agenda of the meeting is presented in Annex 3 to this report.

This publication consists of two parts: Part I, the Group's report and recommendations; and Part II, the working papers presented at the meeting. (The views and opinions expressed in the working papers are those of the individual authors and do not necessarily reflect the views of the secretariat of UNIDO.) In addition certain papers were presented to the meeting as background for discussion.[1]

Experts from the fertilizer-deficit countries of Brazil, India, Mexico, the Sudan and the United Arab Republic attended the meeting. Consultants from the fertilizer-surplus countries of Austria, the Federal Republic of Germany, Japan, the United Kingdom and the United States participated. UNIDO was represented by Mr. I. H. Abdel-Rahman, the Executive Director; Mr. N. K. Grigoriev, Director of the Industrial Technology Division; Mr. M. D. Verghese, Chief of the Fertilizers, Pesticides and Petrochemical Industries Section and five experts from this Section. The list of participants is given in Annex 2.

Mr. N. K. Grigoriev in opening the meeting described UNIDO as a catalyst and an international servicing institution to assist the efforts of the developing countries to industrialize rapidly and successfully.[2]

Mr. Taha Zaky, Managing Director of Egyptian Chemical Industries (KIMA), United Arab Republic, was elected Chairman of the meeting.

The Expert Group, at the conclusion of its work, reviewed the draft outline of the report of the meeting and generally approved the recommendations presented in paragraphs 69 to 93 of the report, though noting specific reservations of the consultant from the Federal Republic of Germany.

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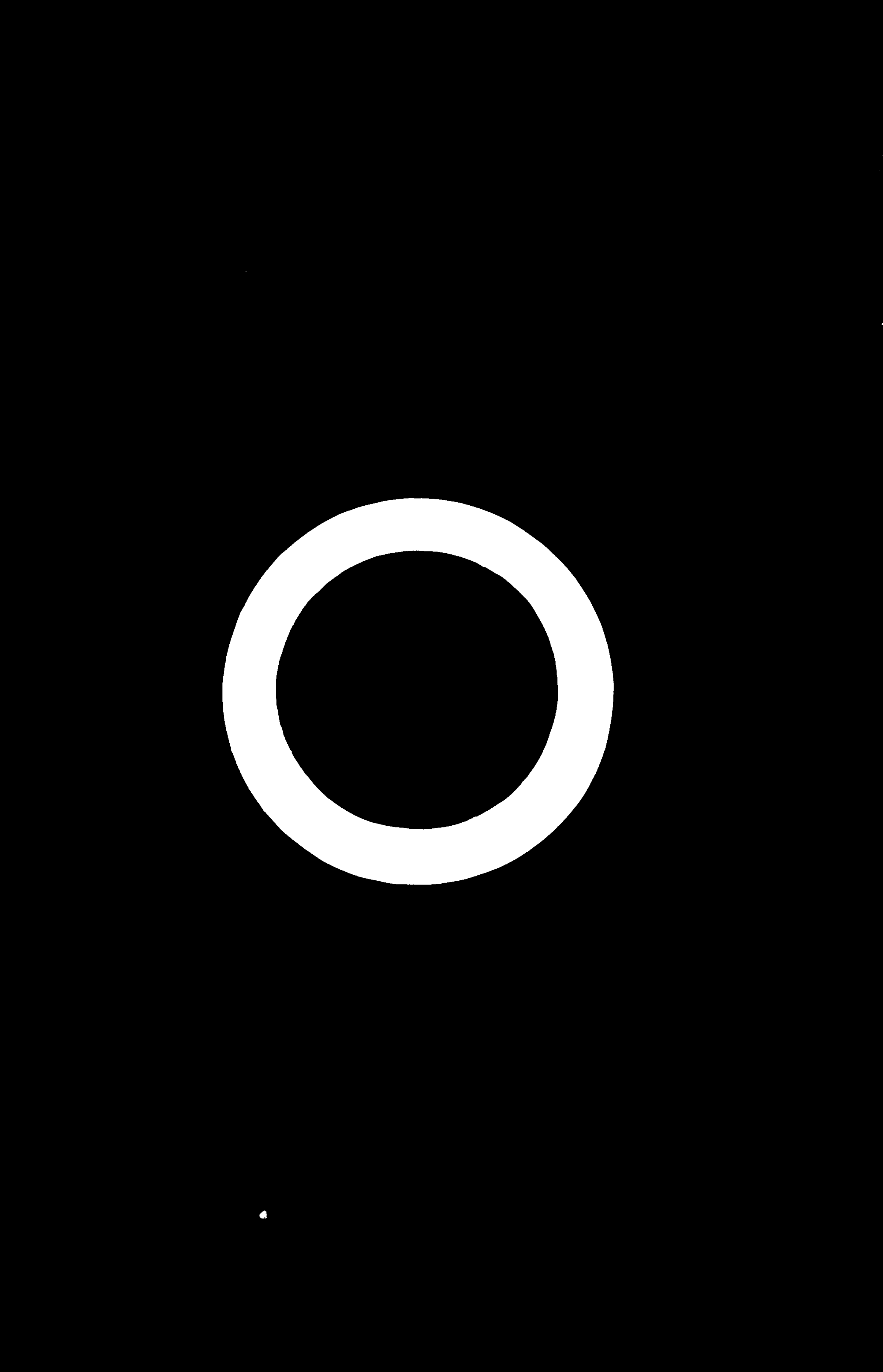
[1] These papers are listed in Annex 4.
[2] The full statement is reproduced in Annex 1.



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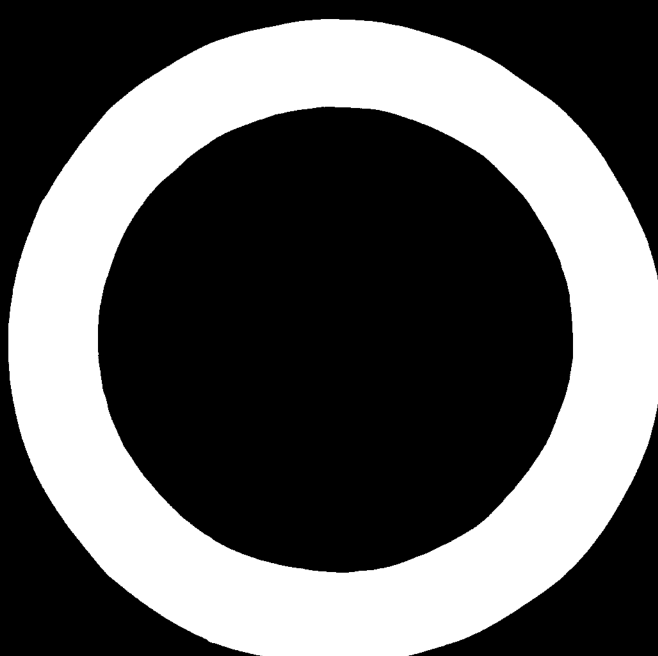


Part I

REPORT AND RECOMMENDATIONS

INTRODUCTION

1. The meeting of the group of experts and consultants from fertilizer-deficit and fertilizer-surplus countries was a follow-up of:

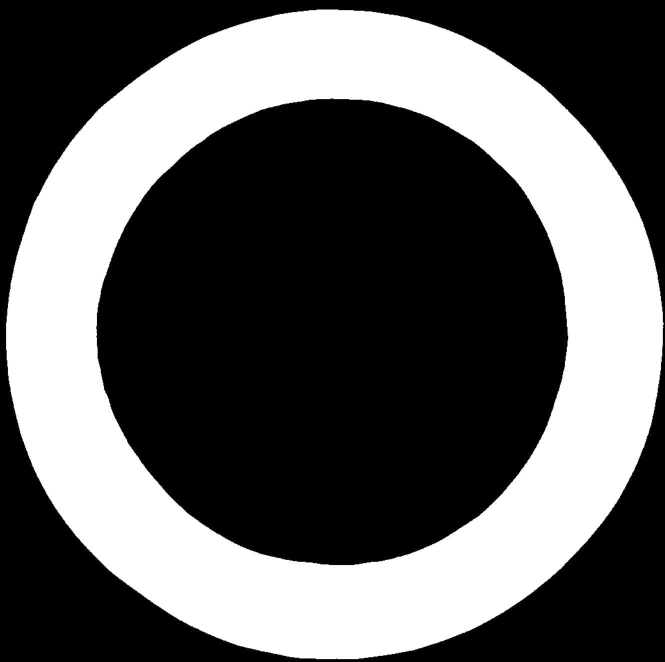
(*a*) A suggestion by an *Ad Hoc* Expert Group meeting on fertilizer production in six selected countries with good natural gas resources held at United Nations Headquarters from 9 to 16 December 1966 that another *Ad Hoc* Expert Group from fertilizer-deficit countries be convened to discuss this topic with respect to certain developing countries;

(*b*) A recommendation adopted by the International Symposium on Industrial Development held in Athens from 29 November to 20 December 1967 that "UNIDO should take action to provide opportunities for those concerned with the development of fertilizer industries to meet at regional as well as sectoral symposia to compare their programmes and suggest measures for improvement".

2. The purpose of the meeting was not only to discuss obstacles to the growth of the fertilizer industry in certain developing countries but also to discuss difficulties in importing the required quantities and types of fertilizer until local production is built up to meet requirements and to suggest possible remedies for both sets of problems.

3. At the concluding session, the Executive Director of UNIDO, Mr. I. H. Abdel-Rahman, expressed the belief that more rapid progress would be assured through undertaking specific projects, however small, rather than by holding global discussions on policy. This Group could be an instrument through which developing countries could make their needs known to UNIDO quickly.

4. The Group's discussions and recommendations are reported in the ensuing pages of Part I.



REPORT OF DISCUSSIONS

LACK OF CAPITAL FOR THE PURCHASE OF EQUIPMENT AND KNOW-HOW

5. Fertilizer is the most important of the many inputs that can increase agricultural yields.

6. The low level of fertilizer use in most of the developing countries is clearly shown by the following table, in which all countries having a population of 5 million or more are classified in five levels according to their *per capita* fertilizer consumption in 1966/1967.

Table 1

Per capita CONSUMPTION OF FERTILIZER IN COUNTRIES HAVING A POPULATION OF 5 MILLION OR MORE

Level of fertilizer consumption (kg)	*Number of countries*	
	Developed	*Developing*
Very high (51 to 100)	9	0
High (26 to 50)	9	1
Medium (11 to 25)	6	7
Low (6 to 10)	0	7
Very low (0 to 5)	0	35

7. The basic conclusion to be drawn from these figures is that most of the developing countries have not yet begun to use fertilizer in amounts approaching either the level of the developed countries or the level that they should reach merely to produce the food and other agricultural products they need for both domestic consumption and export. Unless food production is increased substantially, a serious food shortage will probably occur in many developing countries by 1980, or even sooner in some of the more vulnerable countries.

8. Although several programmes should be carried out concurrently to avert or at least alleviate the impending food crisis in Asia, Africa and Latin America, one that should be accelerated as rapidly as possible, and that will be particularly important in the 1970s and 1980s, is the expansion of the fertilizer industry in fertilizer-deficit countries.

9. Fertilizer production goals for 1970 will probably not be attained in many of the developing countries. Now is the time to begin serious planning and policy making to achieve the essential production targets for 1975 and 1980. This will require vast sums of both foreign exchange and local currency for capital investment.

10. The consensus of the Expert Group was that lack of capital, largely in terms of foreign exchange but also in terms of the local currency, is the basic factor limiting the expansion of the fertilizer industry in developing countries. Since approximately half the capital necessary for most large construction projects must be in foreign exchange and most current loans require an equity participation in the project of about 10 per cent in foreign exchange, it is evident that a vast reservoir of foreign exchange credits for the developing countries is needed. Also, because even the relatively small amount of foreign exchange needed for equity participation in most loans may be difficult to obtain in most developing countries, it is essential that more funds be made available through agencies like the International Development Association (IDA) that may provide all the foreign exchange capital in the form of a loan.

11. For almost two decades, the problems of financing industrial expansion in developing countries have been under continuous discussion by expert groups, seminars and symposia of various international organizations, but no solutions appear to have been found. Careful examination shows that the three main sources of external financing, namely, bilateral, multilateral and private investment, have proved inadequate to meet the requirements of development.

12. For example, with respect to fertilizer plants India's sources of capital in Japan, Italy and the United Kingdom are almost exhausted. France and the Federal Republic of Germany may be sources of capital in the period of the Fifth Five-year Plan but only for moderate amounts. Major undertakings in the fertilizer industry, therefore, will probably have to be financed largely by the United States, the Union of Soviet Socialist Republics and the World Bank. The Government of the United States and the World Bank are apparently still opposed to granting loans to India for fertilizer plants in the public sector. The Soviet Union has not, up to the present, assisted India in any fertilizer projects. Therefore, it seems likely that any large flow of capital into India for further development of the fertilizer industry will have to be for projects in the private sector, although assistance for projects in the public sector may come from countries with centrally planned economies. This state of affairs prevails in most of the developing countries.

13. The principal sources of foreign exchange capital for fertilizer projects in the developing countries during the past ten to fifteen years have been:

(*a*) The countries' own foreign exchange reserves;

(*b*) Foreign private firms;

(*c*) Foreign banks;

(*d*) Credit from suppliers of equipment, backed by government guarantee.

14. Although great in number, international lending agencies and governmental

foreign aid agencies have been a relatively minor source of foreign exchange capital. It is notable also that the countries with centrally planned economies have been an extremely small source of capital for such projects. The principal sources of foreign exchange capital have been the Federal Republic of Germany, France, Italy, Japan, the United Kingdom and the United States.

15. The most prolific source of foreign exchange equity capital in the years ahead will most likely be foreign private firms. Developing countries wanting to create or expand their fertilizer industries, therefore, should try to make their policies relating to foreign private investment as attractive to potential investors as possible consistent with their particular economic, social and political philosophies.

16. In many cases suppliers of equipment from developed countries have obtained firm financial commitments from private financial institutions in their countries to permit them to extend credit to developing countries, but the Governments of the developed countries have withheld guarantees of the proposed credits; this has resulted in the abandonment of the transactions.

17. In other cases where bilateral loans have been involved, the restrictions on the sources of procurement of raw materials and plant equipment have been so stringent that not only the cost of a project has risen but also its completion date has been unnecessarily extended many times. Tied loans have had an inhibitive effect when the lender would not permit the design and engineering to be done in the developing country although that country had adequate and appropriate facilities.

18. Many developing countries have set up so many unrealistic regulations regarding equity participation and have interfered in management policy, scope of operation, product pricing, etc., that private sources of capital from developed countries have been unwilling to participate in loans to developing countries. These barriers are tragic in that foreign private firms appear to be one of the most prolific sources of foreign exchange equity capital.

Problems relating to raw materials

19. Although the Expert Group realized that it may often be more costly for a developing country to produce fertilizer than to import it, some experts believed that as the ultimate goal, at least some, if not all, of the fertilizer-manufacturing steps should be performed in the developing countries. This goal is essential if a country is to develop and if foreign exchange is to be conserved – in short, if the country is to have an indigenous fertilizer industry. An industry starts with raw materials. Because of the vast quantities of fertilizer that are needed, the required quantities of raw materials are equally vast.

20. Fixed nitrogen is the first plant nutrient desired in a developing country because its use results in spectacular increases in crop yields. Although there are a few processes available for direct fixation of atmospheric nitrogen, most of the world's supply of fixed nitrogen is produced in the form of ammonia based upon hydrocarbon raw materials. These hydrocarbons include natural

gas, naphtha, fuel oil, and coal, with processing difficulties increasing in that order.

21. Although natural gas is the preferred raw material, naphtha appears to be the best compromise in the absence of local supplies of natural gas. It takes 86 tons of naphtha to produce 100 tons of ammonia. In a 600-ton-per-day ammonia plant, the production cost increases from 100 per cent at a 100 per cent on-stream factor to 145 per cent at a 60 per cent on-stream factor. Thus, an assured daily supply of naphtha is necessary if production costs are to be kept low. The same conclusions apply to other hydrocarbons used as raw materials for ammonia synthesis.

22. Of the three major plant nutrients, nitrogen, phosphate and potash, potash generally is the nutrient least likely to be in short supply. The cost per unit of K_2O is the lowest of the three primary nutrients; its purchase, therefore, least affects a country's balance of payments. Capital costs for the production of potash are much higher than for nitrogen or phosphate. With the current over-production of potash, however, it appears that this nutrient should cause no problems of supply.

23. The case of phosphate is different because most phosphate is made available as a plant food through reaction with sulphuric acid, so that the phosphate supply is tied to the sulphur supply.

24. Except in a few isolated cases, there is not enough electrical energy available in developing countries for electrothermal reduction processes to make a significant impact on the supply of phosphates for agriculture.

25. Many phosphate deposits have been found throughout the world, and more are being discovered every year. The availability of phosphate rock is not a critical supply problem. However, because of the shortage and increased cost of sulphur, the sulphur problem creates a phosphate problem. The fact that the United States sells sulphur for $40 per ton while Mexico sells it for $45 per ton is an example of the law of supply and demand. However, some countries have been forced to pay prices greatly in excess of current world prices.

26. Two processes that by-pass the use of sulphur were discussed at length. The first is the manufacture of sulphuric acid by means other than the classical brimstone method. The most promising of these appears to be the process whereby sulphuric acid is manufactured from gypsum by carbon reduction with cement as a by-product. Gypsum is a common commodity throughout the world, and the cement by-product apparently is needed by many developing countries. If a gypsum process also utilized the by-product gypsum from a phosphoric acid plant, the result would be a self-contained operation.

27. The second way to by-pass the use of sulphur is to solubilize rock-phosphate through one of the nitric phosphate processes. The newer processes, like the Norsk-Hydro and the Czechoslovak SCHZ processes, are capable of yielding products with a high degree of P_2O_5 water-solubility.

28. The nitrate form of nitrogen resulting from a nitric phosphate process has been found agronomically effective for all crops except rice in flooded culture, but recent data indicate that even here ammonium nitrate is effective.

Inadequacy of infrastructure

29. The Expert Group pointed out that the creation or expansion of a fertilizer industry in a developing country is a slow process beginning with a long period of gestation. If a plant is built too early, the size of the market may dictate an uneconomic scale of operation. If a country imports fertilizer in the early years to build up a growing agricultural market while using its capital resources to build infrastructure until such time as the market and the infrastructure can support a plant of economic scale, then the entire project has a much better chance of success. Most of the participants felt that the long period between conception and fruition indicates that the fertilizer industry should be treated as infrastructure in order to obtain long-term capital on a soft-credit basis.

30. "Infrastructure" encompasses the sociological and economic policy of a country. It includes therefore, the physical aspects needed for logistics, i. e. the transportation system, including roads, railways and airlines, and the communications system, including telephone, radio and telegraph. However, it also includes the will of a people to work as well as the extent of literacy within a country. For example, a country with advanced infrastructure can build a chemical products pipeline in seven weeks, from the conception of the idea to the commissioning of the project, whereas in a country with rudimentary infrastructure the same project would take seven years.

31. In developing countries the lack of suitable infrastructure lies at the root of delays in implementing projects. Farmers in a certain area may be taught how to increase crop yields substantially by the use of fertilizer only to find at harvest time that the crops cannot be moved fast enough to the market because of inadequate roads or freight-handling facilities. It does not suffice, therefore, to import machinery and up-to-date processes if the supporting infrastructure is lacking.

32. It would seem desirable to relate the growth of industrialization to the growth of infrastructure. In some developing countries a single superphosphate operation may be all the industrialization that the infrastructure can support. In other developing countries the infrastructure may be advanced enough to support a modern ammonia plant. As infrastructure expands through internal leadership, the indigenous development of the fertilizer industry will also expand.

Shortage of trained personnel

33. Most developing countries have individuals of high intelligence and with good academic training. But many of these persons have no practical knowledge about the day-to-day operation of plants because there has been no domestic industry. In such cases fellowships sponsored by UNIDO are of immense value. The fellowships make possible the practical training of qualified personnel in those industries upon which UNIDO projects are based—projects that will have a catalytic effect on the growth of a particular industry.

34. The fertilizer industry has its own special requisites in that it varies from

the highly mechanized ammonia and urea plants through the somewhat less complicated phosphoric acid plants to the single superphosphate plants.

35. Each type of operation requires its own category of training, not only at the managerial level, but also at the maintenance and operating levels. Moreover, supporting staff, that is, the quality control chemical group, must be trained. Fertilizer chemistry is complex because of its many variables. As a result, the analytical function consists of a large number of empirical methods not normally encountered in chemistry textbooks.

36. The Expert Group pointed out that, since so many of the developing countries have advanced beyond the first phase of construction and start-up and passed into the second phase of sustained operation, it should be feasible to train personnel in the more advanced of the developing countries. It seems likely that the training climate and the rapport between teachers and students will be better in a country in which the industry has only just gone through the problems facing the less-advanced countries.

37. Apparently, developing countries dislike buying know-how. Training programmes, however, can be part of a purchase agreement, whether the purchase is of equipment, such as ammonia compressors, or of raw materials, such as phosphate rock.

38. But training should not be limited to the technical side of a project. Contrary to general opinion, the availability of a commodity does not automatically generate a use for it. In the fertilizer industry, whose customers are the most conservative of people, the acceptance of fertilizer requires an extensive education programme. Such a programme requires trained market experts and agronomists. Therefore, it is important that the training of distribution personnel go hand in hand with the training of technical personnel.

Marketing inadequacies

39. The Expert Group pointed out that marketing inadequacies are one of the main obstacles to the growth of the fertilizer industry in developing countries.

40. As previously mentioned, the final customer, the farmer, is generally extremely conservative and in some countries even believes that fertilizer poisons the soil. In some developed countries there are farmers who believe that crops grown with the use of chemical fertilizer are not so nourishing as those fertilized with animal manure. Marketing, therefore, has to begin with education at the farmer level, using experts and agronomists who not only are knowledgeable in the science of fertilizer use but also understand the farmer's outlook.

41. Fertilizer must be treated as a capital input into the agricultural economy. Therefore, the prices paid for fertilizer and those obtained for farm produce must bear such a relation to each other that the farmer's profit will increase as he uses more and more fertilizer, up to the point of diminishing returns. In some developing countries this relation can be achieved only when the Government sets the prices both for fertilizer and for farm produce. In some parts of

India, as part of a marketing campaign, special price concessions are given to initiate fertilizer sales in new areas.

42. As with any commodity, there must be an incentive to sell fertilizer. Some countries allow so little profit on the sale of fertilizer that the dealer has no incentive to sell more.

43. Farmers generally do not have money to buy fertilizer until their crops have been harvested and sold. In many countries there is no credit system permitting the farmer to purchase fertilizer at planting time and to pay for it at harvest time. Some areas have begun to set up credit arrangements to permit such purchases, not by lending money but by providing paper credit in kind using 75 per cent of the land title deed as collateral.

44. If the farmer has to travel a long distance to obtain his fertilizer he may decide it is not worth the effort. It is necessary, therefore, to establish depots and warehouses so that the farmer is never more than a few hours' travelling distance from the nearest supply of fertilizer.

45. It is not enough to induce the farmer to buy fertilizer. He must be shown personally how and when to spread it, so that the proper coverage, measured in kilograms per hectare, can be obtained.

46. In many of the developing countries the land situation resembles that in India, where 70 per cent of the farms are less than one hectare in area, while 20 per cent are in the one-to-five-hectare range. For such small farms, even a single bag of fertilizer may be too much to use at one time. Under these conditions, the farmers must be educated to organize into groups sufficiently large to permit the purchase of fertilizer in economic quantities.

47. The Expert Group pointed out that with the limited means of transport available in most developing countries, fertilizer should be of the highest concentration practicable in order to decrease the unit weight handled for specific application rates. In many cases this creates an additional educational burden if, for example, the farmer has been using ammonium sulphate containing 21 per cent nitrogen and is asked to use urea containing 46 per cent nitrogen.

48. In developing countries where nitrogen, because its use produces such spectacular increases in crop yields, is the most widely used plant nutrient, special efforts should be made to utilize it in the most concentrated form consistent with its cost per unit. For this reason the use of anhydrous or aqua ammonia should be investigated. Again, the direct application of ammonia will involve new marketing techniques, a new method of distribution, and mechanical means of application.

Internal policies

49. The Expert Group noted with satisfaction that fertilizers are not subject to export duties. However, it was also noted that many developing countries have penalized the establishment of an indigenous fertilizer industry, or other industries, by imposing heavy import duties on the equipment needed for them, even when the equipment was obtained by means of a loan. In effect, this means

that the developing country is siphoning part of the loan from equipment purchases to other internal uses.

50. These developing countries also impose import duties on spare parts, supplies and raw materials for fertilizer plants, thereby hampering the operation financially. Such import duties exist even where no comparable spare parts, supplies or raw materials are available within the developing country. When this occurs in the public sector, the cost of production goes up. When this occurs in the private sector, not only does the cost of production go up but also the prospects for future investment deteriorate.

51. In many developing countries tariffs for power, water and other utilities are uneconomic. The Expert Group noted that where special concessions have been made regarding the tariffs for these services, fertilizer plants have been built far more quickly because of the more favourable investment climate.

52. An anomaly in the purchase of fertilizer by developing countries is that these purchases are often part of a seeding programme aimed at educating the farmer in the use of fertilizer in the hope that the market will be developed to a point where a plant large enough to achieve economies of scale can be built. In almost all cases such fertilizer is purchased on a spot tender basis. Generally, the tender offers coincide with the period of most intensive manufacture of fertilizer for internal use by the fertilizer-surplus countries who bid on the tender. As a result, many of the tender bids are not realistic because the potential supplier is not interested in taking on additional business at the time of the tender offer.

53. If the developing countries would try to establish long-term contracts for fertilizers, as they do for other commodities, the potential suppliers could offer them much more attractive prices because the suppliers could schedule the bid production as part of an over-all production programme, with the inherent manufacturing economies brought about by a uniform work load at their plants.

54. In most developed countries an intensive manufacturing and shipping season in the spring is followed by one of less intensity in the autumn. These fluctuations are caused by the demands of the local market. Some plants ship almost 90 per cent of their yearly output during two months in the spring and operate with reduced crews at part capacity for the rest of the year. Such plants would offer attractive prices in order to continue working during the off-season. In addition, the cost of spot tenders is increased because ocean-going vessels have to be found quickly.

55. The only known case of a long-term fertilizer purchase commitment discussed at the meeting was a special barter deal between Austria and Hungary.

Pricing policies and cost of production

56. Although the relation between fertilizer prices and those of farm produce was discussed as part of the general marketing philosophy, the Expert Group believed that the subject should merit special attention in a section devoted to pricing. It was noted that in developing countries that have subsidized fertilizer

prices the use of fertilizer has risen as a consequence. In other countries the same effect has been achieved by providing a bonus to the farmer for crop production beyond a stated tonnage. This level could be reached only by using more fertilizer. Even in developed countries like the United States where there is no subsidy for fertilizer, the Government maintains a fixed minimum price for agricultural products, which guarantees the farmer a given price for his produce regardless of the market price. On the other hand, countries like Australia and England provide price subsidies for certain classes of fertilizers that meet government specifications. Apparently, price support at either end of the agricultural programme is a necessity if farmers are to be stimulated towards high production targets.

57. Utilization of a by-product helps to lower the cost of production of the main product. The following examples were mentioned:

(*a*) During the manufacture of superphosphate or phosphoric acid, fluorine is evolved. The evolved fluorine normally is scrubbed out of the effluent gases to minimize air pollution. However, if the scrubbed fluorine is reacted with common salt, an efficient insecticide and fungicide, sodium fluosilicate, results. In some cases the scrubbing water is concentrated to yield a 25 per cent fluosilicic acid, which can be used to fluoridate drinking water with the aim of preventing tooth decay.

(*b*) A by-product of wet-process phosphoric acid manufacture is gypsum. In Japan, this gypsum is used as a raw material for the manufacture of wall plaster and building products. In other cases gypsum is used as a fertilizer for groundnuts. In still other cases gypsum can be utilized as a raw material for a combination sulphuric-acid-cement process.

(*c*) Carbon dioxide is a by-product of the manufacture of ammonia. Although not strictly in the by-product category in this case, CO_2 is a raw material for the manufacture of urea. Carbon dioxide can be collected and processed into a solid as "dry ice" with potential for refrigeration especially during air transport, because dry ice leaves no residue. Carbon dioxide and ammonia can be reacted with gypsum to yield ammonium sulphate and calcium carbonate.

Inadequate project planning and execution

58. The Expert Group pointed out that new fertilizer projects require expertise of a high order, especially during the planning stage and continuing through the construction and start-up phases. They believed that UNIDO could perform a most valuable service in this respect by ensuring that the experts brought in for planning were able to visualize the entire project with all its ramifications.

59. In many cases projects have been located near the source of raw materials, but the markets have proved to be too far away for the ready disposal of the products. Other projects have been located in areas lacking a good source of water. In other instances the Government of the developing country wanted a

project in a special area in order to initiate industrialization there with no regard to markets, utilities or the availability of personnel.

60. The success of a project depends upon the mutual accord between the Government of the developing country and the planning group responsible. For liaison in this area the Expert Group believed that experts from developing countries would be particularly valuable. The consensus was that UNIDO should approach the developing countries for dossiers of appropriate personnel from which a roster of experts could be drawn up to augment rosters from the developed countries.

61. It was pointed out that many developing countries do not realize that they pay excessively for projects by insisting on too rigid turn-key contracts. The more rigid the turn-key contract, the higher the contingency fee that a contractor includes in his bid to ensure that he will be able to guarantee performance.

62. The Group felt that fertilizer projects would benefit from the advice of agronomists in the early planning stages to ensure the correct ratio of product mix in the fertilizer produced. For example, a urea plant located in an agricultural area where foliar feeding is common will require processes that result in urea of low biuret content, since biuret is a toxic element in foliar sprays. The nutrient requirements of the region must also be known when planning a mixed fertilizer project so that the proper ratio of nitrogen to phosphate capacity can be determined.

63. In some countries where plants have been erected without agronomic planning, it was found after the plant was on stream that the farmers would not use the product because the product mix was different from what they had previously been using.

64. It was pointed out that, although economy of scale is important in reducing production costs, especially in the case of ammonia plants, it is uneconomical to built a large plant that may have to operate at partial capacity for years until the demand rises to meet the full capacity.

65. A consultant indicated that in cases where there is no limitation of production owing to demand, a modern total energy ammonia plant in an industrialized European country could increase output from 60 per cent to 90 per cent during the first four years of operation, while in a developing country the same plant would be able to increase its operating factor only from 40 per cent to 80 per cent over the same period. A plant or process too sophisticated for the economy of the region may never reach an economic level of operation.

Lack of effective regional co-operation

66. The advantages of regional co-operation as against individual national efforts in the indigenous development of a fertilizer industry were emphasized. If the economies of scale indicate a 1,000-ton-per-day ammonia plant near a source of cheap natural gas based on an export market, it is obvious that regional co-operation is needed if the operation is to succeed.

67. Simple economics dictate that if country A has phosphate rock and country B has cheap natural gas, it will be to their mutual advantage for country A to manufacture superphosphate for both itself and country B, and country B to manufacture ammonia and/or nitrogen fertilizers for both itself and country A. With the larger market, each country can build plants that utilize economy of scale. Without co-operation, the insistence on having both nitrogen and phosphate plants within each country could result in the failure of both projects in both countries. For developing countries to expand industrially there must be a strong feeling of national pride, but this feeling must be tempered at times if regional co-operation is to succeed.

68. The problem of regional co-operation appears to be at least as complex as that of financing. The Expert Group believed that these two problems are sufficiently similar and important for the United Nations to take the lead in finding a solution to them. The Expert Group thought that a special committee should be set up to diagnose, prescribe and implement a practical means for (*a*) financing the expansion of the fertilizer industry in developing countries, and (*b*) studying regional groups of developing countries so that these groups can make a greater effort to collaborate in solving their fertilizer supply problems.

RECOMMENDATIONS[1]

LACK OF CAPITAL FOR PURCHASE OF EQUIPMENT AND KNOW-HOW

69. The Expert Group *recommends* that immediate steps be taken by the United Nations to ensure the implementation of the UN recommendations of 1960 that the developed countries allocate 1 per cent of their gross national product *per annum* for financing development in the developing countries. It further recommends that a larger share of foreign aid funds be allocated to ensure a more rapid and continuous development of the fertilizer industry, reminding the United Nations at the same time that fertilizers are one of the most important factors in food production.

70. The Group *recommends* that the United Nations, UNIDO, the International Bank for Reconstruction and Development (IBRD) and other international institutions take immediate action to implement the recommendation of the UNIDO Symposium held in Athens in December 1967 that the fertilizer industry be classified as an infrastructure project. This means that the above-mentioned institutions will make capital available to fertilizer projects on the same terms as those extended to other infrastructure projects like transport, railways, etc.

71. The Group further *recommends* that the funds of the International Development Association (IDA) be replenished and that a substantial portion of these funds be used to supply loans to the fertilizer industry in developing countries.

72. The Group *recommends* that the Governments of developed countries facilitate the extension of credit by suppliers of equipment from their countries to the developing countries.

73. The Group *recommends* that developing countries review their policies with a view to attracting a larger flow of foreign capital for investment in fertilizer projects within developing countries.

74. The Group *recommends* that a special committee be created from representatives of the United Nations, UNIDO, Food and Agriculture Organization (FAO), the World Food Programme, International Bank for Reconstruction and Development (IBRD), and experts from developing countries to prepare

[1] Dr. Greif Sander from the Federal Republic of Germany, who participated in the meetings, did not agree with a number of the recommendations put before the Expert Group.

a working plan for the solution of the financing problems encountered by the developing countries in their efforts to create or expand their fertilizer industries. It is reiterated that the development of a fertilizer industry and the use of its products in developing countries is one of the principal factors to be considered in finding a solution to the world food problem.

Problems relating to raw materials

75. The Group *recommends* that developing countries initiate studies to determine the most economic sources of hydrocarbons as raw material for the domestic production of nitrogen.

76. The Group *recommends* that developing countries explore fully the possibility of regional co-operation with regard to the assurance of a firm supply of phosphate to safeguard themselves against the time when lack of phosphate may become a limiting factor in crop production.

77. The Group *recommends* that developing countries initiate a study to estimate the amount of potash they may require in the immediate future.

78. The Group *recommends* that UNIDO bring to the attention of developing countries alternative sources of sulphur, including sulphur-saving processes and electrothermal methods for the production of phosphate fertilizers.

79. The Group *recommends* that UNIDO, together with the United Nations Conference on Trade and Development (UNCTAD), FAO and any other international organizations involved, investigate the price structure of the raw materials necessary for the production of fertilizer with a view to stabilizing prices and ensuring that there will be no discrimination in f.o.b. prices to developing countries.

80. The Group *recommends* that in view of the ample supply situation over the coming years, the possibility of introducing long-term fertilizer contracts be explored, since they would better meet the continuous import requirements of the developing countries. Since fertilizer is practically the only mass-produced commodity on the world market lacking such a long-term marketing concept, the case of existing credit-based fertilizer contracts of this kind could be studied to improve purchasing performance and make full use of existing and future supply and transport facilities.

Inadequacy of infrastructure

81. The Group *recommends* that developing countries mobilize their resources to develop infrastructure to the best of their ability, while giving first priority to those items of infrastructure that relate to fertilizer production, distribution and use.

Shortage of trained personnel

82. The Group *recommends* that UNIDO take steps, in co-operation with the developing countries, to promote the training of personnel in the fields of

fertilizer technology, plant maintenance, management and the marketing of fertilizers.

MARKETING INADEQUACIES

83. The Group *recommends* that developing countries, while recognizing marketing inadequacies as a major problem, take immediate action to introduce a streamlined credit system, using counterpart funds, where available, for this purpose.

84. The Group *recommends* that developing countries strive to raise the plant nutrient content in fertilizers and use high-analysis solid fertilizers. They should also explore the possibility of using anhydrous or aqua ammonia and liquid fertilizers in direct application.

85. The Group *recommends* that the local fertilizer industry in each developing country develop its own agronomic research units in order to assess independently the best cultural practices and product mix and promote their application.

INTERNAL POLICIES

86. The Group *recommends* that fertilizers, plant equipment, spare parts, supplies and raw materials for fertilizer production be exempt from customs and excise duties in developing countries and that developed countries continue their policy of exempting products related to agricultural programmes from export duty.

87. The Group *recommends* that developing countries explore their long-range requirements for fertilizers and raw materials with a view to making more favourable purchasing arrangements through long-term contracts.

PRICING POLICIES AND COST OF PRODUCTION

88. The Group *recommends* that the pricing policy of government bodies concerned with agricultural products in a developing country include an incentive to stimulate farmers to use more fertilizer, either a bonus for agricultural products or a subsidy for fertilizer.

89. The Group *recommends* that developing countries take steps to utilize economically all by-products resulting from fertilizer production, since this helps to reduce the cost of production.

INADEQUATE PROJECT PLANNING AND EXECUTION

90. The Group *recommends* that UNIDO maintain liaison with developing countries from the conception of a fertilizer project to its completion by providing experts or groups of experts for every phase of project planning and execution.

91. The Group *recommends* that UNIDO establish a roster of experts from developing countries by approaching them for the names of appropriate individuals.

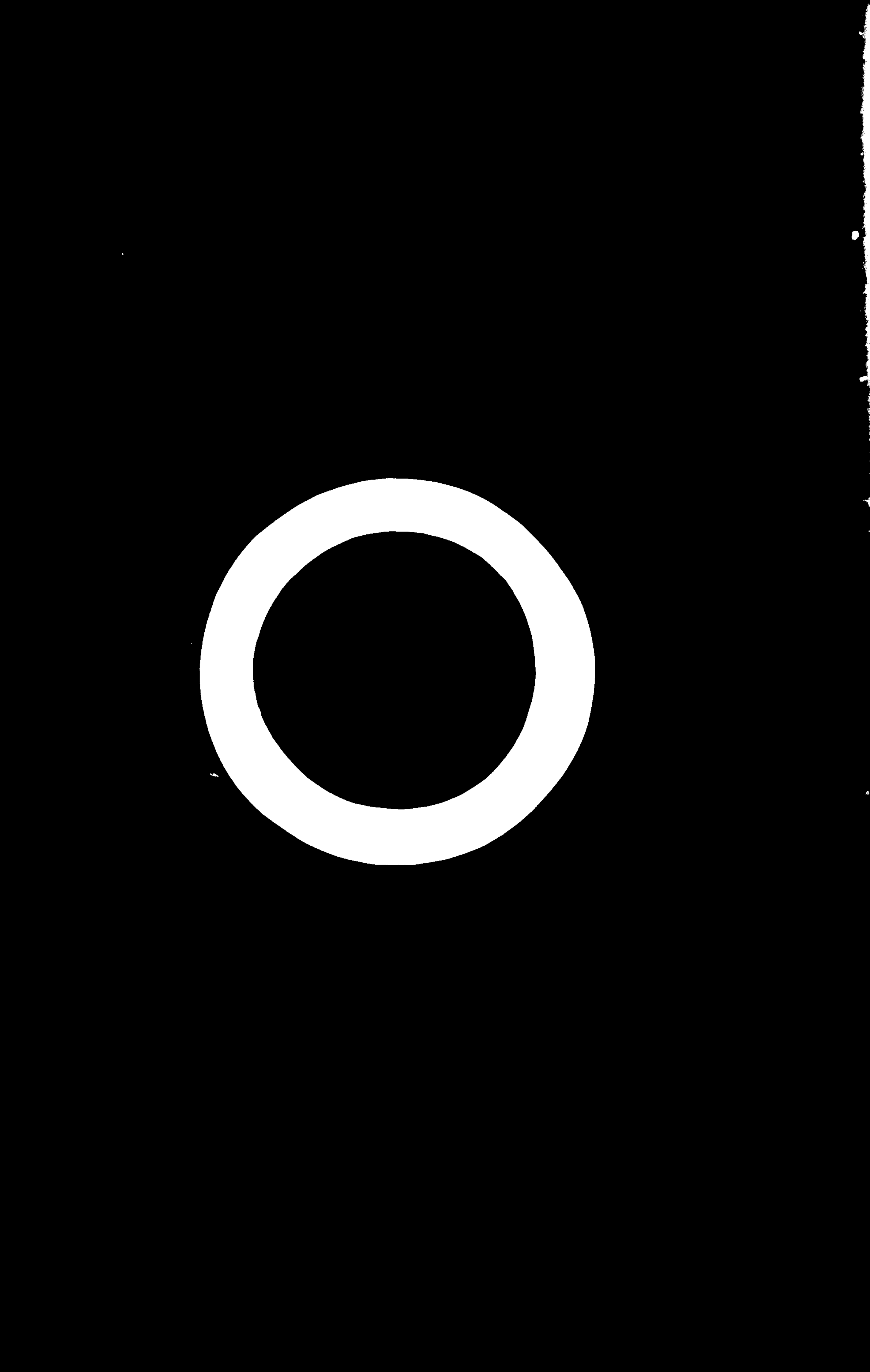
Lack of effective regional co-operation

92. The Group *recommends* that developing countries initiate studies so that regional co-operation may be promoted to the greatest extent possible.

93. The Group *recommends* that the special committee proposed in connexion with problems of financing include in its agenda the study of regional groups of developing countries so that these groups can make a greater effort to solve their fertilizer supply problems through collaboration.

Part II

WORKING PAPERS PRESENTED AT THE MEETING



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THE FERTILIZER INDUSTRY IN BRAZIL

THE MARKET

Present status

The growth of agricultural production in Brazil has been mainly a result of the continuous expansion of the area of cultivation, as the yields are still extremely low. It has been estimated that only 12 per cent of the nutrients taken up from the soil by crops is returned in the form of mineral fertilizers (Nogueira, 1966)[1]. A substantial increase in the rate of the application of fertilizers is of the utmost importance if the production of food is to keep pace with the growth of population. It can be seen that the rates of application of fertilizers are still far below the minimum acceptable levels by comparing the apparent consumption of the three primary nutrients with the estimated requirements, calculated for the ten most important crops.

Table 1

TOTAL APPARENT CONSUMPTION AND ESTIMATED REQUIREMENTS IN 1961 FOR FERTILIZER NUTRIENTS FOR THE TEN MOST IMPORTANT CROPS

(Thousand tons of nutrients)

	N	P_2O_5	K_2O
Total apparent consumption	55	119	71
Estimated requirements for the ten most important crops	987	1,181	961

Source: Banco Nacional do Desenvolvimento Econômico (1965) *Mercado brasileiro de fertilizantes, 1950—1970,* 2. ed., Rio de Janeiro.

The total consumption of the three primary nutrients shows a very irregular annual increase, as can be seen in table 2.

[1] All references are listed at the end of this paper.

Table 2

TOTAL APPARENT CONSUMPTION OF MINERAL FERTILIZERS

(Tons of nutrients)

Year	N Production	N Imports	N Total	P_2O_5 Production	P_2O_5 Imports	P_2O_5 Total	K_2O Imports
1958	2,578	38,812	41,390	53,478	89,871	143,349	65,082
1959	10,679	34,106	44,785	68,486	55,519	124,005	57,425
1960	15,726	51,034	66,760	77,427	54,164	131,591	106,146
1961	12,021	43,043	55,064	69,766	49,000	118,766	70,727
1962	12,926	37,358	50,284	63,974	55,819	119,793	68,127
1963	13,452	48,609	62,061	44,955	108,430	153,385	91,750
1964	7,243	43,651	50,894	47,918	84,488	132,406	69,196
1965	14,684	56,103	70,687	46,116	75,203	121,319	98,604
1966	5,776	64,684	70,460	52,419	63,435	115,854	92,527
1967	9,800[a]	99,764	109,564	66,865	152,008	218,873	136,402

[a] Approximate.

This is partly due to fluctuations in the value of the currency. Inflation forces the Government to adjust periodically the foreign exchange rate. When a devaluation of currency is expected, as was the case at the end of 1967, great quantities of fertilizers purchased at the original rate are imported for stockpiling; this distorts the apparent consumption.

All potassium requirements and about 80 per cent of nitrogen and phosphate fertilizers are still imported. In 1964 (Nogueira, 1966) Brazil spent $19.6 million for fertilizer imports.

The figures given in table 2 do not include the use of organic fertilizers. In the state of São Paulo, where the farming techniques are the most advanced, manure accounts for about 70 per cent of the total consumption of fertilizer (Nogueira, 1966). On the other hand, the consumption figures are not evenly distributed throughout the country (table 3).

Table 3

REGIONAL DISTRIBUTION OF FERTILIZER CONSUMPTION IN 1963

(Per cent)

North	Centre	Centre-South	South
7.8	3.2	71.2	17.8

Source: Banco Nacional do Desenvolvimento Econômico (1965) *Mercado brasileiro de fertilizantes, 1950—1970,* 2. ed., Rio de Janeiro.

The rates of application in the state of São Paulo (centre-south region) are about four times greater than the average for the country as a whole. This may be due to a number of factors, but it should be pointed out that the main crop in this region is coffee, the only farm product in Brazil for which the market is guaranteed by the Government.

Consumption estimates

The Government has, however, developed new policies to promote the use of fertilizers and intends to promote them further in the future. The data for 1967 already reflect the influence of government policy. For the scheduling of the fertilizer industry the Ministry of Planning established consumption goals that were based on the availability of funds to provide new incentives (Bellotti and Frazão, 1967; Petrobrás, 1968). The goals will be reviewed periodically in accordance with the effect of the new policies. For a first approach a 15 per cent annual increase has been assumed from 1965 on, as is shown in table 4.

Table 4

ESTIMATED CONSUMPTION OF NUTRIENTS, ASSUMING A 15 PER CENT ANNUAL INCREASE WITH 1965 AS BASE YEAR

(Thousand tons)

Year	$N + P_2O_5 + K_2O$
1965	298
1966	343
1967	395
1968	454
1969	522
1970	600
1971	690

To determine the individual quantities of each of the three primary nutrients, the $N : P_2O_5 : K_2O$ ratios over past years is shown in table 5 (Bellotti and Frazão, 1967).

Table 5

$N : P_2O_5 : K_2O$ RATIOS

Period	*N*	P_2O_5	K_2O
1950–1954	1.0	3.8	1.6
1955–1959	1.0	3.4	1.6
1960–1964	1.0	2.2	1.4
1965–1966	1.0	1.5	1.3

It can be seen that the structure of the consumption of fertilizers in Brazil shows a remarkable deviation from the 1 : 1 : 1 optimum nutrient ratio; however, there is a clear trend towards an improvement.

A 1.0 : 1.6 : 1.2 (N : P_2O_5 : K_2O) ratio has been assumed for 1971 (Bellotti and Frazão, 1967). Based on this structure and on a total consumption of 690,000 tons, the requirements for each type would be: N, 181,700; P_2O_5, 290,800; K_2O, 218,100.

The Ministry of Planning uses these figures as a basis for its plans for the fertilizer industry.

The industry

Raw materials

Brazil has abundant primary sources for the production of phosphorus and potassium fertilizers, but, unfortunately, lacks the hydrocarbons required in the production of ammonia and the sulphur needed for the acid treatment of natural phosphates. A map of Brazil showing the primary sources of fertilizers is appended to this article.

Phosphorus

Large deposits of mineral phosphates are distributed throughout the country in the states of Pernambuco (Olinda phosphorite), São Paulo (Ribeira valley apatite) and Minas Gerais (Araxá apatite). Total known reserves exceed 120 million tons containing more than 30 million tons of P_2O_5 (Nogueira, 1966).

Sulphur

Sulphur, the raw material for the production of sulphuric acid, is used for making natural phosphates soluble and for making ammonium sulphate. Almost all the sulphur required has to be imported at very high prices that raise considerably the cost of production of superphosphates and ammonium sulphate. In 1964, 140,801 tons of sulphur were imported at an average price of \$29.00 a ton, but by 1966, when imports amounted to 184,400 tons, the average price had increased to \$45.00 a ton. At present, only 8,000 tons a year, based on the processing of refinery tail-gases, are produced, but a further unit with a capacity of 10,000 tons is planned for 1969.

Potassium

While drilling for oil in the state of Sergipe (Carmópolis), the state-owned company, Petrobrás, discovered a layer of potassium salts at a depth ranging from 200 to 600 metres. An area of 470 km^2 was declared a "national reserve" for two years, and the Ministry of Energy and Mines signed a contract of some \$4.7 million for the development work. According to preliminary estimates, the reserves could reach 1,400 million tons of sylvinite and 12,000 million tons of carnallite. As the deposits are located close to oil fields, the mining will be carried out in conjunction with oil production.

Hydrocarbons

The known reserves of natural gas in the states of Bahia and Sergipe are relatively small and amount to 24,500 million m^3 (Petrobrás, 1968). The gas fields are about 2,000 km away from the fertilizer markets of the centre-south region. Brazilian oils, however, are deficient in light fractions, and all naphtha for the petrochemical industry will have to be imported or supplied by oil-cracking operations.

Existing plants

Domestic production can supply part of the demand for nitrogen and phosphorus fertilizers, but all the potassium needed has to be imported. The capacity of plants for the production of nitrogen fertilizers is much less than the demand, but the capacity of the phosphorus fertilizer industry can meet all national requirements.

Nitrogen fertilizers

The most important producer is the state-owned company, Petrobrás, which has a unit for the production of 28,000 tons of ammonia per year at Cubatão, São Paulo. This plant converts ammonia into nitric acid, ammonium nitrate and calcium ammonium nitrate fertilizers (20.5 per cent N and 27.0 per cent N). The percentage of nitrogen converted to fertilizers, which was 77 per cent in 1963, fell to 42 per cent in 1967 owing to competition from low-priced imports of ammonium sulphate. Profits from sales of ammonia, nitric acid and ammonium nitrate to chemical industries and for explosives are greater, since the freight charges for importing these materials assure a margin of protection to the domestic industry. It is interesting to note that calcium ammonium nitrate does not fetch a better price in comparison with ammonium sulphate, although it contains calcium and magnesium nutrients. Sales of the Cubatão fertilizer plant in 1967 are shown in table 6.

Table 6

CUBATÃO FERTILIZER PLANT — SALES IN 1967

Product	*Tons of product*	*Contained tons of N*
Ammonia	5,060	4,167
Nitric acid, 54 per cent concentration	25,366	3,044
Ammonium nitrate	8,540	2,904
Fertilizers (20.5 per cent N and 27.0 per cent N)	35,434	7,425

Plans to expand ammonia plant capacity to 130 or 180 tons/day and to produce 100 tons/day of nitrogen solutions are under study.

Ammonium sulphate with a total annual output of 2,600 tons of nitrogen. is produced in the three principal steel works of Brazil.

Phosphate fertilizers

The total installed capacity for making natural phosphate, bicalcium phosphate and thermophosphate is about 150,000 tons/year of P_2O_5, but production in 1967 was limited to 66,865 tons (table 7).

Table 7

PRODUCTION OF NATURAL PHOSPHATES, BICALCIUM PHOSPHATES AND THERMOPHOSPHATES

Company	*Average content (%)*	P_2O_5 *Yearly capacity (tons)*	*1967 production (tons)*
Natural phosphate			
C. T. Paulista, Pernambuco	25	–	2,750
Fosforita Olinda, S.A., Pernambuco	31	75,000	24,222
Serrana, S. A., São Paulo	37	29,000	31,416
Socal, S. A., São Paulo	28	5,600	1,955
CAMIG, Minas Gerais	29	30,000	4,364
Bicalcium phosphate			
Cia. Igarassu, Pernambuco	38	6,000	1,465
Thermophosphates			
Fertiminas, Minas Gerais	20	–	693
		150,000	66,865

A small proportion of the natural phosphates is delivered to farms as it comes from the mine; the remainder is used as raw material for superphosphates. Production reached a maximum of 77,000 tons in 1960 and thereafter began to decrease. The lack of proper facilities for the low-price shipment and transport of the natural phosphates of Fosforita Olinda, S. A., from Pernambuco to the centre-south region has been the main reason for the low output. Natural phosphate from Florida, United States, often arrives at the port of Santos for sale at a lower price than the product from Pernambuco.

At present only single superphosphates are produced in Brazil. In 1967, 90,550 tons were supplied (table 8).

Imports include chiefly triple superphosphate and diammonium phosphate. The lack of sulphur and the resulting high price of sulphuric acid favour imported products, which account for about 30 per cent of the total requirements.

Table 8

PRODUCTION OF SINGLE SUPERPHOSPHATES

(Tons of P_2O_5)

Company	*Capacity*	*1967 production*
Profertil, Pernambuco	6,000	2,600
Quimbrasil, São Paulo	48,000	38,000
Cia Superfosfato, São Paulo	28,000	13,000
Elekeiroz, São Paulo	12,000	7,360
Ferticap, São Paulo	6,000	4,150
CRA, R. G. Sul	4,000	4,160
ICISA, R. G. Sul	5,000	4,120
Policarbono, Minas Gerais	2,000	1,160
Copebrás, São Paulo	24,000	16,000
	135,000	90,550

Mixed fertilizers

More than 70 companies are operating in the field of fertilizer formulations with a total annual capacity of about 2 million tons (Nogueira, 1966). Only solid mixtures are supplied, and they are produced by the simple mixing of solid primary components. Ammoniation of acidulated phosphate rock with nitrogen solution was introduced in some superphosphate plants during 1968. Neither mixed solutions nor suspensions are produced in the country.

New projects

Requirements for nitrogen and phosphorus fertilizers for 1971 are expected to reach 180,000 tons of N and 290,000 tons of P_2O_5. Existing industries will be able to supply only about 15,000 tons of N and 150,000 tons of P_2O_5. To make up the difference, the Government is encouraging new projects by offering incentives. As a result, numerous projects have been submitted to GEIQUIM (Executive Group for the Chemical Industry), a group within the Ministry of Industry and Commerce that evaluates and decides on such projects. The fertilizer projects approved and under way are listed in table 9.

These new projects will add 160,000 tons of N, 50,000 tons of P_2O_5 as natural phosphates and 85,000 tons of P_2O_5 as superphosphates to existing plants.

One project now under study that could strongly affect the phosphate fertilizer industry is the production of elementary phosphorus by electric reduction in Minas Gerais (Samel, 1968).

The most important project approved was presented by Ultrafertil, a subsidiary of Philips Petroleum Co. This company will shortly control more than

60 per cent of the total production of ammonia in Brazil and will also furnish N-P-K compound fertilizers; it has already begun establishing fertilizer distribution stations inland. To combat this new and powerful competitor several smaller companies, traditionally operating in this field, have joined together to form ANDA (National Association for the Development of Fertilizers), through which they can co-ordinate production and distribution.

Table 9

PROJECTS APPROVED BY GEIQUIM

Company	*Location*	*Products*	*Capacity (t/d)*	*Investment (millions of dollars)*
Petrobrás, S.A. ..	Camaçari (Bahia)	Ammonia	200	16.1
		Urea	250	
Ultrafertil, S.A. .	Cubatão (São Paulo)	Ammonia	455	54.2
		Phosphoric acid	227	
		Nitric acid	570	
		Sulphuric acid	645	
		Diammonium phosphate	486	
		Complex fertilizer	907	
Serrana, S.A.	Jacupiranga (São Paulo)	Natural phosphate (36 per cent P_2O_5)	430	5.0
Copebrás	Cubatão (São Paulo)	Sulphuric acid	140	4.0
		Phosphoric acid	50	
		Triple superphosphate		

FERTILIZER POLICIES

Incentives to increase the use of fertilizers

From 1957 to 1961 the consumption of fertilizers was greatly encouraged by the Government, which abolished customs duties and aided the import of fertilizers by setting up a special, favourable foreign exchange rate (Locchi, 1966). A subsidy was simultaneously created for the domestic industry. This subsidy covered both the custom duties that had been abolished and the difference between the special and normal exchange rate. As a result, the use of mineral fertilizers increased continuously during this period.

In 1961 the special exchange rate for fertilizer imports was abolished, and, consequently, prices rose. From 1961 to 1966 the market remained stagnant, although some incentives had been granted, such as a credit from the Brazilian Coffee Institute for sales of fertilizer to coffee farmers.

By the middle of 1966, a special fund to provide financial incentives for the use of fertilizer was established, called Funfertil (Oliveira Lima, 1967). Farmers can obtain interest-free loans to purchase fertilizer, and the repayment need not be made until 45 days after the crops have been harvested. The selling company is partially responsible for the repayment. Funfertil was responsible for the encouraging increase in consumption of fertilizers in 1967.

Protection of the domestic industry

In spite of the increase in the use of fertilizers, the share of the over-all consumption covered by domestic production is dwindling (Locchi, no date), as shown below:

Year	*Percentage*
1961	36
1962	31
1963	18
1964	20
1965	20
1966	19
1967	16

This decline is mainly due to three factors:

(*a*) Imports are arranged through the Banco do Brasil, with a three months' interest-free credit to give the same financial terms the home producer would have to use his own funds or organize suitable loan facilities.

(*b*) Fertilizers are delivered at Brazilian ports at prices much lower than those at which they are sold in the country of origin. The periodical *Nitrogen* (Anon., 1967) published the following f.o.b. prices per ton of ammonium sulphate delivered in bulk for March/April 1967: Belgium, $46.10; Federal Republic of Germany, $57.50; the Netherlands, $47.20; United States, $35.30. The average c.i.f. and f.o.b. prices of imported ammonium sulphate in 1967 were per ton $41.57 and $31.02 respectively.

(*c*) Brazilian manufacturers of superphosphates have to pay about $45.00/ton f.o.b. for sulphur, which is extremely high compared with the price of $32.00 (Locchi, no date) paid by the American producer.

In an attempt to remedy this situation a representative of the domestic industry (Locchi, no date) recommended to the Institute for Applied Economic Research (IPEA), a group attached to the Ministry of Planning, that they:

(*a*) Re-establish the subsidy abolished in 1961 or reintroduce customs duties of 10 to 15 per cent for fertilizers. The second alternative would obviously be prejudicial to agriculture.

(*b*) Establish 180 days' credits for sales of the domestic industry to mixers and distributors.

Primary sources of fertilizers in Brazil

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THE FERTILIZER PROMOTION CAMPAIGN IN SOUTH INDIA

Until 1959, the farmer of South India had seen fertilizer but not used it. Before the Second World War, some well-to-do farmers in the Tanjavar district of Madras state had used imported ammonium phosphate, but after the war this had been forgotten. Ammonium sulphate was known in some places as company salt. Some farmers, heeding the advice of agricultural officers, had tried it on their fields. Results were good in several cases; problems arose, however, in others owing to a lack of knowledge of its proper use. Planters were using fertilizers, but not intensively. The average farmer believed that chemical fertilizers spoiled his soil and that the grain, fruits and vegetables grown with the assistance of such fertilizers were not so good or tasty as those grown with organic manure. Many educated farmers, keen to try chemical fertilizers, found that they were not always readily available.

At that time only two factories produced nitrogen fertilizers in India, Fertilizers and Chemicals, Travancore, Ltd. (FACT) and Sindri. There were a number of superphosphate producers, but because there was no market, the production rate never reached even 50 per cent of capacity.

As a result of the five-year plans, community development programmes had become a matter of national policy, and facilities for extension work had been set up. FACT recognized that for a successful promotional campaign, the active co-operation and participation of the Departments of Agriculture and Community Development, as well as the farmers of the region, were essential. It was also necessary to work out a plan. FACT, therefore, invited the senior and district officials of the government departments concerned and some enlightened farmers to attend a conference. At this conference, held in 1959, a rough draft of a plan was drawn up.

It was decided that the area of action should be clearly demarcated. The potential market of FACT comprised the four southern states of India — Kerala, Madras, Mysore and Andhra Pradesh. Since FACT was located in Kerala, this state became the centre of the market. It was planned to carry out an intensive programme in Kerala, with extensive work in the other three states.

The plan for Kerala was divided into three phases. The object of the first was to bring home to the farmers and to people in general the benefits of using chemical fertilizers. This plan included the following features:

(*a*) A thirty minute film, with stars in the cast and a story with popular local appeal, was shown in 200 cinemas in Kerala in a period of four months. The story, built around the "Onam", the national festival, nevertheless demonstrated the results achieved by chemical fertilizers. The film became very popular and helped a large number of people to get some idea of the benefits to be gained by using chemical fertilizers.

(*b*) An advertising campaign was carried on through a series of articles appearing in the press.

(*c*) Demonstration plots were organized in farmers' fields. These fields, one acre in area, were chosen by FACT in consultation with departmental officials and leading farmers. There was a demonstration plot and a control plot; on the former scientific methods and chemical fertilizers were used, and on the latter the usual practice of the area was followed. Sowing, fertilization, transplanting, weeding and harvesting were carried out, with farmers observing. Demonstrations were undertaken not only for paddy rice but also for crops such as coconuts, bananas, tapioca, ginger, and pepper. By the first half of 1960 FACT was running more than 500 demonstration plots in Kerala alone (area, 15,000 square miles, population, 20 million).

(*d*) Public meetings were organized where speakers explained developments in other countries, the profitability of using fertilizers and so forth. To attract a large audience, cultural programmes were also arranged at the end of each meeting.

(*e*) Quantities of pamphlets were printed in the local language describing the qualities of various fertilizers and methods of application and distributed at public meetings, exhibitions, cinemas, theatres and in market places.

(*f*) The distribution system was properly organized; central and sub-depots were opened so that the farmers could obtain their fertilizers near by.

(*g*) A number of agronomists were employed in the field to meet farmers and advise them on the proper use of fertilizers. They also assisted the farmers in completing the necessary forms to enable them to procure loans from co-operative or government sources. The aim of FACT was to place in the field a number of trained and devoted young men who would, in due course, come to be looked upon by the farmer as his friends.

The first phase produced some encouraging results. Farmers became increasingly interested in fertilizers, but there was no rush to buy them. The second phase was, accordingly, launched in 1961.

As a result of the experience gained during the first phase, more intensive work was planned for the second phase, with a programme covering the whole state and emphasizing a "fertilizer festival".

The fertilizer festival was perhaps one of the most significant contributions made by FACT to fertilizer promotion. Since India is a land of festivals, the average rural Indian is attracted by any festival; for him a festival is a rare occasion for enjoyment. Shed of its frills, the fertilizer festival was essentially an educational programme. According to a plan drawn up at the beginning of the season in consultation with the district officials, villages were chosen beforehand and representative farmers selected and advised in advance. Adequate publicity was also organized. On the appointed day, government officials and agronomists of FACT arrived at the village selected and conducted a seminar in which the farmers previously selected participated. At the same time FACT had a mobile exhibition depicting products, processes and benefits that could accrue from using fertilizers. Mobile soil-testing kits were used to demonstrate ways of analysing soil. Farmers queued up with packets of earth, like parents waiting with ailing children at the out-patient department of a mobile hospital. The seminar also dealt with problems relating to the principal crops of the village. The emphasis was not on pious platitudes about increasing food production, but on profit. The conservative farmer was quick to grasp the significance of a profitable proposition.

Lively discussions took place and continued until late in the afternoon. In the evening a public meeting was held in which senior officials, including ministers, took part. Their participation served to emphasize the importance of fertilizer.

Fertilizer festivals had a tremendous effect on the farmers of Kerala. The seminars helped to clear up their doubts about the use of fertilizers and enabled them to assess the profitability involved.

An elaborate network of depots was organized to ensure that supplies of fertilizer were available in each district; this greatly promoted consumption.

Apart from fertilizer festivals, the second phase included the following measures:

(*a*) Seminars held at villages, community centres and at the district level;
(*b*) The publication of success stories in the press;
(*c*) Prizes awarded to farmers and co-operatives for the highest yields and to salesmen making the biggest sales;
(*d*) A price reduction in order to persuade farmers to buy;
(*e*) The introduction of incentives for retail agents by awarding commissions for increased sales;
(*f*) Extensive soil testing;
(*g*) Intensive propaganda about the need for a balanced fertilization programme;
(*h*) Exhibitions

By the time the second phase was under way, there were noticeable changes in the pattern of fertilizer consumption. More and more farmers tended to use

N-P-K mixtures. In 1959, under 4 million rupees'[1] worth of fertilizer was consumed in Kerala; by 1964, the figure had risen to 45 million. An awareness of the potential of fertilizers had been developed, but the main problem that hindered their maximum use was the fragmentation of land. About 76 per cent of land holdings had less than one acre, with 22 per cent having between one and five acres. It was imperative that even the small farmer should use fertilizer. The third phase of the campaign, therefore, concentrated on the productivity and profitability aspects of cultivation.

The year 1966 was designated India Productivity Year. Hitherto, productivity programmes had been confined to industry. In 1966, Kerala broke new ground by introducing a number of agricultural productitivity programmes. These programmes, lasting from two to three weeks, received a good response from the young, educated farmers, who took pains to understand the economics of agricultural production. Just at that time high-yielding seeds responsive to fertilizer were being introduced so that the propaganda for the introduction of such seeds was made simultaneously with the organization of training programmes on the proper choice of fertilizers, modern cultural practices, and measures of pest control. The government policy of subsidizing agricultural commodities and the appointment of an agricultural price commodities commission also gave an impetus to the consumption of fertilizers.

At present the problem of land fragmentation is being attacked. FACT selected an area of 100 acres and persuaded the 242 farmers owning the land to work it jointly. FACT provided the supervision and services as well as a supply of fertilizers and pesticides at wholesale rates. This provided a model for others to follow. Such a joint effort immediately began to show results. Sources of irrigation were improved, canals cleared and mechanical ploughing carried out by rented equipment at much less cost. The farmer was gradually realizing the advantages of a co-operative effort.

Today the states of Andhra Pradesh, Kerala and Madras lead the rest of India in consumption of plant nutrients per acre and also in yields per acre. In 1967/1968 FACT sales in Kerala alone amounted to 65 million rupees (at 1959 prices). Although devaluation of the rupee led to a steep rise in the price of fertilizer, consumption has continued to grow in the southern states. Price control for the product is essential to keep up the trend.

The FACT programme was successful because of several factors that included:

(*a*) The establishment of a good distribution network. In Kerala, FACT has today 55 central depots and 4,000 sub-depots, of which 2,700 are co-operatives. No farmer has to go farther than 4 kilometres to buy his supplies of fertilizers.

(*b*) The availability of a supply of pesticides at the fertilizer depot.

(*c*) A reliable price policy.

(*d*) A strict regard for the maintenance of quality.

[1] One dollar equals 7.50 rupees.

(e) The provision of an effective field service with a large force of agronomists available.

(f) Promptness in attending to complaints and inquiries.

(g) Good relations with the government departments concerned and with the press.

(h) Manufacturers of fertilizer who identify themselves with the farmer.

The most gratifying aspect of the venture was that the total expenditure never exceeded 1 per cent of the turnover. That was possible only because of the participation of the government departments concerned and the co-operation of the farmers.

Fertilizer festivals have now become a national instrument for the promotion of fertilizer. The governments of other Indian states as well as other fertilizer manufacturers have been using this medium for the last two years.

Having at first concentrated on the centre of its market, FACT has extended similar activities to Andhra Pradesh, Madras and Mysore during the last three years. Results in these states have been equally encouraging.

The farmer is conservative in his outlook, but he is also very sensitive. He wants to see his friends frequently to talk and laugh and share his problems with them. The salesmen in the field employed by the manufacturer of fertilizer have to bear this in mind. It is essential to follow up both in the field and at the personal level. Whenever there is a birth, a death or a marriage in a farmer's family, the man in the field should be present as a member of the family. The Indian farmer likes to have the fertilizer salesman as a family friend, guide and philosopher; the training of a salesman is, therefore, very important.

Each region has its local folklore and traditions. Organizers of fertilizer promotion campaigns should take this into account if the farmer is to be won. Accustomed to the ravages of the climate, the farmer has developed considerable resilience, but this resilience helps a conscientious salesman in the field to harness the farmer's faith and enthusiasm to a productive aim.

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THE FERTILIZER INDUSTRY IN MEXICO

Introduction

In Mexico, high productivity in agriculture has been considered a target of the utmost importance to ensure the continuing economic development of the country and to attain a high standard of living for its people.

High agricultural yields are vital, not only to meet the demand for foodstuffs in the country as a whole, but also because of the urgent need to increase the purchasing power of the peasants, who in Mexico represent approximately 50 per cent of the population. Unless the rural population has sufficient purchasing power, industry will lose the support of a very large sector of the national market and its development will be retarded.

Mexico's climatic conditions and geographical features, such as erratic rainfall, only a relatively small expanse of land receiving adequate rainfall, torrential water courses, make agriculture a difficult and costly undertaking. Extensive areas in northern Mexico have very low rainfall and can be classified as desert; on the other hand, the south-eastern coastal plains are subject to high rainfall and are inclined to become flooded. Most of the country does not have snow in winter, so melted snow cannot be counted on for irrigation.

Because of these natural handicaps, the Mexican Government has had to invest large sums in irrigation and in a complex system of flood control. Although investment in these undertakings has been going on for more than a century, only during the last thirty-five years has considerable capital investment been made.

To ensure that the funds used for irrigation produce a maximum return, it has been necessary to modernize agriculture by using intensive farming methods designed to give high yields. In addition to constant expenditures on irrigation and flood control, every appropriate agricultural technique has been applied, including the use of specially selected hybrid seeds, insecticides and, most important of all, ever-increasing quantities of fertilizer. Generally speaking, Mexican soil has a low nitrogen content; it contains an average amount of phosphorus and an average to high amount of potassium. Nitrogen deficiency is usually detected before deficiencies in phosphorus or potassium.

Fertilizer consumption has increased in proportion to the quantities of aforesaid deficiencies. Thus, three or four times as much nitrogen has been used than phosphorus, while the consumption of potassium-based fertilizers (K_2O) is only half that of phosphate fertilizers (P_2O_5).

Of Mexico's total area of 169 million hectares, only 23.8 million hectares, (14.1 per cent) consist of cultivated land. A further 11.2 million hectares (6.6 per cent) are potentially productive.

Cultivated land can be classified according to water resources as irrigated land, land receiving a heavy rainfall throughout the year and land with a seasonal heavy rainfall; according to use, it may be classified as land for crops and for fruit, as shown in table 1.

Table 1

BREAKDOWN OF CULTIVATED LAND (HECTARES)

	Crops	*Fruit*	*Total*
Irrigated land	3,408,439	106,871	3,515,310
Land with a heavy rainfall throughout the year	753,467	140,022	893,489
Land with a seasonally heavy rainfall	18,344,862	1,063,251	19,408,113
	22,506,768	1,310,144	23,816,912

The Mexican Ministry of Agriculture and Animal Husbandry estimates that during 1967, 15.3 million hectares were harvested; of these, 3.38 million were irrigated; 11.58 million were land with a seasonally heavy rainfall; and 0.33 million were land with a heavy rainfall throughout the year. The harvested land represented, in fact, the sum total of productive land, with the exception of land that was not sown, or where crops were lost because of the weather.

In 1949 only 27,000 hectares were fertilized, while in 1959 the area fertilized rose to 1.1 million hectares; by 1964 the figure was 2.66 million hectares. During 1967, 4 million hectares were fertilized, representing 16.8 per cent of cultivable land and 26.2 per cent of total harvested land; 2.43 million hectares of irrigated land and 1.57 million hectares of land with seasonally heavy rainfall were fertilized.

Mexico has under way a fertilization programme drawn up by several government agencies, the minimum target being the short-term fertilization of the following areas: 4.34 million hectares in 1968; 4.72 million hectares in 1969; and 5.16 million hectares in 1970. Reports received for the first few months of 1968 showed that the target for 1968 would certainly be met and would very likely be exceeded.

The medium-term fertilization programme, which extends to the end of 1975, provides for the fertilization of a total area of 10.8 million hectares, a net increase of 6.8 million hectares over 1967. According to the programme, the additional 6.8 million hectares will consist of 1.2 million hectares of irrigated land and 5.6 million hectares of land with a seasonally heavy rainfall.

A joint survey made by the Ministries of Agriculture and of Water Resources concludes that, on a long-term basis, the total area to be fertilized will be 16.4 million hectares. This will be made up of 9 million hectares of irrigated land and 7.4 million hectares of land with seasonally heavy rainfall.

It can be seen, therefore, that in the next few years the Mexican fertilizer industry will be faced with a sharply increasing demand. This increase will be due not only to the fertilization of new areas but also to the more intensive use of fertilizers on already fertilized land.

Agricultural production increased at an average yearly rate of 4.1 per cent between 1962 and 1967, and the supply of foodstuffs increased by 5.7 per cent during the same period. The figures for the annual increase in the production of the main cereals between 1962 and 1967 are as follows: maize, 4.3 per cent; wheat, 8.1 per cent; beans, 615 per cent; and rice, 8.3 per cent. Mexicans are confident that these figures can be improved over the next few years and that the growth rate of agricultural production can outpace that of population by an even greater margin.

Although the progress made under the fertilization programme has been modest up to now, the country has become self-sufficient with respect to the main agricultural and livestock products and even has surpluses for export. But there is still a long way to go; the primary need is to increase the purchasing power of the people, so that the domestic consumption of foodstuffs, especially that of high-protein foods of nutritional value, will rise.

Exports of agricultural products (cotton, coffee, fruit, etc.), which have traditionally been sent abroad in large quantities, have continued at a steady rate, and in some cases at a considerably higher one than ever before despite growing domestic demand. Such exports are a most valuable asset to the country's economy in that they provide much needed foreign currency.

Present position of the fertilizer industry

The Mexican fertilizer industry was set up originally with the help of a number of small firms, and the plants they installed were usually small and uneconomic. But with time the situation has changed; and now fertilizer production is virtually in the hands of two large concerns, although four other small firms are still in existence. The two large firms are Petróleos Mexicanos, the state oil firm responsible for supplying anhydrous ammonia, and Guanos y Fertilizantes de México, S. A., a concern owned jointly by the State and private interests, which produces all types of solid fertilizers (single-nutrient, multi-nutrient and formulation fertilizers). Guanos y Fertilizantes de México, S. A., was established with the help of the Government, the aim being to accelerate fertilizer production and to rationalize the economic structure of the industry. The expansion of Guanos y Fertilizantes de México was brought about by the installation of new plants and the absorption of several small firms. It now controls approximately 90 per cent of the solid fertilizer sector. Consolidation into a giant fertilizer undertaking has made it possible to draw up reliable fertilizer production programmes and to build large plants with low unit costs of production.

Fertilizers produced and used in Mexico are:

(a) *Nitrogen fertilizers*: anhydrous ammonia (for direct application), urea, ammonium nitrate, and ammonium sulphate;

(b) *Phosphate fertilizers*: calcium superphosphate and triple superphosphate;

(c) *Multinutrient fertilizers*: monoammonium phosphate and diammonium phosphate, normally used as ingredients in formulations;

(d) *Formulations*: fertilizers formulated with varying ratios of nitrogen, phosphorus and potash.

The raw materials come for the most part from domestic sources. Mexico is expected to become self-sufficient in ammonia when a plant with a capacity of 400 tons per day starts up production in March 1968, followed in July 1968 by a large plant with a capacity of 1,200 tons per day. The production and distribution of ammonia in Mexico will be discussed at greater length later because of its special features.

Mexico has more than enough sulphur to meet domestic fertilizer requirements, but raw materials rich in phosphorus and potassium have traditionally been imported. Phosphate rock is imported from Florida, United States. Mexico has phosphate minerals with a low percentage of P_2O_5 that are uneconomic to exploit. Mention, however, must be made of a plant, expected to go into operation at the beginning of 1969, that will beneficiate each year 100,000 tons of phosphate rock containing calcium carbonate, with an 18 per cent P_2O_5 content. This will raise the concentration of P_2O_5 to 30 per cent, thus giving 60,000 tons of the concentrated product each year.

Data on total fertilizer consumption, production, importation, installed processing capacity and new projects are given in tables 2 through 6, which are appended to this text.

As imports are costly, the Government has been making a great effort to attain self-sufficiency in the domestic fertilizer industry. It hopes to achieve this goal by the end of 1968.

The new urea and ammonium sulphate plants that Guanos y Fertilizantes de México will put into operation during 1968 are expected to render imports superfluous. The company will invest over 100 million pesos[1] during 1968 on new plant and equipment. Last March, a urea plant in Camargo with a capacity of 75,000 tons per year began production, and next June an ammonium sulphate plant with a capacity of 150,000 tons per year will begin to operate in Guadalajara. The General Manager of Guanos y Fertilizantes de México stated recently: "This year (1968), we shall be importing fertilizers for the last time; quantities imported will be approximately 80,000 tons of ammonium sulphate and 25,000 tons of urea."

Current investment in fertilizer plants, excluding ammonia plants, totals 1,115.8 million pesos ($89 million); 1,114.5 million pesos is being invested in

[1] One dollar equals 12.50 pesos.

new plants scheduled for completion before 1970, including an 880 million pesos project ($70 million) estimated to produce 1,065 million tons per year of sulphuric acid, 204,000 tons per year of triple superphosphate and 550,000 tons per year of phosphoric acid with 54 per cent P_2O_5. Most of the initial output under this project will be exported, since more phosphate fertilizers than necessary for domestic consumption will be produced.

THE PRODUCTION AND DISTRIBUTION OF AMMONIA

The Government has given the state-owned oil firm, Petróleos Mexicanos, the task of producing all the anhydrous ammonia required domestically for the production of solid fertilizers and for other industrial uses. The programme that the company has drawn up to meet the demand for ammonia is based on the following premises:

(*a*) The primary justification for investment in new plant is the growing need of the home market; exportable surpluses will only occur temporarily while there is a disparity between installed capacity and home demand. Scant consideration should be given to the export market when making investment plans.

(*b*) Production must be organized efficiently so that anhydrous ammonia can be marketed at moderate prices without the aid of government subsidies or financial support from other operations within Petróleos Mexicanos.

(*c*) Ammonia must be distributed by terminals with a large handling capacity and low-pressure, low-temperature storage facilities.

Ammonia production began in Mexico in 1951 with one plant with a capacity of 60 tons per day. A second plant, with a capacity of 90 tons per day went into operation in 1961. Both plants belong to Guanos y Fertilizantes de México and can be considered as the first stage of the Mexican ammonia programme.

The second stage began in 1962 with the coming into operation of two plants with a capacity of 200 tons per day owned by Petróleos Mexicanos. The original idea was to build three plants instead of two, but the consensus of opinion during planning was that the programme was over-ambitious and went beyond the immediate requirements of the domestic market. However, time has shown that the first and second stages of the programme were on too limited a scale, since the demand for nitrogen fertilizers increased so rapidly that the four plants could barely meet 50 per cent of domestic requirements.

The third stage began recently with the completion of two large plants, one of which began to operate in March 1968 and the other expected to begin production in June. The first is a plant with a capacity of 400 tons per day and is situated in the thickly populated centre of Camargo in north-western Mexico; the second has a capacity of 1,200 tons per day and is in Minatitlán, Vera Cruz, in the south-east. Both plants have a modern transport system at their disposal.

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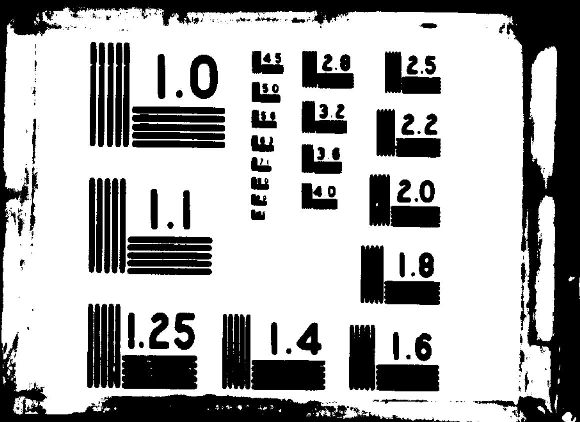


In view of Mexico's size, the location of ammonia plants is of crucial importance. Availability of raw materials, analysis of present and future markets for nitrogen fertilizers and the over-all transport problem are the three main factors that have had most bearing on the question.

Almost all the ammonia produced in Mexico is derived from natural gas. Originally it was thought possible to produce ammonia from liquid hydrocarbons in plants situated in consumer areas far from the natural gas fields, but later it seemed more economic to build large plants close to the sources of natural gas, together with an efficient system of transport including maritime transport. Preliminary surveys showed lower average costs for this arrangement and also greater flexibility and better storage facilities.

It can be said generally that modern ammonia plants using gas as their raw material have lower production costs and require less capital than any other type of ammonia plant. At the same time, these plants are functionally simpler and more reliable.

Natural gas reserves in Mexico are situated fairly far from the main areas of fertilizer consumption, and consequently it was necessary to adopt a hybrid solution with regard to location. In general, medium-size plants will be built at the end of existing or projected pipelines. Large plants will be located close to the biggest natural gas reserves. They will also be close to a seaport — hence the choice of Minatitlán, which is on the banks of the river Coatzacoalcos, navigable as far as the Gulf of Mexico, and situated, furthermore, at a reasonable distance from the Pacific seaport of Salina Cruz across the isthmus of Tehuantepec.

Because of its location, the recently finished plant with a capacity of 1,200 tons per day will ship much of its production to consumer centres and thus take advantage of the low cost of maritime transport. It is also hoped that it will have the additional advantage of flexibility of distribution, which will make production at full capacity possible throughout the year.

Agricultural areas are widely dispersed throughout Mexico and are at varying altitudes. There is, therefore, a steady demand for fertilizers for ten months of the year. Consequently, Mexico is not unduly troubled by storage problems, something that presents difficulties for large ammonia plants the world over.

In view of the fairly steady consumer demand throughout the year, three decisions were taken to diminish the storage problem as far as possible. The first was to arrange with Guanos y Fertilizantes, the concern responsible for solid fertilizers, that its plants should be installed beside the ammonia plants, since solid fertilizers can be stored much more easily than ammonia. Approximately 50 per cent of ammonia produced during the third stage will be converted continuously into solid fertilizers. It was thought that if all ammonia were to be converted into solid fertilizer the storage problem would disappear; however, the direct application of ammonia has a growing appeal owing to the low cost per unit of nitrogen obtained by this method. Direct application is encouraged whenever it is possible to do so.

The storage programme of Petróleos Mexicanos has been formulated on the basis that Mexico will soon be producing and consuming 3,000 tons of ammonia per day. The ammonia will be stored in refrigerated tanks, at atmospheric pressure, each one having a capacity of 20,000 tons. In the future, medium-size tanks with a capacity of 12,000 tons will be built in areas of average consumption.

The ammonia storage programme has included up to now the installation of six large tanks, each with a capacity of 20,000 tons, of which two will be in Minatitlán and will serve as storage vessels for production and at the same time supply the national distribution network. Another tank will be located at the port of Salina Cruz, on the other side of the isthmus of Tehuantepec, and will supply the vessels which transport the product along the coast of the Pacific Ocean. The Salina Cruz tank will receive ammonia through an ammonia pipeline six inches in diameter that starts at Minatitlán. The other three projected tanks will be located at the Pacific seaports of Guaymas and Rosarito and at Tampico on the Gulf of Mexico.

Transporting ammonia by sea requires vessels with refrigerated tanks that operate at atmospheric pressure. At the beginning of this year a refrigerated tanker with a capacity of 8,000 tons of ammonia for transport on the Pacific Ocean and a barge with a capacity of 2,500 tons of ammonia for transport in the Mexican Gulf, were delivered. Both vessels will handle ammonia at minus 33° C using refrigeration equipment to keep the cargo at this temperature.

The outstanding feature of the equipment in the new ammonia plant with a capacity of 1,200 tons per day is the use of centrifugal compressors. The process is based on the latest techniques. There is, for instance, a single train, high pressure in the reforming and low pressure in the synthesis portion. It was not easy to decide to install a plant with such enormous capacity; however, after taking into account the great economies that can be made with this new type of plant, compared with those of traditional design, it was decided to go ahead and brave the risks inherent in the use of new designs. One reason behind this decision was the satisfactory operation over a period of years of four plants of the conventional type. Without the experience thus gained, a high-capacity plant would presumably not have been built.

The need to transport ammonia by pipeline across the isthmus is among the factors making this decision economically possible. The ammonia pipeline is scheduled to begin operation in July this year, and at the first stage, while a single plant with a capacity of 1,200 tons per day is in operation, will carry 500 tons per day. This volume could be increased to 1,000 tons per day when the second high-capacity ammonia plant has been built. The total length of the ammonia pipeline is 260 kilometres with an intermediate pumping station.

The pipeline will operate without thermic insulation and at ambient temperature. No special alloys were used and it is of standard steel. The ammonia will heat up to ambient temperature as it flows from the departure point, and on its arrival in Salina Cruz it will be recooled to the storage temperature of minus 31° C.

A map of the Mexican Republic showing ammonia plants and existing storage terminals is appended.

This survey of the fertilizer industry in Mexico shows clearly that the foundations have now been laid and that, with sound planning, the targets set in this important field will be achieved.

Table 2

CONSUMPTION OF FERTILIZERS

(Tons)

Year	*Ammonium sulphate*	*Ammonium nitrate*	*Urea*	*Single and triple superphosphates*	*Multinutrient, mixed and DAP*	*Annual total*
1956	117,991	47,021	17,793	80,633	78,339	341,777
1957	105,777	41,208	27,029	88,715	114,447	377,176
1958	99,975	53,461	30,144	82,650	134,972	401,202
1959	133,344	41,942	42,083	103,149	153,496	471,014
1960	137,442	70,097	42,781	98,005	155,638	503,963
1961	145,025	69,430	43,139	106,994	120,873	485,461
1962	143,826	124,787	46,113	128,771	131,466	574,963
1963	148,061	131,474	83,348	163,513	195,167	721,563
1964	158,509	156,393	113,490	167,188	235,972	832,552
1965	265,700	142,832	119,086	166,047	195,213	888,878
1966	276,698	175,335	131,294	197,102	236,372	1,016,801
1967	301,624	166,436	122,340	202,372	224,790	1,017,562

Consumption of anhydrous ammonia used directly is not included in the above table. Although it is difficult to assess precise amounts, the following estimates are available for the last few years: 1965 — 149,000 tons; 1966 — 179,000 tons; 1967 — 219,700 tons.

Table 3

PRODUCTION OF FERTILIZERS

(Tons)

Year	*Ammonium sulphate*	*Ammonium nitrate*	*Urea*	*Single super-phosphate*	*Triple super-phosphate*	*Multi-nutrient*	*Mixed*	*DAP*	*Annual total*
1955	64,902	—	—	74,979	—	—	47.725	—	187,606
1956	80,131	—	—	77,138	—	—	54,634	—	211,903
1957	92,658	—	—	84,560	—	—	73,469	—	250,687
1958	90,298	—	—	78,085	—	—	70,437	—	238,820
1959	105,928	10,209	—	99,514	—	—	94,297	—	309,958
1960	134,795	53,825	—	94,095	—	—	74,191	—	356,906
1961	145,025	52,335	—	104,031	—	—	77,592	—	378,983
1962	143,846	123,076	17	109,400	15,168	1,555	88,192	—	393,062
1963	148,021	122,733	38,938	117,024	45,309	58,719	94,398	853	625,995
1964	149,712	127,278	81,748	122,613	40,423	81,387	94,462	4,278	702,123
1965	191,980	94,319	96,221	131,328	33,857	112,552	81,223	10,251	751,731
1966	218,223	146,788	104,077	149,260	47,809	137,506	98,199	7,176	909,038
1967	229,318	162,707	96,369	157,947	44,572	140,710	85,734	24,925	942,282

Table 4

QUANTITIES OF IMPORTED FERTILIZER
(Tons)

Year	*Ammonium sulphate*	*Ammonium nitrate*	*Urea*	*Ammonium phosphates*	*Multinutrient, others and mixed*	*Annual total*
1956	37,860	47,021	17,793	3,495	23,705	129,874
1957	13,119	41,208	27,029	4,155	40,978	126,489
1958	9,677	53,461	30,144	4,565	64,535	162,382
1959	27,416	31,733	42,083	3,635	59,199	164,066
1960	2,647	16,272	42,781	3,910	81,447	147,057
1961	—	17,095	43,139	2,963	43.281	106,478
1962	—	1,711	46,096	4,203	41,719	93,729
1963	40	8,741	44,410	1,180	42,050	96,421
1964	8,797	29,115	31,742	4,152	60,123	133,929
1965	73,720	48,513	22,865	862	1,438	147,398
1966	58,475	28,547	27,217	33	667	114,939
1967	72,306	4,129	26,671	3	751	103,860

Table 5

FERTILIZER PRODUCTION CAPACITY (MAY 1968)
(excluding ammonia plants)

Firm	*Type of fertilizer*	*Number of plants*	*Total capacity (tons/year)*	*Individual capacity (tons/year)*	*Location*
Guanos y Fertilizantes de México, S. A. ..	Ammonium sulphate	5	256,000	33,000	Coatzacoalcos
				33,000	Córtazar
				110,000	Cuautitlán
				72,000	Torreón
				8,000	Monclova
Industrias Químicas de México, S. A.	Ammonium sulphate	2	80,000	40,000	Zacapu
				40,000	Guadalajara
Companía Minera ASARCO, S. A.......	Ammonium sulphate	1	5,000	5,000	Nva. Rosita
Guanos y Fertilizantes de México, S. A....	Ammonium nitrate	2	178,000	62,700	Monclova
				115,500	Minatitlán
Guanos y Fertilizantes de México, S. A....	Urea	3	190,000	58,000	Salamanca
				58,000	Minatitlán
				74,000	Camargo
Guanos y Fertilizantes de México, S. A. ..	Multinutrient, mixed and DAP	2	215,000	50,000	Monclova
				165,000	Minatitlán
Guanos y Fertilizantes de México, S. A. ..	Single superphosphate	2	125,000	120,000	Cuautitlán
				5,000	Sn. Cristobal Ecatepec
Fertilizantes de México, S. A.	Single superphosphate	1	5,000	5,000	Estación Vergel
Guanos y Fertilizantes de México, S. A. ..	Triple superphosphate	2	100,000	50,000	Monclova
				50,000	Minatitlán
	Total	20	1,154,200		

Table 6

FUTURE FERTILIZER PLANTS
(excluding ammonia plants)

Firm	*Type of fertilizer*	*Number of plants*	*Total capacity (tons/year)*	*Individual capacity (tons/year)*	*Location*
Guanos y Fertilizantes de México, S. A. ..	Ammonium sulphate	2	268,000	150,000	Guadalajara
				118,000	Coatzacoalcos
Guanos y Fertilizantes de México, S. A. ..	Ammonium nitrate	1	100,000	100,000	Guaymas
Guanos y Fertilizantes de México, S. A. ..	Ammonium sulphate	1	164,000	164,000	Guaymas
Guanos y Fertilizantes de México, S. A. ..	Urea	1	165,000	165,000	Coatzacoalcos
Fertilizantes Fosfatados Mexicanos	Triple superphosphate	1	204,000	204,000	Pajaritos
	Total	6	863,000		

NOTES: (*a*) The installations of Fertilizantes Fosfatados Mexicanos also include:
1 sulphuric acid plant with a capacity of 1,065,000 tons/year
1 phosphoric acid plant with a capacity of 555,000 tons/year

(*b*) The following data about a plant (although not a fertilizer plant), for beneficiating phosphate rock should be noted:

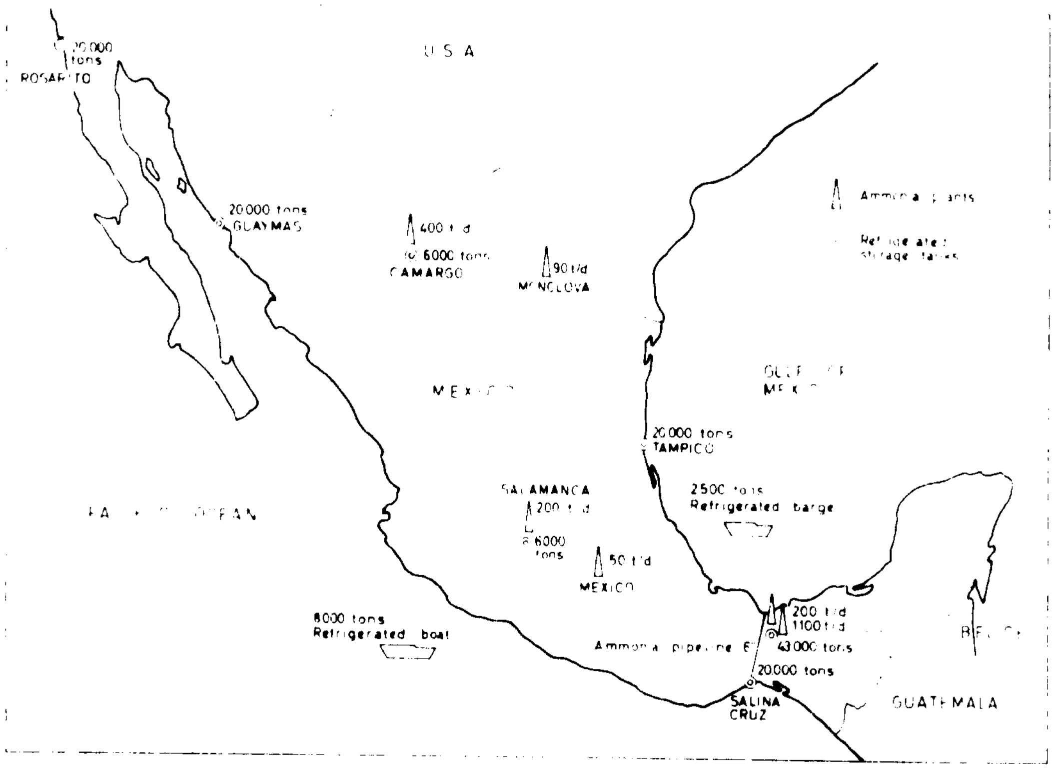
Firms: Guanos y Fertilizantes de México, S. A. (Mayoritaria)
Zincamex
Fomento Minero

Investment: $18,000,000

Feed: 100,000 tons/year mineral of 18 per cent P_2O_5

Product: 60,000 tons/year mineral of 30 per cent P_2O_5

AMMONIA PLANTS AND EXISTING STORAGE TERMINALS IN MEXICO



D01448

Abdalla Abdel Wahab,
Under-Secretary,
Ministry of Industry and Mining,
the Sudan

PROSPECTS FOR FERTILIZERS IN THE SUDAN[1]

The Sudan is, at present, predominantly dependent on agriculture for its economy and is likely to remain so for some time to come. Indeed, its role as a food-producing country in a rapidly expanding world could become of even greater importance. The Sudan is a vast country with 100 million feddans[2] of potentially cultivable land, of which only about 8 million are being used. Consequently, the expansion and development of new agricultural areas forms a large part of government development plans.

Fertilizers will be needed in ever larger quantities to increase the agricultural yield and provide for future expansion and development. Farming in the Sudan is still mainly in the hands of small peasant farmers not yet accustomed to the proper use of fertilizers and their effectiveness as an aid to production, although much success has been achieved in the Gezira and elsewhere, where the purchase and distribution of fertilizers and instruction on their use are under proper direction.

The situation is being remedied as quickly as possible by education and the increased availability and distribution of fertilizers, but there is still much to be done. In particular, the cost of fertilizers must be reduced; generous credit must be extended to the farmer to cover the period between planting and the sale of his products.

The Sudan at present imports nearly 55,000 tons of urea *per annum*, but it is estimated that by the early 1970s the demand will have increased to about 100,000 tons, which, at an estimated cost of $74 per ton, c. i. f. Port Sudan, would involve an annual expenditure in foreign currency of about $7,400,000. This enormous drain on scarce foreign exchange is sufficient reason for undertaking a study of the possibility of manufacturing fertilizers domestically. Technical and economic feasibility studies for such an industry were recently carried out by the Sudan Industrial Research Institute and published in February 1968.

Since soils of the Sudan are mainly deficient in nitrogen, most of the fertilizers used are of a nitrogenous nature. Urea has been chosen as the most suitable

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1 In the absence of Mr. Wahab, this paper was presented at the meeting by Mr. Abdalla Fadlalla.

2 One feddan = 1.04 acres = 0.42 hectares.

fertilizer for domestic manufacture; and, in the absence of natural gas, light naphtha, which is available in sufficient quantities from the refinery at Port Sudan, will be used as the raw material. Ammonia, and its by-product carbon dioxide, can be produced by the steam-reforming process. It would, of course, be possible to import ammonia more cheaply, but in this case carbon dioxide would have to be manufactured at a very high cost instead of being available at practically no cost from the local production of ammonia.

It is estimated that the establishment of a plant for the manufacture of 100,000 tons of urea *per annum* would require a capital investment of $20 million. It would also require the availability of relatively large quantities of electricity and water, a highly technical staff, a reasonably cheap transport system and an efficient system of distribution.

Four possible sites were considered for the plant's location:

Port Sudan. This is the main port of the Sudan and its refinery is the source of the raw material, naphtha. For an annual production of 100,000 tons of urea, about 43,000 tons of naphtha must be supplied continuously over eleven months of the year, or approximately 1,000 tons a week. If the plant is situated close to the refinery this presents no problems of transport, which could be carried out by means of a short pipeline, or of storage facilities. The difficulty, however, is in providing the utilities for such a plant in this location. The total electric capacity of the two generating stations of Port Sudan is 8 MW, of which only about 6 MW is available, owing to shutdowns for routine maintenance, etc. As the maximum demand already is about 4 MW, there is clearly no possibility of meeting the 5 MW requirements needed for the fertilizer plant. The plant would have to produce its own electic power thermally. Fresh water is another problem. The present supply to the town comes from the Khor Arbaat catchment area in the Red Sea hills, about 35 kilometres distant. The supply through the existing pipelines is limited to 14,000 tons per day, and in recurrent periods of drought, restrictions have to be imposed on consumption during the summer months. Even if additional pipelines were installed it is not certain that a continuous supply of fresh water would be available for processing and cooling purposes. Water could, of course, be pumped from the sea and desalinated, but this would be costly. Cooling with sea-water is possible but would involve special construction materials that are also costly.

Khartoum area. This lacks the advantage of being near either the centres of consumption of fertilizers or the source of raw materials. It could, however, more readily provide skilled workers for the feeder industries essential for the support of large-scale industry.

Roseires area. It might be assumed that the plant would have cheaper electricity if it were to be erected near the hydroelectric supply station. However, of all sites considered, Roseires is the most remote from Port Sudan and is at a considerable distance, too, from the main centres of consumption. Transport costs and difficulties would be at a maximum.

Sennar area. Sennar is the railway junction for Khartoum, Kassala, Roseires and Kosti, and it is nearest to the centres of consumption. Electricity is available, and water can be pumped from the Blue Nile. During the two months when the river is in flood, a considerable amount of sediment is carried in the water, but this can be dealt with by installing suitable filters. If the plant is placed within a mile or so of the town, as is proposed, domestic and drinking water can be obtained from the town supply.

The main problem is the cost of transport of naphtha from Port Sudan to Sennar, a distance of about 600 miles. Although the weight of the finished product, urea, is two-and-a-half times that of naphtha, the former is a bagged material that can be transported easily in ordinary trucks, while the latter, a highly inflammable liquid, must be carried in tank wagons. The railway from Port Sudan to Sennar is a single track, and experience indicates an average turn-round time of ten days. On the basis of 1,000 tons of naphtha per week, with a reasonable allowance for maintenance and breakdowns, at least sixty 40-ton tank cars will be required. The cost is estimated at S£6,500 per car, plus, of course, the cost of maintenance workshops. Adequate facilities for storage must also be provided at Sennar to allow for breakdowns on the railway for various reasons, including the heavy rains.

Sudan Railways have also pointed out the difficulties of transporting certain items of plant from Port Sudan to an inland site, in particular, the carbon dioxide absorption tower, which is about 42 metres long and weighs some 25 tons, and the urea reactor, which is 24 metres long and weighs about 110 tons. The maxmum length of a single standard truck is 10 metres, and the maximum weight that can be carried, even on available low loaders, is 49 tons. These difficulties can be overcome, as elsewhere, by slinging the long items across trucks, properly spaced and supported on swivelling cradles (to protect them over the curves of the railway), and by carrying the heavy items on two trucks with, perhaps, additional bracing. Sudan Railways have not had any experience with these unusual methods and would need instruction and help in their application.

The labour required will have to be highly skilled and capable of dealing effectively with the intricacies of a modern, highly instrumented, high-pressure and high-temperature chemical plant. Intensive training at all levels will be necessary during the period of construction, and the need for foreign technical management for a certain time can be envisaged.

The total capital cost of the project is likely to exceed $20 million, and the country would be obliged to obtain loans to finance the foreign currency component of the cost.

The attached tables give statistical, technical and economic information pertaining to the project. A map of the Sudan is appended.

The great jump in consumption estimated for 1970 to 1973 will come about only if the Kenana (Rahad) land is utilized according to the Ten-Year economic Development Plan.

Table 1

CONSUMPTION OF NITROGEN FERTILIZERS IN THE SUDAN (1960–1967)

Year	*Consumption (tons of N)*
1960	19,217
1961	25,003
1962	19,095
1963	20,265
1964	16,869
1965	22,469
1966	26,734
1967	27,780

Table 2

PROJECTED FUTURE DEMAND FOR NITROGEN FERTILIZERS

Year	*Tons of N*
1968	29,344
1969	31,368
1970	39,270
1971	45,158
1972	50,670
1973	54,350

Table 3

RAW MATERIALS AND UTILITY REQUIREMENTS PER TON UREA

	Per 0.585 ton ammonia	*Per ton urea*	*Total requirements per ton urea*
Naphtha (ton)	0.42–0.45	–	0.435
Electricity (kWh)	440	190	630
Cooling water (m^3)	38–175	121	270
Boiler feed-water (ton)	1.23–2.5	1.5	2.9
Steam (185 psig; ton)	–	1.85	1.85

Table 4

ESTIMATE OF CAPITAL COST FOR UREA PLANT IN SENNAR[a]

No.	Item	Total cost ($)	Foreign exchange	Local currency equivalent
1.	Equipment f. o. b.			
1 a.	Ammonia plant	4,600,000	4,600,000	—
1 b.	Urea plant	3,300,000	3,300,000	—
1 c.	Auxiliary plants	3,100,000	3,100,000	—
2.	Total equipment f. o. b.	11,000,000	11,000,000	—
3.	Freight and insurance (8% of item No. 2)	880,000	880,000	—
4.	Rail transport	107,000	—	107,000
5.	Civil engineering (40% of item No. 2)	4,400,000	660,000	3,740,000
6.	Erection (20% of item No. 2)	2,200,000	1,100,000	1,100,000
7.	Development and start-up (5% of item No. 2)	550,000	440,000	110,000
8.	Total plant investment	19,137,000	14,080,000	5,057,000
9.	Inventory (2.5% of item No. 8)	480,000	240,000	240,000
10.	Liquid cash (25% of yearly operating costs)	950,000	450,000	500,000
11.	Total capital required	20,567,000	14,770,000	5,797,000

[a] Plant capacity 100,000 tons/year.

Table 5

ESTIMATED COST OF MANUFACTURING UREA, SITE SENNAR[a]

Item	*Unit*	*Cost per unit* ($)	*Annual quantities*		*Total annual cost* ($)	*Foreign exchange component* ($)	*Local currency component* ($)
			Ammonia unit	*Urea unit*			
Naphtha	ton	20.00	43,500		870,000	870,000	—
Transport cost of naphtha	ton	14.20	43,500	—	617,000	—	617,000
Fuel oil (for steam boiler)	ton	20.00	—	11,300	226,000	226,000	—
Transport cost of fuel oil	ton	9.90	—	11,300	112,000	—	122,000
Electric power	1,000 kWh	12.75	44,000	19,000	803,000	—	803,000
Treated water	ton	0.28	140,000	150,000	81,200	81,200	—
Catalysts and other chemicals	—	—	—	—	170,000	170,000	—
Bags	piece	0.19	—	2 million	380,000	380,000	—
Local salaries, wages and overhead costs	—	—	—	—	500,000	—	500,000
Salaries of foreign experts	—	—	—	—	60,000	30,000	30,000
Sub-total	—	—	—	—	3,819,200	1,757,200	2,062,000
Depreciation: 4% buildings					176,000	26,000	150,000
10 per cent of other part of fixed capital					1,473,000	1,342,000	131,000
Interest: 4% of fixed capital					823,000	591,000	232,000
Maintenance: 4% of equipment cost					440,000	320,000	120,000
Manufacturing cost of 100,000 tons of urea	ton	68.75	—	100,000	6,731,200	4,036,200	2,695,000

[a] Plant capacity 100,000 tons/year.

Table 6

PROFITABILITY OF THE SENNAR PROJECT AND SAVING IN FOREIGN EXCHANGE

The present world price of urea, bulk, 46 per cent N, is \$84 (f. o. b. New York). However, urea was imported at \$75.3 c. i. f. Port Sudan in 1967. The price of urea has lately shown a tendency to decrease. A price of \$74.0 c. i. f. Port Sudan, \$80.0 at Sennar, was assumed for the calculation of the annual foreign exchange saving and profits.

A. *Profitability* (dollars)

Annual revenue from sales	100,000 × 80 =	8,000,000
Annual operating cost[a]		6,731,200
Annual profit		1,268,800

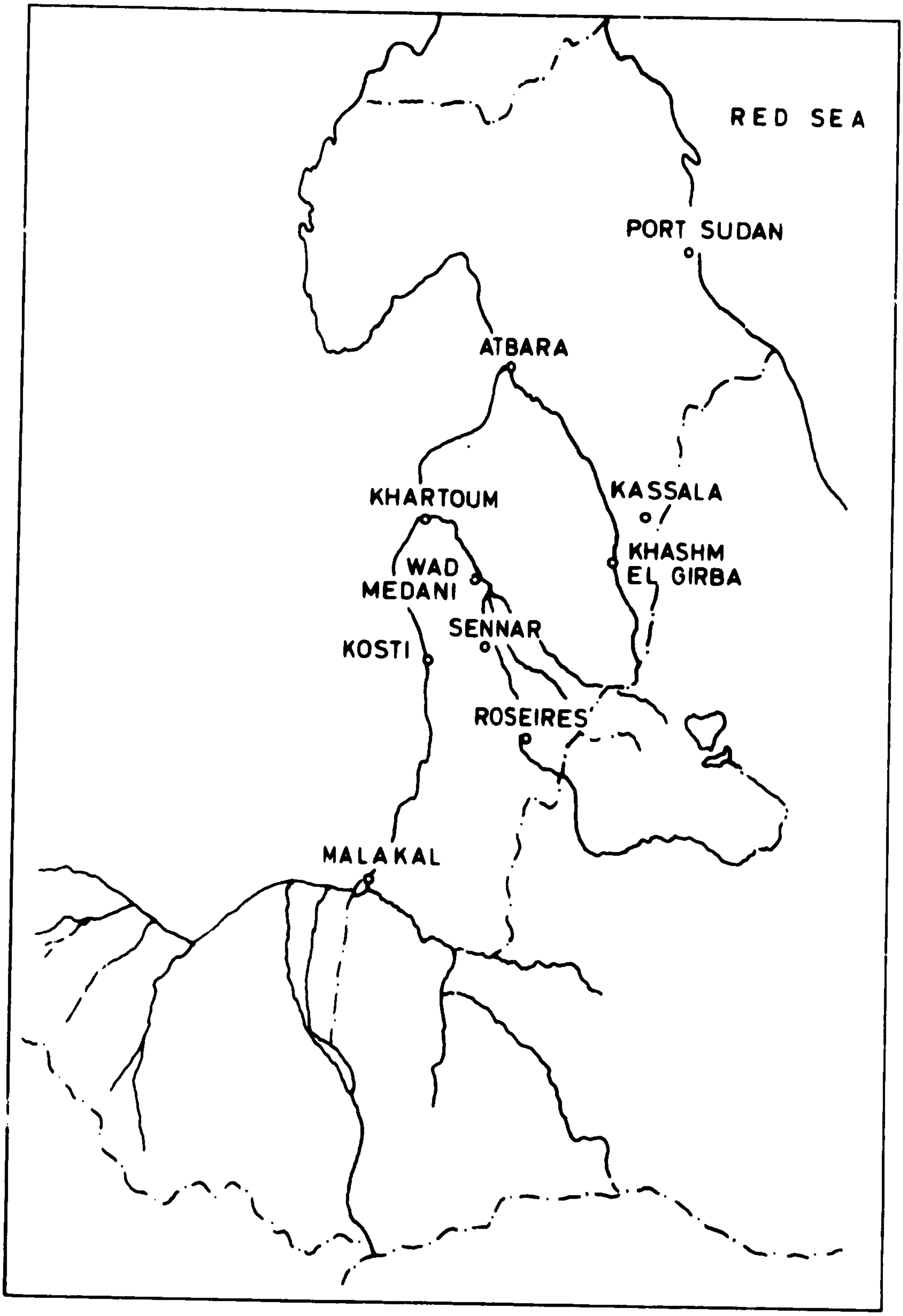
Profitability $\frac{1,268,800}{20,567,000} = 6\%$

B. *Foreign exchange savings* (dollars)

Cost of imported urea (c. i. f. Port Sudan)		100,000 × 74
		7,400,000
Total foreign exchange expenditure (including depreciation, interest, naphtha and fuel cost)		4,036,200
Net foreign exchange savings per year		3,363,800

[a] Four per cent of the fixed capital is included as interest in the figure for annual operating costs.

MAP OF THE SUDAN



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DEVELOPMENT OF THE FERTILIZER INDUSTRY IN THE UNITED ARAB REPUBLIC

INTRODUCTION

Table 1 shows clearly that in 1952, 94.3 per cent of the population owned 35.4 per cent of the total area under cultivation, while 0.4 per cent of the population owned 34.2 per cent of the total cultivable area.

Table 1

POPULATION AND DISTRIBUTION OF LANDHOLDINGS

Individual holding (acres)	*1952*		*1965*	
	Population (%)	*Total area* (%)	*Population* (%)	*Total area* (%)
Under 5	94.3	35.4	94.5	57.1
5	2.8	8.8	2.4	9.5
10	1.7	10.7	1.9	8.2
20	0.8	10.9	0.9	12.6
50	0.2	7.2	0.2	6.1
100	0.2	27.0	0.1	6.5

Such a land distribution represented a serious injustice which had to be corrected before any further measures for the development of agriculture could be undertaken. Land reform legislation to ensure a maximum measure of social justice is a necessary precondition for successful agricultural development.

HORIZONTAL DEVELOPMENT OF AGRICULTURE

The Aswan High Dam

The horizontal development of agriculture, which means increasing the area of land under cultivation, demands full utilization of available water resources. Hence, the United Arab Republic gave first priority to controlling the Nile river and making the maximum use of its waters. After detailed studies had been carried out it was decided to create a reservoir by constructing the High Dam at Aswan to store and control the waters of the Nile, including the flood waters. By this means 32 thousand million cubic meters of water could be saved annually.

The advantages of this project may be summarized as follows:

(*a*) An increase in the cultivable area of 2 million acres, which represents an increase of 33 per cent of the total cultivable area for 1952;

(*b*) The guaranteed availability of water for the total cultivable area, both old and new;

(*c*) Protection against floods;

(*d*) Lowering of the underground water level, with consequently improved drainage and increased productivity of the land;

(*e*) Substantial increase in the area under rice cultivation;

(*f*) Improved conditions along the Nile that permit navigation throughout the year;

(*g*) Hydroelectric power generation of up to ten thousand million kWh/year to be used for industrial and agricultural development.

The construction of the High Dam has resulted in an increase in the national income of an estimated E£234 million *per annum*.

The estimated cost of the project amounted to E£415 million, of which 35 per cent had to be in foreign currency to cover the cost of construction and power equipment.

Construction began on 9 January 1960, and the first stage was completed on schedule on 14 May 1964. The second stage of the construction will be completed by the end of 1968, twelve months ahead of schedule.

Work on the hydroelectric power station is progressing satisfactorily, and four units are already in operation. Another four will be in service by October 1968 and the last four by the beginning of 1969, also a year ahead of schedule. The construction of the first 500 kVA high-tension transmission line linking Aswan with Cairo was completed and commissioned in early January 1968. When the second 500 kVA transmission line is finished this year the entire high-voltage network covering the Nile delta will be in operation.

Development of other water resources

The Government is also working on the development of underground water resources and desalinization of sea-water. The full development of these two water resources will allow a substantial increase in the area of land under cultivation.

THE DEVELOPMENT OF THE FERTILIZER INDUSTRY

It was decided to give a high priority to the development of a domestic fertilizer industry because fertilizers are the main input affecting the vertical development of agriculture, which means increasing the yield per acre, and the necessary raw materials were available.

It was hoped that a domestic fertilizer industry would produce enough to meet all local requirements and eventually a surplus for export. It was also decided to increase the allocation of foreign currency for the importation of fertilizers to cover as much as possible of the gap between local production and demand. The foreign currency allotment is apportioned according to the requirements of other projects in the social and economic development plan.

Production of nitrogen fertilizers

Table 2 shows the annual production of nitrogen fertilizers in the United Arab Republic from 1951/1952 to 1964/1965.

Table 2

ANNUAL PRODUCTION OF NITROGEN FERTILIZERS

(Thousand tons)

	Calcium nitrate (15.5% N)	*Ammonium sulphate (20.6% N)*	*Calcium ammonium (20.5% N)*	*Total equivalent (15.5% N)*
1951/1952	111	—	—	111
1959/1960	250	—	20	276.4
1960/1961	265	—	176	497
1961/1962	265	—	356	735
1962/1963	267	—	321	690
1963/1964	275	64	427	902
1964/1965	275	80	434	928

Table 2 shows that the total production in 1964/1965 was 836 per cent of that in 1951/1952.

Local production of nitrogen fertilizers has, in fact, gone up to 1,146,000 tons (expressed as product with 15.5 per cent N) in 1966/1967, but this study is restricted to the period from 1951/1952 to 1964/1965.

Production of single superphosphate fertilizer

Table 3 shows the annual phosphate fertilizer production during the period 1951/1952 to 1964/1965. Only single superphosphate is produced in the UAR.

Table 3

ANNUAL PRODUCTION OF SINGLE SUPERPHOSPHATE FERTILIZER

(Thousand tons)

1951/1952	*1959/1960*	*1960/1961*	*1961/1962*	*1962/1963*	*1963/1964*	*1964/1965*
106	178	185	171	159	171	266

The production of single superphosphate fertilizer in 1964/1965 was 250 per cent of that in 1951/1952.

Consumption of nitrogen fertilizers

Table 4 compares the estimated and actual consumption of nitrogen fertilizers from 1960/1961 to 1964/1965.

Table 4

ESTIMATED AND ACTUAL ANNUAL CONSUMPTION OF NITROGEN FERTILIZERS

Period	*Consumption (tons of 15.5% N equivalent)*		*Actual/ estimated percentage*	*Percentage increase in annual consumption*
	Estimated	*Actual*		
1960/1961	1,333,000	1,143,000	85.8	—
1961/1962	1,442,000	1,189,600	82.5	4.0
1962/1963	1,582,000	1,254,600	79.3	5.5
1963/1964	1,722,000	1,457,800	84.7	16.19
1964/1965	1,978,000	1,685,816	85.2	15.71

This table shows that the consumption of nitrogen fertilizers has been steadily increasing and that the actual consumption of nitrogen fertilizers averages 83.5 per cent of the estimated consumption—a deficiency of 16.3 per cent *per annum.*

Consumption of phosphate fertilizers

Table 5 compares the estimated and actual consumption of fertilizers from 1960/1961 to 1964/1965.

Table 5

ESTIMATED AND ACTUAL ANNUAL CONSUMPTION OF PHOSPHATE FERTILIZERS

Period	*Consumption (tons of fertilizer)*		*Actual/ estimated percentage*	*Percentage increase in annual consumption*
	Estimated	*Actual*		
1960/1961	351,000	226,000	64.6	—
1961/1962	402,000	242,300	60.5	6.9
1962/1963	463,000	248,600	53.7	2.2
1963/1964	535,000	289,200	54.1	15.4
1964/1965	556,000	322,279	58.0	11.4

The above table shows that the actual consumption of phosphate fertilizers from 1960/1961 to 1964/1965 has increased at an average rate of 9.3 per cent *per annum* and that the actual consumption averages 58.1 per cent of the estimated consumption—an average annual deficiency of 41.9 per cent.

Consumption of potash fertilizers

Table 6 compares the estimated and actual consumption of potash fertilizers from 1960/1961 to 1964/1965.

Table 6

ESTIMATED AND ACTUAL ANNUAL CONSUMPTION OF POTASH FERTILIZERS

Period	*Consumption (tons of fertilizer)*		*Actual/estimated percentage*
	Estimated	*Actual*	
1960/1961	9,000	3,500	38.9
1961/1962	13,000	2,700	20.8
1962/1963	19,000	1,800	9.5
1963/1964	26,000	2,000	7.7
1964/1965	27,000	1,200	4.4

Table 6 shows that the consumption of potash fertilizers was decreasing annually from 1960/1961 to 1964/1965, that actual consumption was much lower than estimated and that the gap between actual and estimated consumption was increasing sharply.

Comparison of fertilizer production and consumption

Nitrogen fertilizers

Table 7

ANNUAL PRODUCTION AND ESTIMATED AND ACTUAL ANNUAL CONSUMPTION OF NITROGEN FERTILIZERS

Period	*Production (P) (tons of 15.5% N equivalent)*	*Consumption (tons of 15.5% N equivalent)*		*P/E* (%)	*P/A* (%)
		Estimated (E)	*Actual (A)*		
1960/1961	497,000	1,333,000	1,143,000	37.28	43.28
1961/1962	735,000	1,442,000	1,189,000	50.97	61.78
1962/1963	690,000	1,582,000	1,254,000	43.62	55.00
1963/1964	902,000	1,722,000	1,457,800	52.38	61.91
1964/1965	928,000	1,978,000	1,685,816	46.91	55.04

Table 7 shows that while the annual production of nitrogen fertilizers almost doubled between 1960/1961 and 1964/1965, this increase covered only 55.04 per cent of the actual consumption for 1964/1965 and 46.91 per cent of the estimated consumption. This is a result of the steady annual increase in the consumption of nitrogen fertilizers from 1960/1961 to 1964/1965.

Phosphate fertilizers

Table 8

ANNUAL PRODUCTION AND ESTIMATED AND ACTUAL ANNUAL CONSUMPTION OF PHOSPHATE FERTILIZERS

Period	Production (P) (tons of fertilizer)	Consumption (tons of fertilizer)		P/E (%)	P/A (%)
		Estimated (E)	Actual (A)		
1960/1961	185,000	351,000	226,600	52.71	81.73
1961/1962	171,000	402,000	242,300	42.43	70.57
1962/1963	159,000	463,000	248,600	34.34	63.95
1963/1964	171,000	535,000	289,200	31.96	59.13
1964/1965	266,000	556,000	322,279	46.99	82.54

Table 8 shows that while production in 1964/1965 was 143.7 per cent of that in 1960/1961, it covered only 46.99 per cent of the estimated and 82.54 per cent of the actual consumption for 1964/1965.

Fertilizer imports

Nitrogen fertilizers

Table 9 shows the amount of nitrogen fertilizer imported annually from 1960/1961 to 1964/1965.

Table 9

ESTIMATED AND ACTUAL ANNUAL IMPORTS OF NITROGEN FERTILIZERS

Period	Imports (tons of 15.5% N equivalent)	
	Estimated	Actual
1960/1961	836,000	646,000
1961/1962	707,000	454,600
1962/1963	892,000	564,600
1963/1964	820,000	555,800
1964/1965	1,050,000	757,816
Total	3,505,000	2,978,816

From table 9 it will be noted that the foreign exchange drain for the import of nitrogen fertilizers for actual consumption was equal to the cost of 2,978,816 tons (on 15.5 per cent N basis) over the period of 1960/1961 to 1964/1965, amounting to approximately $90 million calculated at average purchase prices prevailing at the time. Nevertheless, there was, at the same time, an estimated nitrogen fertilizer deficiency of 526,184 tons (on 15.5 per cent N basis) below the estimated demand for consumption.

Phosphate fertilizers

Table 10 indicates the amount of phosphate fertilizer imported annually from 1960/1961 to 1964/1965.

Table 10

ESTIMATED AND ACTUAL ANNUAL IMPORTS OF PHOSPHATE FERTILIZER

Period	Imports (tons SSP)	
	Estimated	Actual
1960/1961	166,000	41,600
1961/1962	232,000	71,000
1962/1963	304,000	89,600
1963/1964	364,000	118,200
1964/1965	290,000	56,279
Total	1,356,000	376,679

From the above table it will be noted that the amount of foreign exchange required for the import of phosphate fertilizer to meet the actual demand was equal to the cost of 376,679 tons over the period 1960/1961 to 1964/1965, or approximately $9.5 million. There was a deficiency in phosphate fertilizer over the same period equivalent to 979,321 tons of single superphosphate (SSP).

Estimate of future fertilizer production and consumption

It is expected that annual production of nitrogen fertilizers will rise to 1,850,000 tons (on 15.5 per cent N basis) by the end of 1970/1975. This means that production will be almost double that for 1964/1965, or about 1,620 per cent of that in 1951/1952.

The demand for fertilizers will increase during the period 1965 to 1975 at an even greater rate than before because of the horizontal and vertical development of agriculture made possible by the construction of the High Dam. Additional acreage will be brought under cultivation (horizontal development). The increased and regular supply of water will make it possible to raise the productivity per acre of both old and new land (vertical development). In both cases more fertilizer will be needed.

Table 11 gives a projection of annual nitrogen fertilizer consumption from 1965/1966 to 1974/1975.

It is thus evident that in spite of the large increase in production of nitrogen fertilizers, there is a persistent and increasing gap between fertilizer production and estimated consumption. By 1974/1975 the estimated consumption will be about 2.7 times local production. On this basis the deficit in 1974/1975 will equal 3.24 million tons of fertilizer with 15.5 per cent N, and this amount of fertilizer will have to be imported.

Table 11

ESTIMATED ANNUAL NITROGEN FERTILIZER CONSUMPTION

(Thousand tons of 15.5% N equivalent)

1964/1965	1,978	1970/1971	3,483
1965/1966	2,175	1971/1972	3,831
1966/1967	2,392	1972/1973	4,214
1967/1968	2,631	1973/1974	4,635
1968/1969	2,894	1974/1975	5,098
1969/1970	3,183		

Potential for further production

The United Arab Republic is rich in raw materials for producing nitrogen fertilizers. Furthermore, recent discoveries of extensive oil and natural gas reserves will also permit the nitrogen fertilizer industry to be developed into one of the major exporting industries. A plant with a capacity of 1,000 tons NH_3 per day is under consideration as a first step in this direction.

The United Arab Republic is also rich in rock-phosphate deposits. With the abundant low-cost hydroelectric energy from the Aswan High Dam the development phosphate fertilizer industry is assured on the basis of the electro-thermal process. This industry could also be developed to meet export market demands on a regional basis. A plant with a production capacity of 300,000 tons P_2O_5 per year is at present under consideration.

The availability of raw materials, skilled labour, a large and steadily developing local market and a strategic geographical location are all factors that would ensure the large-scale development of the fertilizer industry.

TRENDS IN THE FERTILIZER INDUSTRY

High-analysis solid fertilizers

An important trend in the fertilizer industry is the systematic changeover to high-analysis fertilizers. For example, the nitrogen fertilizer industry started in 1952 with the local production of calcium nitrate 15.5 per cent N. The next stage was the production by Egyptian Chemical Industries (KIMA) of calcium ammonium nitrate (Nitrokima) with a concentration of 20.5 per cent N, which was later up-graded to 26.0 per cent N and is now 31 per cent N, or double the original concentration. It was also decided to produce urea with a concentration of 46 per cent N. Further, heavy-duty polyethylene bags have replaced jute bags.

In the past the production of phosphate fertilizers was based on SSP, but in the future it is to be based on triple superphosphate (TSP).

The use of high-analysis fertilizers will reduce the cost to the farmer.

Anhydrous and aqueous NH_3

The production and use of anhydrous NH_3 and/or aqueous NH_3 would allow a minimum capital investment in plant construction and a minimum cost of production per N unit. An intensive techno-economic study of the use of anhydrous NH_3 and aqueous NH_3 in the United Arab Republic is now being prepared.

Complex fertilizers

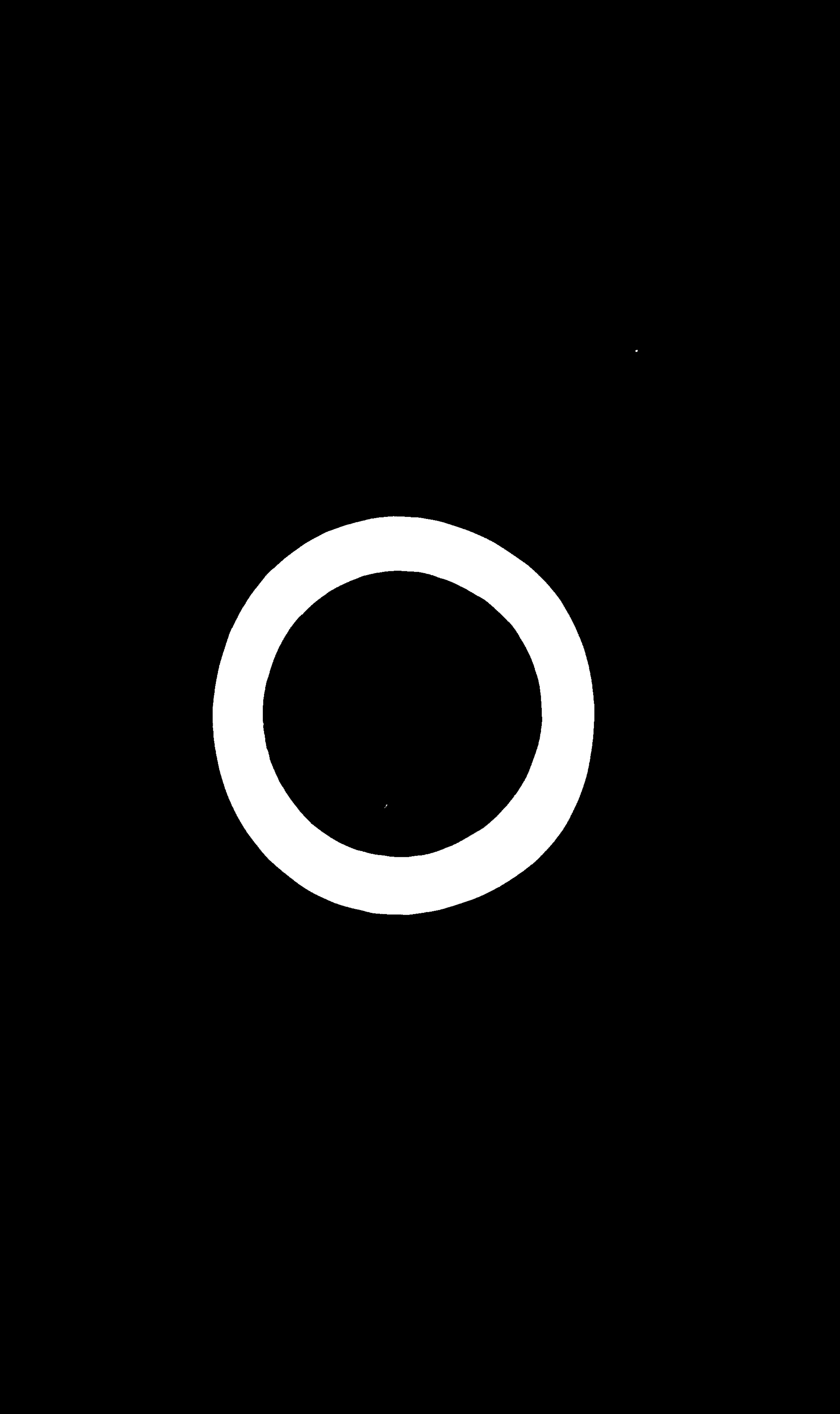
With the availability of phosphorus and phosphoric acid (on completion of the phosphorus complex of KIMA), as well as nitrogen, further development of the fertilizer industry should be based on the production of complex fertilizers (N-P-K) (2 : 1 : 0) and (2 : 1 : 0.5) as the first steps to producing crop fertilizers for application to specific crops, e. g. rice or cotton. The nutrient ratios have to be determined on the basis of intensive field research and experimental studies. The development of the complex fertilizer industry on such a basis would ensure substantial benefits to the farmers.

The production of fertilizers is, of course, not an end in itself; fertilizer is a major input to agriculture, and crops of rice or corn are the ultimate end-product. Hence, the targets for the fertilizer industry must be:

(*a*) Maximum production *per annum*;

(*b*) Minimum cost of production per unit of nutrient whether N, P or K in single form or complex combinations;

(*c*) Minimum cost per unit of nutrient to the farmer.



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FACTORS AFFECTING AND INHIBITING THE GROWTH OF THE FERTILIZER INDUSTRY IN DEVELOPING COUNTRIES

Plant capacity and on-stream factor

The majority of ammonia plants in developing countries have a capacity of not more than 300 tons per day, while those in the planning stage or being built usually have a capacity of about 500 or 600 tons per day. In the developed countries, on the other hand, ammonia plants usually have a capacity of over 1,000 tons per day. This factor has suddenly changed the pattern of the world ammonia trade, with the result that plant capacity in developing countries is not keeping up with progress.

It is widely accepted that an ammonia plant with a capacity of 1,000 tons per day is not easy to operate at 100 per cent on-stream factor even in developed countries because of processing and marketing problems. At the same time, if a plant of this size is operated at 80 per cent on-stream factor, there is no difference in manufacturing costs compared with a 600-tons-per-day plant at 100 per cent operation. Every effort will therefore be made to attain the highest possible on-stream factor by the owners of the larger plants, and this will result in increased competition. The products of the larger plants will thus be delivered to developing countries at much lower prices than they can be produced by the smaller-capacity plants of developing countries.

In such a situation, it would be highly desirable for developing countries to re-examine and rationalize their existing fertilizer plants, particularly in the nitrogen field, in consultation with experts from developed countries to determine whether they are still competitive.

The number of state-owned plants in developing countries greatly exceeds the number of plants in private hands, though the Governments of such countries have not restricted private enterprise. For instance, in India the Third Five-Year Plan set as a goal the construction by private enterprise of nine nitrogen plants with a joint capacity of 530 thousand tons/year out of fifteen plants with a total capacity of one million tons/year.

In fact, only two private plants with a capacity of 18,000 tons/year were erected compared with eight state-owned plants with a total capacity of 570,000 tons/year. Such a failure on the part of private enterprise resulted in a lowering of the over-all level of the economic plan.

Private firms in developing countries face many difficulties. They often lack sufficient capital to enter the fertilizer business. Another difficulty is that government fertilizer policy may encourage inefficiency and discourage investment. For example, the fertilizer price is sometimes decided by adding the manufacturing cost to a percentage of the profit. The effect of this is that a plant manager is unwilling to try to make a saving in cost, while the prospective investor is deprived of motivation for new investment because of a low return and insecurity. Such arbitrary price policies scare off foreign investors, with the result that the growth of the fertilizer industry is hampered. If, however, the Government were mindful in this respect, owners of foreign capital who are experienced in planning and operating the industry would contribute greatly to its progress.

Process, labour and related industries

At present, a developing country can easily obtain the latest technology and can purchase the most modern plants, guaranteed for production and quality of the product on a turn-key basis. But lack of experience in related industries that form the basis of the fertilizer industry results in a heavy expenditure for plant erection because of the necessity for importing the main items of equipment. For example, even in India, where related industries have been developed to some degree, the foreign exchange necessary for such expenditure is said to be more than 50 per cent of the total cost of erection. Again, in some developing countries, imports of certain items of equipment are prohibited or high duties imposed in order to protect the underdeveloped related industries. This has the effect of increasing the cost of erection of the plant or of delaying the building schedule. Such difficulties offset the advantages of the latest technology.

While some senior chemical engineers are available in developing countries, many of them lack experience; it is also especially difficult to obtain enough foreman-class operators. This is one of the reasons for the low plant on-stream factor.

To promote the expansion of the fertilizer industry, the developing countries must recognize the great gap that exists between them and the developed countries with respect to technology, economic level, and social conditions. Means must be found to close this gap.

Stimulation of fertilizer demand

If an industry is to grow, there must be an active demand in the country for its product. In most developing countries farmers do not have enough experience in the use of fertilizer; thus, it is essential to stimulate demand, to distribute fertilizer and collect money from farmers for the establishment of an investment organization in the fertilizer business.

Too much cannot be said about the necessity of popularizing the use of fertilizer among farmers. Another urgent need in developing countries is to obtain the services of enough agricultural specialists. Statistics indicate that the recent ratio of farmers to agricultural specialists is 300 to 1 in Japan, 700 to 1 in India, and 4,700 to 1 in Brazil.

To stimulate demand it is important to convince farmers of the profit that can be gained from using fertilizer on their crops. With this in mind, the Government should extend financial aid to farmers for the purchase of fertilizer and a credit system at low interest rates should be established.

Distribution

In developing countries fertilizer from one plant is distributed over a wider area than it is in developed countries because of the lower rates of fertilizer application, while the number of customers of farmers is larger. In addition, storage and transport facilities are inadequate.

In some developing countries, the distribution of fertilizer is organized by the Government or by co-operative associations strongly supported by it, while private distributors are only in a subordinate position. When fertilizer production is operated by an agency of the Government, in most cases its distribution is undertaken by another agency. Thus, production and distribution are not correlated. This results in insufficient consideration being given to an efficient system of distribution.

Once the plant capacity is enlarged to a 24-hour operation, the method by which fertilizer is stored, shipped and distributed becomes one of the key factors in the growth of the industry.

Conclusions

The main factors that affect and inhibit the growth of the fertilizer industry in developing countries have been briefly described. Naturally, these factors are interrelated, and it requires a great deal of effort over a long period to overcome them.

In most developing countries the fertilizer industry has not been integrated into the chemical industry, as in developed countries. Thus, many difficulties exist that prevent it from becoming an efficient operation. In spite of these disadvantages, however, it should be possible for developing countries, with assistance from developed countries, to establish a fertilizer industry on a sound basis, with an economical plant location, a sufficient supply of raw materials, adequate capacity and high on-stream factor.

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FERTILIZER OUTLOOK IN THE DEVELOPING COUNTRIES

Need for more fertilizer in the developing countries

Most of the developing countries obtain very low agricultural yields, although there are some notable exceptions. Also, many of the developing countries have serious food shortages. The basic cause of the low crop yields and the resulting food shortages is the low level of fertilizer use. The introduction of the new high-yielding, fertilizer-responsive varieties of rice, wheat and other grains during the past few years reinforces this fact.

To obtain high agricultural yields many inputs are involved, including fertilizer, water, improved seed varieties, pest control chemicals, better tools and machinery, and improved methods, but in most of the developing countries the limiting factor in agricultural production is the level of fertilizer use. This is likely to remain true in the immediate future, though the water supply may become the major limiting factor some day. Pest control can also be the limiting factor in crop yields at particular times in particular locations.

The large differences in yield between the developed countries and the developing countries leaves a great potential for improvement in yields in the latter, as may be seen from the following examples:

Yield for 1965 (kg/hectare)

Rice (paddy)		*Potatoes*	
Japan	4,950	Netherlands	26,200
Cambodia	1,070	India	8,500
Wheat		*Soybeans*	
United Kingdom	4,060	Canada	2,040
Algeria	600	Korea (Rep. of)	560
Maize			
USA	4,630		
Philippines	660		

The extensive use of fertilizer is the major cause of the high yields in the developed countries shown above.

The low level of fertilizer use in most of the developing countries is clearly illustrated by table 1(a),[1] which classifies all countries with a population of over five million in terms of five categories of fertilizer consumption in 1966/1967. Table 1(a) is summarized as follows:

Level of Fertilizer Consumption (kg/capita)	*Number of countries*	
	Developed	*Developing*
Very High (51 – 100)	9	0
High (26 – 50)	9	1 (Cuba)
Moderate (11 – 25)	6	7
Low (6 – 10)	0	7
Very Low (0 – 5)	0	35

Table 1(b) gives the detailed data on which table 1(a) is based.

The basic conclusion to be drawn from the data in tables 1(a) and 1(b) is that most of the developing countries have not yet begun to use fertilizer in amounts even approaching those used by the developed countries nor in the amounts they should be using to produce the food and other agricultural products they need for domestic consumption and for export.

Fertilizer production and consumption in developing countries

While the consumption of fertilizers is very low in the developing countries, the production of fertilizers is even lower. Virtually all the developing countries have fertilizer deficits, that is, they import part or all of the fertilizer they consume. Moreover, the size of these deficits seems likely to get larger rather than smaller during the next decade, if present economic trends continue. The only exceptions to the fertilizer-deficit position of the developing countries at present are (1) Chile, Kuwait, and Trinidad and Tobago, which have a nitrogen surplus; (2) Morocco and Tunisia, which have a phosphate surplus; and (3) Israel, which has a potash surplus.

Tables 2a, 2b and 2c summarize the production and consumption of fertilizers in Asia, Africa and Latin America in 1966/1967 with projections to 1975/1976. The trends in the fertilizer deficits shown on these tables are summarized as follows:

[1] All tables and figures appear at the end of this paper.

FERTILIZER DEFICITS

(Thousand tons)

	1966/1967			Estimated 1975/1976		
	N	*P_2O_5*	*K_2O*	*N*	*P_2O_5*	*K_2O*
Asia (except Japan)	2,220	440	165	4,000	1,000	700
Africa	340	(140)[a]	200	800	(200)[a]	500
Latin America..........	385	315	350	1,000	900	750
Total	2,945	615	715	5,800	1,700	1,950

[a] Surplus.

The figures for 1975/1976 in tables 2a, 2b and 2c were derived from graphical projections for each country or region based on FAO data for 1955/1956 to 1966/1967, combined with information on current and planned fertilizer projects in the developing countries. The consumption figures are estimates of probable consumptions and are not intended to be estimates of "need". The estimate for phosphate production in Africa in 1975/1976 is based on expected increases in Morocco, Senegal, Togo and Tunisia. The estimates for potash production in 1975/1976 are based on expected increases in the Congo (Brazzaville), India, Israel, Jordan and Peru.

On the assumption that all countries, except the very smallest, look forward to producing enough fertilizer to meet their own requirements, the annual fertilizer requirements for a hypothetical country with a population of 10 million may be summarized as follows:

Minimum requirement for minimal agricultural efficiency (thousand tons)	*Desirable consumption for significantly higher agricultural efficiency (thousand tons)*	*Possible maximum consumption to support population at a high standard of living (thousand tons)*
100 N	200 N	300 N
50 P_2O_5	100 P_2O_5	150 P_2O_5
25 K_2O	50 K_2O	75 K_2O

The "minimum requirement" is based on 10 kg *per capita* of N, 5 kg *per capita* of P_2O_5 and 2.5 kg *per capita* of K_2O, or a total of 17.5 kg *per capita* of N-P-K. Among the developing countries only China (Taiwan), Chile, Cuba and South Africa were at this level of fertilizer consumption in 1966/1967.

The "possible maximum consumption" corresponds to 52.5 kg *per capita* of N-P-K which is the level already in effect in several European countries and also in Australia. Probably no developing country will attain this level for many years, but it is a target that should be seriously considered by densely populated countries, such as Ceylon, China (Taiwan), India, Indonesia, North Korea, North Viet-Nam, Pakistan, the Republic of Korea, the Republic of Viet-Nam and the United Arab Republic.

Table 3 shows the quantities of nitrogen and phosphate required to establish the "minimum" level of fertilizer consumption in developing countries with probable populations of 13 million or more in 1975. In most cases the "minimum" level of fertilizer consumption in 1975 is several times the actual level of consumption in 1966/1967. The "minimum" level of 10 kg *per capita* of N and 5 kg *per capita* of P_2O_5 is admittedly an arbitrary one and will vary greatly from country to country, depending on population density in relation to arable land, water supply, the pattern of crops, dietary habits and other factors.

Alternative approaches to fertilizer production

Assuming that all countries would like to produce their own fertilizers, what are the alternative approaches to developing an indigenous fertilizer industry? The answer to this question varies greatly depending on whether a country has one or more of the following raw materials within its borders:

(*a*) Natural gas or naphtha (from indigenous oil refineries); (coal and lignite are omitted from consideration as raw materials because of the high cost of ammonia produced from them);
(*b*) Phosphate rock;
(*c*) Potash minerals;
(*d*) Sulphur (in one form or another).

Many developing countries have one of these raw materials, some have two, a few have three, but none, with the possible exception of Peru, has all four, in contrast to the United States and the Soviet Union, which have all four raw materials in abundance. Peru has natural gas, phosphate rock and potash and possibly also sulphur. China (mainland) may have all four raw materials, but in limited quantities so far as is known.

Figure 1 shows the location of natural gas, phosphate rock and potash in Asia, Africa and Latin America and in some neighbouring areas of Europe, North America and Australia.

Opportunities for establishing or expanding an indigenous fertilizer industry in a country have been greatly widened during the past few years by the advent of several new techno-economic developments:

(*a*) A drop in the price of liquid ammonia in many areas as a result of the new low-cost ammonia technology;
(*b*) Availability of liquid ammonia in shipload quantities;
(*c*) Availability of liquified natural gas (LNG) in shipload quantities;
(*d*) Availability of phosphoric acid (54% P_2O_5) and soon also of super-phosphoric acid (72% P_2O_5) in shipload quantities;
(*e*) Probable availability of elemental phosphorus in shipload quantities in the near future;

(*f*) New, improved processes for the production of nitrophosphate fertilizers by the action of nitric acid on phosphate rock. which eliminates the need for sulphur.

Consider again the hypothetical country with a population of 10 million and assume that it has none of the basic raw materials for fertilizer production. The following alternatives are available for indigenous fertilizer production (omitting potash):

1. Imported naphtha or LNG $\rightarrow NH_3 \rightarrow$ Urea or AN
Imported phosphate rock + sulphur $\rightarrow$ SSP, TSP or MAP/DAP $\rightarrow$ NP/NPK
2. Imported naphtha or LNG $\rightarrow NH_3 \rightarrow HNO_3$
Imported phosphate rock $\rightarrow$ NP/NPK (nitrophosphate process)
3. Imported naphtha or LNG $\rightarrow NH_3 \rightarrow$ Urea or AN
Imported phosphoric acid $\rightarrow$ MAP/DAP $\rightarrow$ NP/NPK
4. Imported naphtha or LNG $\rightarrow NH_3 \rightarrow$ Urea or AN
Imported elemental phosphorus $\rightarrow H_3PO_4 \rightarrow$ MAP/DAP $\rightarrow$ NP/NPK
5. Imported liquid ammonia $\rightarrow$ AN
Imported phosphate rock + sulphur $\rightarrow$ SSP, TSP or MAP/DAP $\rightarrow$ NP/NPK
6. Imported liquid ammonia $\rightarrow HNO_3$
Imported phosphate rook $\rightarrow$ NP/NPK (nitrophosphate process)
7. Imported liquid ammonia $\rightarrow$ AN
Imported phosphoric acid $\rightarrow$ MAP/DAP $\rightarrow$ NP/NPK
8. Imported liquid ammonia $\rightarrow$ AN
Imported elemental phosphorus $\rightarrow H_3PO_4 \rightarrow$ MAP/DAP $\rightarrow$ NP/NPK

If the hypothetical country should by chance have a plentiful supply of electric power at low cost, several additional alternatives would be available:

9. Electricity $\rightarrow NH_3 \rightarrow$ AN
Imported phosphate rock + sulphur $\rightarrow$ SSP, TSP or MAP/DAP $\rightarrow$ NP/NPK
10. Electricity $\rightarrow NH_3 \rightarrow$ AN
Imported phosphoric acid $\rightarrow$ MAP/DAP $\rightarrow$ NP/NPK
11. Electricity $\rightarrow NH_3 \rightarrow HNO_3$
Imported phosphate rock $\rightarrow$ NP/NPK (nitrophosphate process)
12. Electricity $\rightarrow NH_3 \rightarrow$ AN
Imported elemental phosphorus $\rightarrow H_3PO_4 \rightarrow$ MAP/DAP $\rightarrow$ NP/NPK
13. Electricity $\rightarrow NH_3 \rightarrow$ AN
Electricity + imported phosphate rock $\rightarrow$ P $\rightarrow H_3PO_4 \rightarrow$ MAP/DAP $\rightarrow$ NP/NPK

However, electricity must be very cheap for these alternatives to be economic, preferably about $0.003 (3 mills) or less per kilowatt hour. In the case of alternative 13, electric power would have to be very cheap indeed for this to be a feasible alternative probably alternatives 9 through 12 would be preferable.

Figure 2 shows some of the interrelationships among the various fertilizer products and processes indicated in the above process schemes. Figure 2 does not show the process utilizing electricity to produce ammonia (from air and water) or elemental phosphorus (from phosphate rock, coke and sand) (alternative 13), nor does it show the details of the various nitrophosphate processes, which are too complex to show on such a chart.

In international trade potash is usually in the form of potassium chloride (KCl – 58 to 60 per cent K_2O). This product can be added to any of the N-P mixtures shown in the above process schemes to give N-P-K mixtures.

The thirteen alternative process schemes shown above are only those of most general applicability. Other alternatives include the production of ammonium sulphate, ammonium chloride, calcium nitrate, sodium nitrate, potassium nitrate, dicalcium phosphate, and potassium metaphosphate.

If sulphur is available in one form or another in the country, production of ammonium sulphate instead of ammonium nitrate, especially in alternatives 5, 7, 8, 9, 10, 12, 13, can be considered. Even if sulphur is available only as gypsum or anhydrite, ammonium sulphate can be produced by the Merseberg process according to the well known reaction:

$$CaSO_4 + 2NH_3 + CO_2 + H_2O \rightarrow (NH_4)_2SO_4 + CaCO_3$$

Also, gypsum or anhydrite can be used for the production of sulphuric acid, with portland cement as a by-product, by carbon reduction in a cement kiln, according to the following chemical reactions:

$$CaSO_4 + C \text{ (coke)} + \text{clay} \rightarrow SO_2 + CO_2 + \text{cement clinker}$$

$$SO_2 + \tfrac{1}{2}O_2 + H_2O \rightarrow H_2SO_4$$

Cement clinker is a fused mixture of calcium silicates and calcium aluminate, the silica and alumina both coming from the clay ($Al_2O_3 \cdot xSiO_2 \cdot yH_2O$).

If surplus hydrochloric acid is available, production of ammonium chloride by direct combination with ammonia can be considered. If there is a good market for sodium carbonate (soda ash), ammonium chloride might be produced by the dual process:

$$2NH_3 + 2NaCl + CO_2 + H_2O \rightarrow 2NH_4Cl + Na_2CO_3$$

However, ammonium chloride is not recommended by agronomists for crops other than those in a very wet environment, such as paddy rice.

Another possibility if surplus hydrochloric acid is available is to produce phosphoric acid by the action of hydrochloric acid on phosphate rock (Israel Mining Industries process):

$$Ca_3(PO_4)_2 + 6HCl \rightarrow 2H_3PO_4 + 3CaCl_2$$

followed by selective extraction of the phosphoric acid with butyl alcohol or other solvent. The calcium chloride produced usually has no value and presents a disposal problem.

It will be noted that alternatives 5, 7, 8, 9, 10, 12, 13 indicate only the production of ammonium nitrate (AN) and not urea. This is because it is not economic to make urea from ammonia unless there is a very cheap source of carbon dioxide, and this is the case usually only at plants where ammonia is being produced from hydrocarbon feed-stocks, such as natural gas, naphtha, fuel oil, crude oil, coal or lignite. Occasionally cheap carbon dioxide may be available from a large limekiln or a brewery, but this is rare.

Nitrophosphate fertilizers are made by the action of nitric acid on phosphate rock:

$$Ca_3(PO_4)_2 + 6HNO_3 \rightarrow 2H_3PO_4 + 3Ca(NO_3)_2$$

($Ca_3(PO_4)_2$ is used as a simplified formula for phosphate rock, ignoring the calcium fluoride and other components present in phosphate rock). The problem in all nitrophosphate processes has been to remove all or most of the calcium nitrate and convert it to ammonium nitrate. Unless the calcium nitrate is largely removed it will revert to dicalcium phosphate ($CaHPO_4$) and to tricalcium phosphate ($Ca_3(PO_4)_2$) during the neutralization step.

Two new processes for removing all or most of the calcium nitrate have become available during the past few years: the low temperature calcium nitrate crystallization process and the ammonium sulphate recycle process. Two plants using the calcium nitrate crystallization process are now in operation, one in Norway and one in Czechoslovakia. A third plant is being built in North Carolina, United States. No plant using the ammonium sulphate recycle process has yet been built, but several variants of the process are being offered by experienced contracting firms. Both these new processes offer the possibility of producing high-quality N-P or N-P-K fertilizers at low cost and with a high degree of water-solubility of phosphate, without using sulphur.

Nitrophosphate fertilizers are mixtures of the following components:

Monoammonium phosphate	($NH_4H_2PO_4$)	(12–62 in pure form);
Diammonium phosphate	$(NH_4)_2HPO_4$	(21-54 in pure form);
Ammonium nitrate	NH_4NO_3	(35- 0 in pure form);
Ammonium sulphate	$(NH_4)_2SO_4$	(21- 0 in pure form);
Dicalcium phosphate	$CaHPO_4$	(0–52 in pure form).

All these components are water-soluble, except dicalcium phosphate, which is citrate-soluble. The proportions of these components vary greatly depending on the nitrophosphate process used and the conditions under which it is carried out.

In the past all the fertilizers made by nitrophosphate processes using nitric acid as the sole acidulant had 50 per cent or less water-solubility of phosphate, frequently around 30 per cent. This degree of water-solubility of phosphate is not considered adequate by agronomists in India, the United Kingdom and some other countries, but these fertilizers are made and used extensively in continental Europe. Now with the new processes mentioned above, water-solubilities of phosphate of 75 per cent and higher are possible so that water-solubility will no longer be a problem.

The two biggest drawbacks to nitrophosphate fertilizers are:

(*a*) They can be made in only a limited range of $N:P_2O_5$ ratios, usually around 2, but possibly in the range of 1.5 to 2.5 depending on the composition of the phosphate rock. The product may be a single product, such as 28-14-0, or it may be in two products, such as 24-24-0 or 20-30-0 plus a corresponding amount of ammonium nitrate as a co-product. But the over-all $N:P_2O_5$ ratio of the entire product or products will be in the range of 1.5 to 2.5.

(*b*) All nitrophosphate fertilizers have 40 to 45 per cent of the nitrogen in nitrate form and 55 to 60 per cent in ammonium form. The presence of a substantial amount of nitrate nitrogen may be a drawback where rice is the major crop.

However, two great advantages are that the cost of producing nitrophosphate fertilizers is low and no sulphur is required. This brief discussion of nitrophosphate processes omits mention of the sulpho-nitric and phospho-nitric processes, since both these processes require sulphur.

Regional movements of fertilizer raw materials and intermediates

Any country can establish a fertilizer industry within its borders even if it has no raw materials at all if it will pay the transport costs involved in importing the raw materials. Fertilizer raw materials, however, are low-value, bulk materials, so transporting them long distances is less economic than would be desirable. Therefore, a country needing fertilizer raw materials should seek nearby sources, from neighbouring countries if possible, or at least from within the region. The low cost of water transport is, of course, a determining factor.

Fertilizer intermediates, such as ammonia, phosphoric acid and elemental phosphorus have become available in shipload quantities only in the past few years, and this has changed the picture greatly for a country lacking indigenous sources of the basic raw materials. The possibilities for establishing or expanding a domestic fertilizer industry are now considerably greater than they were a few years ago.

Figure 1 shows that natural gas is quite widely distributed in Asia, Africa and Latin America, although there are notable exceptions such as Brazil, India, East Africa and southern Africa (except Mozambique and Angola). Phosphate rock is also quite widely distributed, but there is none in Asia between the Red Sea area and Japan except in North Viet-Nam and Christmas Island. Potash is much more restricted in distribution, being available in the developing countries only in Brazil, the Congo (Brazzaville), Ethiopia, Israel, Jordan and Peru, and of these only Israel has produced potash for export. Almost all the world's potash is still produced by Canada, the United States, Europe and the Soviet Union.

Table 4 shows some possible regional movements of fertilizer raw materials and intermediates (excluding potash). The six regions shown are:

1. West coast of Africa (Gibraltar to South Africa)
2. Indian Ocean/Red Sea/Persian Gulf (Suez-Burma-South Africa triangle)
3. Mediterranean/Black Sea
4. Western Pacific/South China Sea (Malaysia-Japan-New Zealand triangle)
5. South American/Central American west coast
6. South American/Central American east coast/Caribbean

There are also obvious possibilities for the exchange of raw materials and/or intermediates between the South American east coast/Caribbean area and the African west coast by water transport across the Atlantic.

The movements of materials indicated in table 4 do not, of course, exhaust all the conceivable ones, but the table does suggest some interesting possibilities for exchanging raw materials among the developing countries.

Table 1 (a)

CLASSIFICATION OF COUNTRIES WITH A POPULATION IN 1966 OF OVER 5 MILLION IN TERMS OF FERTILIZER CONSUMPTION PER CAPITA

(kg/capita of N + P_2O_5 + K_2O in 1966/1967 crop year)

Developed countries		*Developing countries*	
	Very high (51 – 100 kg/capita)		
Austria	Eastern Germany		None
Australia	France		
Belgium	Sweden		
Bulgaria	USA		
Czechoslovakia			
	High (26 – 50 kg/capita)		
Canada	Poland		Cuba
Federal Republic of Germany	United Kingdom		
	USSR		
Greece	Yugoslavia		
Hungary			
Netherlands			
	Moderate (11 – 25 kg/capita)		
Italy	Romania	Chile	North Korea
Japan	Spain	China (Taiwan)	South Africa
Portugal	Switzerland	Korea (Rep. of)	UAR
		Mexico	
	Low (6 – 10 kg/capita)		
	None	Central America[a]	Peru
		Ceylon	Turkey
		Colombia	Venezuela
		Malaysia	
	Very low (0 – 5 kg/capita)		
	None	Afghanistan	Madagascar
		Algeria	Morocco
		Angola	Mozambique
		Argentina	Nepal
		Brazil	Nigeria
		Burma	North Viet-Nam

[a] Includes the five Central American Common Market countries (Costa Rica, Guatemala, El Salvador, Honduras and Nicaragua) plus Panama.

Table 1 (a) (continued)

Developed countries	*Developing countries*	
	Cambodia	Pakistan
	Cameroon	Philippines
	China (mainland)	Saudi Arabia
	Congo (Dem. Rep.)	Sudan
	Ecuador	Syria
	Ethiopia	Thailand
	Ghana	Uganda
	India	United Republic of Tanzania
	Indonesia	Upper Volta
	Iran	Viet-Nam (Rep. of)
	Iraq	Yemen
	Kenya	

Table 1 (b)

COMPARISON OF COUNTRIES WITH A POPULATION IN 1966 OF OVER 5 MILLION IN TERMS OF FERTILIZER CONSUMPTION *per capita*[a]

(for fertilizer year 1966/1967)

	Fertilizer consumption $N+P_2O_5+K_2O$ *(thousand tons)*	*Population (millions)*	*Fertilizer consumption (kg/capita)*	
1. Australia	1,144.7	11.6	98.7	Very high
2. Eastern Germany	1,410.0	17.0	83.0	Very high
3. France	3,378.1	49.6	68.1	Very high
4. Czechoslovakia	927.8	14.3	64.8	Very high
5. United States	12,630.1	196.8	64.3	Very high
6. Bulgaria	445.0	8.3	53.7	Very high
7. Sweden	399.9	7.8	51.4	Very high
8. Austria	365.3	7.3	50.0	Very high
9. Belgium	475.5	9.5	50.0	Very high
10. Federal Rep. of Germany	2,757.2	57.6	47.9	High
11. Netherlands	577.2	12.5	46.3	High
12. Poland	1,450.0	31.9	45.5	High
13. Canada	785.5	20.0	39.3	High
14. Hungary	398.1	10.2	39.0	High
15. *Cuba*	270.0	7.8	34.6	High
16. Greece	261.6	8.6	30.4	High
17. United Kingdom	1,655.2	54.9	30.2	High
18. Soviet Union	6,222.0	234.3	26.6	High
19. Yugoslavia	501.6	19.7	25.4	High

[a] Countries listed in order of fertilizer consumption *per capita*, developing countries in italics.

Table 1 (b) (continued)

	Fertilizer consumption $N+P_2O_5+K_2O$ *(thousand tons)*	*Population (millions)*	*Fertilizer consumption (kg/capita)*	
20. Spain	758.7	31.9	23.8	
21. Switzerland	137.7	6.1	22.6	
22. *South Africa*	408.0	18.3	22.3	
23. Japan	2,120.0	98.9	21.4	
24. Italy	1,111.3	51.9	21.4	
25. *China (Taiwan)*	241.6	12.9	18.7	
26. *Chile*	155.9	8.8	17.7	Moderate
27. Romania	336.4	19.2	17.5	
28. *Korea (Rep. of)*	464.5	29.2	15.9	
29. *North Korea*	198.0	12.5	15.8	
30. Portugal	132.9	9.2	14.4	
31. *Mexico*	439.1	42.2	10.4	
32. *UAR*	306.0	30.4	10.1	
33. *Central America*[b]	130.6	14.5	9.0	
34. *Peru*	104.0	12.0	8.7	
35. *Colombia*	150.8	18.4	8.2	
36. *Ceylon*	86.0	11.5	7.5	Low
37. *Malaysia*	67.3	9.7	6.9	
38. *Turkey*	190.2	32.0	5.9	
39. *Venezuela*	51.0	9.0	5.7	
40. *Philippines*	161.2	33.5	4.8	
41. *Viet-Nam (Rep. of)*	80.4	16.7	4.8	
42. *Morocco*	63.5	13.7	4.6	
43. *Algeria*	49.5	11.4	4.3	
44. *Sudan*	50.7	13.9	3.6	
45. *Ecuador*	18.0	5.2	3.5	
46. *China (mainland)*	2,320.0	750.0	3.1	
47. *Brazil*	249.8	83.9	3.0	
48. *Kenya*	27.0	9.6	2.8	
49. *India*	1,237.8	494.1	2.5	
50. *Syria*	12.5	5.5	2.3	
51. *Argentina*	50.0	22.7	2.2	Very low
52. *Iran*	47.0	24.0	2.0	
53. *Thailand*	58.8	31.5	1.9	
54. *Pakistan*	214.5	121.1	1.8	
55. *Saudi Arabia*	10.1	6.9	1.5	
56. *Cameroon*	7.5	5.3	1.4	
57. *Mozambique*	9.0	7.0	1.3	
58. *North Viet-Nam*	26.0	19.6	1.3	
59. *Indonesia*	112.5	106.8	1.1	
60. *Madagascar*	6.3	6.6	1.0	
61. *Iraq*	6.8	7.3	0.9	

[b] Includes the five Central American Common Market countries plus Panama.

Table 1 (b) (continued)

	Fertilizer consumption $N+P_2O_5+K_2O$ (thousand tons)	Population (millions)	Fertilizer consumption (kg/capita)	
62. *Uganda*	6.7	7.7	0.9	Very low
63. *Angola*	4.4	5.2	0.8	
64. *United Republic of Tanzania*	8.8	10.7	0.8	
65. *Ghana*	5.3	7.9	0.7	
66. *Burma*	7.0	25.2	0.3	
67. *Cambodia*	1.7	6.5	0.3	
68. *Congo (Democratic Republic of)*	2.2	16.0	0.1	
69. *Ethiopia*	1.2	23.0	0.1	
70. *Nepal*	1.0	10.3	0.1	
71. *Nigeria*	7.4	58.7	0.1	
72. *Upper Volta*	0.7	5.0	0.1	
73. *Afghanistan*	0.1	15.9	nil	
74. *Yemen*	—	5.0	nil	

Source: Monthly Bulletin of Agricultural Economics and Statistics, February 1968, FAO, Rome.

Table 2 (a)

AREAS OF NITROGEN DEFICIENCY: 1966/1967 AND 1975/1976[a]

(Thousand tons N)

	1966/1967			*1975/1976*		
	Pro-duction	*Con-sumption*	*Deficit or surplus*[b]	*Estimated pro-duction*	*Estimated con-sumption*	*Deficit*
Asia (except Japan)						
China (mainland)	800	1,850	1,050	1,500	3,000	1,500
India	309	830	521	2,000	3,500	1,500
Korea (Rep. of)	81	240	159			
Pakistan	93	170	77			
Indonesia	41	110	69			
Turkey	33	96	63			
Ceylon	—	45	45			
Viet-Nam (Rep. of) ..	—	45	45			
Malaysia	—	44	44	2,000	3,000	1,000
Philippines	21	65	44			
Thailand	—	36	36			
North Viet-Nam	—	13	13			
Lebanon	—	12	12			
Syria	—	10	10			
All other countries[c] ...	312	344	32			
Total	1,690	3,910	2,220	5,500	9,500	4,000
Africa						
UAR	165	250	85			
Zambia/Rhodesia	—	46	46			
Sudan	—	40	40			
South Africa	75	108	33	1,000	1,800	800
Morocco	—	25	25			
Algeria	—	20	20			
Kenya	—	13	13			
All other countries ...	—	78	78			
Total	240	580	340	1,000	1,800	800

Source: Monthly Bulletin of Agricultural Economics and Statistics, February 1968, FAO, Rome.

[a] Countries listed in each area in order of deficits in 1966/1967.

[b] Brackets ( ) denote surplus.

[c] Includes several countries in Asia whose production and consumption were substantial but production and consumption were approximately balanced and therefore these countries are not listed by name in the table. These include China (Taiwan), Iran, Israel, and North Korea.

Table 2 (a) (continued)

	1966/1967			1975/1976		
	Production	*Consumption*	*Deficit or surplus*[b]	*Estimated production*	*Estimated consumption*	*Deficit*
Latin America						
Mexico	171	320	149			
Cuba	5	105	100			
Brazil	6	68	62			
Argentina	4	30	26			
Peru	60	80	20			
Colombia	40	60	20	1,500	2,500	1,000
Trinidad and Tobago	47[d]	54	7			
Venezuela	26	31	5			
Netherlands Antilles	30	3	(27)			
Chile	150	53	(97)			
All other countries	16	141	125			
Total	555	945	390	1,500	2,500	1,000
Grand Total	2,485	5,435	2,950	8,000	13,800	5,800

[d] This production figure for Trinidad and Tobago is misleading, since it excludes the ammonia produced in Trinidad and shipped to the United States, United Kingdom and other countries. Trinidad and Tobago is really a surplus nitrogen producer.

Table 2 (b)

PHOSPHATE FERTILIZER DEFICIT AREAS — 1966/1967 AND 1975/1976[a]

(Thousand tons P_2O_5)

	1966/1967			1975/1976		
	Production	*Consumption*	*Deficit or Surplus*[b]	*Estimated Production*	*Estimated Consumption*	*Deficit or Surplus*[b]
Asia (except Japan)						
India	151	274	123	900	1,000	100
Korea (Rep. of)	2	125	123			
Turkey	36	91	55			
Pakistan	1	31	30			
Philippines	16	41	25	1,300	2,200	900
Viet-Nam (Rep. of)	—	25	25			
Thailand	—	18	18			
Iran	—	15	15			
All other countries[c]	429	455	26			
Total	635	1,075	440	2,200	3,200	1,000
Africa						
Kenya	1	13	12			
Morocco	105	26	(79)	800	600	(200)
Tunisia	145	14	(131)			
All other countries[c]	299	357	58			
Total	550	410	(140)	800	600	(200)
Latin America						
Chile	8	84	76			
Cuba	15	90	75			
Colombia	10	56	46			
Brazil	63	90	27	900	1,800	900
Mexico	84	98	14			
Costa Rica	—	12	12			
Argentina	4	12	8			
All other countries[c]	31	88	57			
Total	215	530	315	900	1,800	900
Grand Total	1,400	2,015	615	3,900	5,600	1,700

Source: Monthly Bulletin of Agricultural Economics and Statistics, February 1968, FAO, Rome.

[a] Countries listed in each area in order of deficits in 1966/1967.

[b] Brackets ( ) denote surplus.

[c] Includes several countries whose production and consumption were substantial but production and consumption were approximately balanced, and therefore these countries are not listed by name in the table. These include Algeria, China (mainland), China (Taiwan), Israel, Peru, South Africa, United Arab Republic, Venezuela, Zambia/Rhodesia.

Table 2 (c)

POTASH FERTILIZER DEFICIT AREAS — 1966/1967 AND 1975/1976[a]

(Thousand tons K_2O)

	1966/1967			*1975/1976*		
	Production	*Consumption*	*Deficit or Surplus*[b]	*Estimated production*	*Estimated consumption*	*Deficit or Surplus*[b]
Asia (except Japan)						
India	—	134	134	50	400	350
Korea (Rep. of)	—	100	100			
Philippines	—	55	55			
China (Taiwan)	—	50	50			
Ceylon	—	40	40			
Malaysia	—	17	17	100	740	640
Pakistan	—	14	14			
Viet-Nam (Rep. of)	—	11	11			
All other countries	—	34	34			
China (mainland)	100	105	5	100	300	200
Israel	300	5	(295)	500	10	(490)
Total	400	565	165	750	1,450	700
Africa						
South Africa	—	85	85			
Zambia/Rhodesia	—	22	22			
Algeria	—	13	13			
Morocco	—	12	12	100	600	500
Sudan	—	10	10			
All other countries	—	58	58			
Total	—	200	200	100	600	500
Latin America						
Brazil	—	92	92			
Cuba	—	75	75			
Colombia	—	35	35			
Martinique/Guadeloupe	—	23	23			
Mexico	—	22	22	50	800	750
Costa Rica	—	10	10			
Venezuela	—	10	10			
Argentina	—	8	8			
All other countries	25	75	50			
Total	25	350	325	50	800	750
Grand Total	425	1,115	690	900	2,850	1,950

Source: Monthly Bulletin of Agricultural Economics and Statistics, February 1968, FAO, Rome.

[a] Countries listed in each area in order of deficits in 1966/1967.
[b] Brackets ( ) denote surplus.

Table 3

SUGGESTED MINIMUM TARGETS FOR CONSUMPTION OF FERTILIZERS IN MAJOR DEVELOPING COUNTRIES IN 1975[a]

	Probable population 1975 (millions)	*Suggested minimum targets for consumption of fertilizers in 1975 (thousand tons)*		*Actual consumption in 1966/1967 (tons)*[d]	
		Nitrogen[b]	P_2O_5[c]	*Nitrogen*	P_2O_5
India	609	6,090	3,045	830,200	274,000
Pakistan	138	1,380	690	170,000	30,500
Indonesia	134	1,340	670	109,900	5,500
Brazil	113	1,130	565	68,000	90,300
Nigeria	81	810	405	4,600	1,800
Mexico	58	580	290	320,000	97,100
Philippines	46	460	230	65,000	41,200
Turkey	42	420	210	95,900	90,700
Thailand	42	420	210	36,000	17,800
United Arab Republic	40	400	200	250,000	55,000
Korea (Rep. of)	36	360	180	239,700	124,800
Burma	31	310	155	6,000	1,000
Iran	30	300	150	30,000	15,000
Argentina	27	270	135	30,000	12,000
Ethiopia	26	260	130	1,200	nil
Colombia	24	240	120	60,000	55,800
South Africa	24	240	120	108,000	215,000
Viet-Nam (Rep. of)	22	220	110	45,200	24,700
Afghanistan	20	200	100	100	nil
Congo (Dem. Rep. of)	19	190	95	1,300	400
Morocco	19	190	95	25,300	26,000
Algeria	17	170	85	20,300	15,900
Sudan	17	170	85	40,000	700
Ceylon	16	160	80	45,000	1,000
Peru	16	160	80	80,000	16,000
Malaysia	15	150	75	43,500	6,500
China (Taiwan)	15	150	75	155,300	36,800
Venezuela	13	130	65	31,000	10,000
United Republic of Tanzania	13	130	65		

[a] Omitting China (mainland), North Korea, North Viet-Nam.
[b] Calculated on basis of 10 kg N *per capita*.
[c] Calculated on basis of 5 kg P_2O_5 *per capita*.
[d] From *Monthly Bulletin of Agricultural Economics and Statistics*, February 1968, FAO, Rome.

Table 4

POSSIBLE REGIONAL MOVEMENTS OF FERTILIZER RAW MATERIALS AND INTERMEDIATES[a] ON THE BASIS OF WATER TRANSPORT

Material	From		To
West Coast of Africa (Gibraltar to South Africa)			
LNG, naphtha or liquid ammonia from	[Caribbean]	→	Angola
	[Mexico]		Cameroon
	Nigeria		Congo (Brazzaville)
	[South America]		Congo (Dem. Rep. of)
Phosphate rock, phosphoric acid or elemental P from	Morocco		Dahomey
	Senegal		Gabon
	Spanish Sahara		Ghana
	South Africa		Ivory Coast
	Togo		Liberia
			Morocco
			Senegal
			Sierra Leone
			South Africa
			Togo
Indian Ocean/Red Sea/Persian Gulf (Suez-Burma-South Africa triangle)			
LNG, naphtha or liquid ammonia from	Burma	→	Burma
	Kuwait		Ceylon
	Iran		Ethiopia
	Iraq		India
	Mozambique		Kenya
	UAR		Madagascar
	Saudi Arabia		Mozambique
Phosphate rock, phosphoric acid or elemental P from	Israel		Pakistan
	Jordan		Rhodesia
	Uganda		South Africa
	UAR		Sudan
			Uganda
			Unit. Rep. of Tanzania
			Zambia
Mediterranean/Black Sea			
LNG, naphtha or liquid ammonia from	Algeria	→	Algeria
	Bulgaria		Greece
	Libya		Israel
	Romania		Lebanon
	USSR		Libya
Phosphate rock, phosphoric acid or elemental P from	Algeria		Syria
	Morocco		Tunisia
	Tunisia		Turkey
	USSR		UAR
			Yugoslavia

[a] Areas in square brackets [ ] are not in the region under consideration but are located a relatively short distance across the Atlantic Ocean.

Table 4 (continued)

Western Pacific/South China Sea (Malaysia–Japan–New Zealand triangle)			
LNG, naphtha or liquid ammonia from	Brunei	→	Australia
	Indonesia		Cambodia
Phosphate rock, phosphoric acid or elemental P from	Australia		China (mainland)
	Christmas I.		China (Taiwan)
	Nauru		Indonesia
	North Viet-Nam		Japan
			Korea (Rep. of)
			Malaysia
			New Zealand
			North Korea
			North Viet-Nam
			Philippines
			Thailand
			Viet-Nam (Rep. of)
South American/Central American west coast			
LNG, naphtha or liquid ammonia from	Chile	→	Central America
	Mexico		Chile
	Peru		Ecuador
Phosphate rock, phosphoric acid or elemental P from	Peru		Mexico
			Peru
South America/Central American east coast/Caribbean			
LNG, naphtha or liquid ammonia from	Argentina	→	Argentina
	Brazil		Brazil
	Colombia		Central America
	Cuba		Colombia
	Curacao		Cuba
	Mexico		Dominican Republic
	[Nigeria]		Guyana
	Trinidad		Haiti
	Venezuela		Jamaica
Phosphate rock, phosphoric acid or elemental P from	Brazil		Mexico
	[Florida, USA]		Paraguay
	[North Africa]		Trinidad and Tobago
	[South Africa]		Uruguay
	[West Africa]		Venezuela

Figure 1

LOCATION OF NATURAL GAS, PHOSPHATE ROCK AND POTASH WITH PARTICULAR REFERENCE TO DEVELOPING COUNTRIES

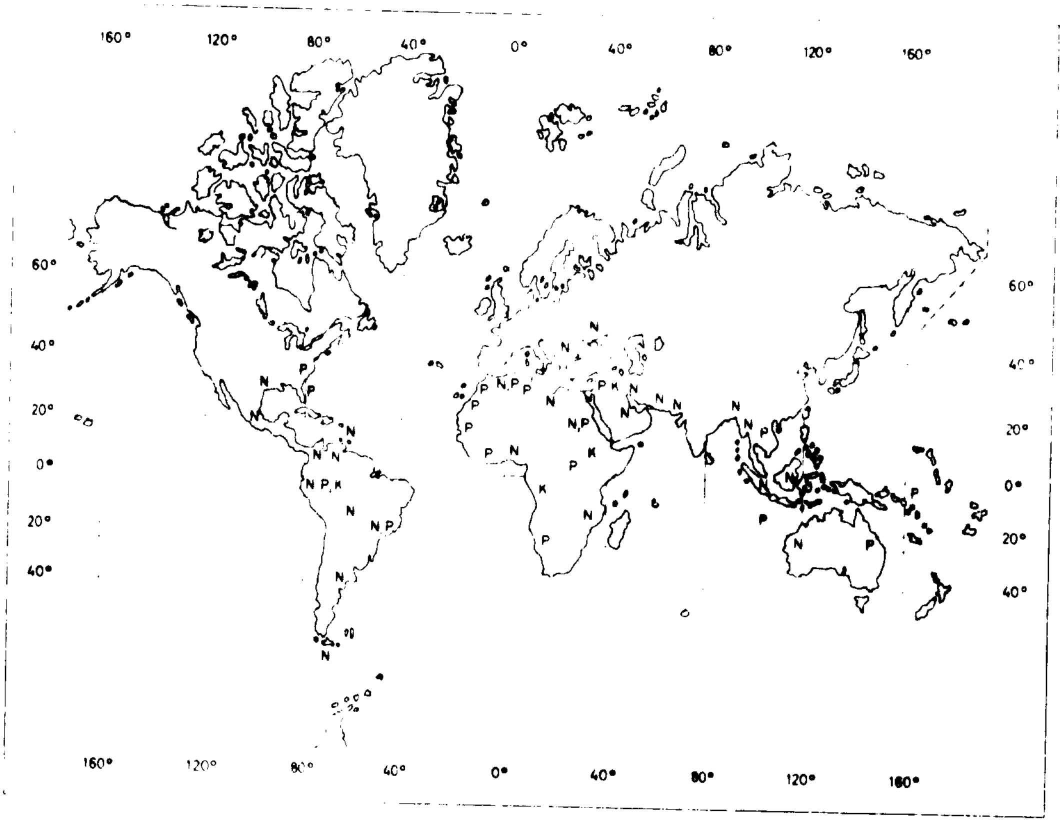
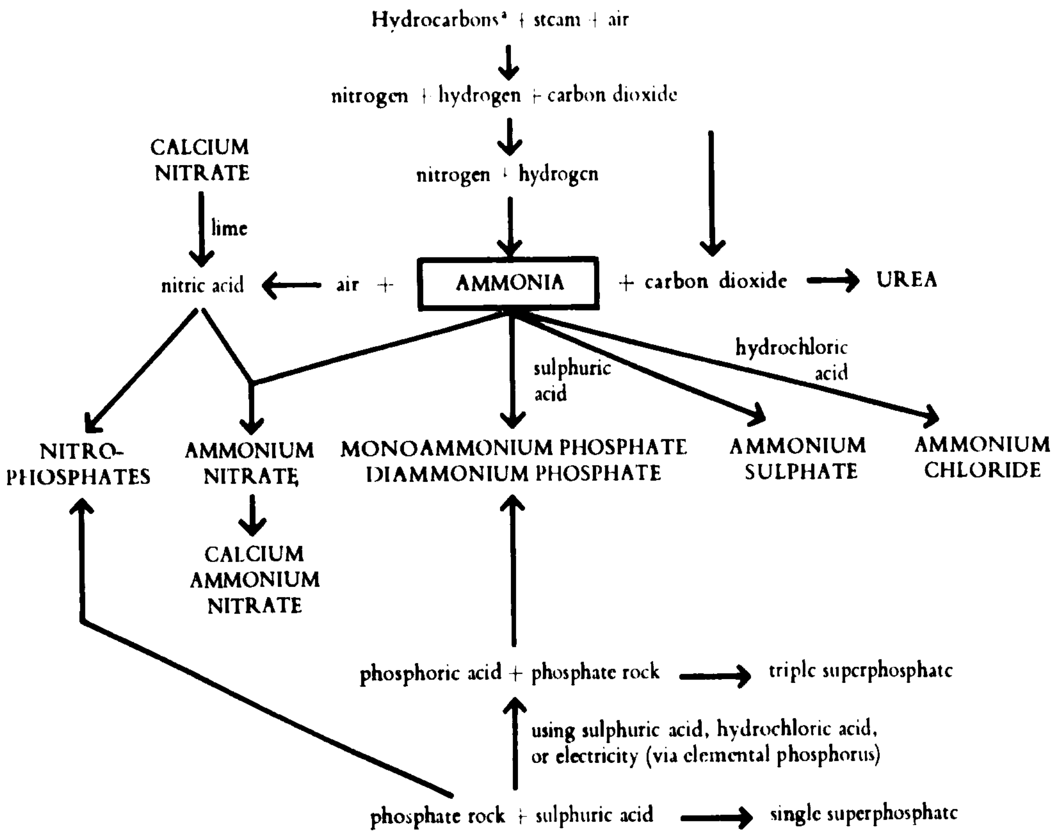


Figure 2

PRODUCT INTERRELATIONSHIPS OF NITROGEN AND PHOSPHATE FERTILIZERS



Note: Capitals indicate products used as fertilizer materials.

[a] Hydrocarbon feed-stock can be natural gas, ethane, liquefied petroleum gases (LPG) or light naphtha for the reforming process. With heavier hydrocarbon feed-stocks, partial oxidation processes would have to be used, which require higher capital costs than the reforming process.

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STATEMENT OF THE CONSULTANT FROM AUSTRIA

INTRODUCTION

The Austrian chemical industry today is only 100 years old, and the chemical factories of the Österreichische Stickstoffwerke Aktiengesellschaft at Linz/Donau (ÖSW), the country's most important chemical enterprise, has been in existence for only a quarter of a century. In size, the Company ranks between medium-size chemical plants on the one hand, and the large chemical world combines such as Badische Analin und Soda-Fabrik (BASF), Imperial Chemical Industries (ICI), or Dupont de Nemours, on the other, whose sales are 10 to 40 times those of the company at Linz. Perhaps the chemical industry in Austria is not an exact model for similar industries in the developing countries, but, in some respects, it may be more interesting than examples from the industrialized countries. Some of the Austrian problems are more closely related to the problems of the developing countries, and the experience of the Austrian chemical industry may be more applicable to the developing countries than that of an industry in a country with a complex infrastructure.

THE IMPORTANCE OF INFRASTRUCTURE

When the industrialization of a country is being planned, economic calculations and market analyses must be made first. Then a financing scheme and a production plan must be drawn up and questions pertaining to raw materials and manpower examined. At a later stage contracts with the partners concerned in the projects must be concluded, the managing officials selected and assigned, bids invited and orders placed. Subsequently, a labour force must be hired, installations set up with the aid of loop-and-trunk layout technique, and agreements containing a penalty clause reached with the suppliers. This method for developing new production is generally followed. It can be carried out with company staff already available, or the labour force can be hired from engineering firms, if the necessary—and by no means small—sums of money are available. Sometimes the existing establishment resists what it regards as a threat to the existing sociological-economic balance, namely, the infrastructure. For instance, in Austria the laying of a pipeline from a rich gas field to a big chemical combine was of particular importance to a large manufacturer of fertilizers. The time taken from the inception of the project to the final commissioning was only a period of seven weeks, while on a previous occasion it had taken seven years to overcome the resistance offered by the established economic infrastructure — a period 52 times as long!

An advanced infrastructure can be most advantageous to further industrialization. At the end of the Second World War in 1945, the industrial capacity of Austria had been largely destroyed, and a considerable technological gap had arisen between Austria and the industrialized countries that had not suffered comparable damage to their economies. Many economic indices, such as energy production and capital formation, had sunk to one tenth or one twentieth of the normal value, so that the standard of living was comparable to that of countries with a very low level of industrialization, such as Ecuador or Ceylon. But, apparently infrastructure as it is understood within the scope of the present study cannot be destroyed so easily as the material products through which it is expressed. In seven years the Austrian standard of living rose to its previous level and continued to rise at an annual rate of 8 to 10 per cent. But if it is difficult to destroy infrastructure it is also not easy to build it up quickly where it did not previously exist, as is shown by comparing the slow growth of the Ecuadorian or Ceylonese industries, for example, with the rapid reconstruction of the Austrian economy.

A country's infrastructure cannot be easily defined or expressed in figures, but the following points may be made:

(*a*) The growth of population in the developing countries is three to five times as fast as that of the developed countries.

(*b*) In highly industrialized countries the standard of living and the infrastructure connected with it differ by a factor of 4 or more.

(*c*) Countries with a high rate of industrial growth also show a high rate of agricultural growth.

(*d*) Because its nitrogen industry is comparatively highly developed, Austria, a small country, has almost attained the same agricultural *per capita* quota as the United States, which otherwise leads by far in the essential index numbers.

(*e*) After industrialization has advanced to a certain level, further growth must be accompanied by a corresponding growth in infrastructure.

(*f*) Infrastructure in Japan is particularly favourable to industrialization and deserves to be studied, particularly in comparison with mainland China. Although China has an ancient culture, a vast territory whose continental dimensions certainly favour the procurement of raw materials, a ready market capable of development, and an industrious and intelligent population, and although China exploded its atomic bomb nineteen years after the United States and sixteen years after the Soviet Union, Chinese infrastructure, as is proved by the low standard of living apparent to any visitor to the country, has remained far behind that of Japan.

Therefore, the character, development and economic effect of infrastructure should be studied. In general, more attention should be paid to the judgement of experts from developing countries than to the routine conceptions of specialists from the developed countries.

The evolution of the Austrian fertilizer industry

Although Austria is included among the developed countries, in certain respects and at certain times its problems have been similar to those of the developing countries. During the last half century Austrian industry has had to be built up twice in a basically new form. The first reconstruction began in 1919 after the disintegration of the Austro-Hungarian monarchy when Austrian industry lost its large, financially sound and flourishing market, which was well-equipped with raw materials, and had to adapt itself to a poverty-stricken market shrunk to one tenth its former size. At the same time the war economy had to be shifted to a peace-time basis. The second reconstruction began in 1946 after the end of the Second World War. With a greatly reduced industrial potential, paralysed by lack of capital and by the difficulties of converting a total war economy to a peace-time one, no longer part of the huge German market, Austria had to adjust to a market that apparently offered very few opportunities for large-scale industry. Although the problems to be solved during the first reconstruction were not overwhelmingly difficult, they proved to be more troublesome and time-consuming than the greater problems of the second reconstruction. This is because the second reconstruction was assisted by generous, target-directed economic aid from the United States and the effectiveness of Austria's infrastructure in 1946 exceeded its 1938 level. (From 1938 to 1945 Austria had been integrated into the German market, which was twelve times the size of the Austrian, and was, at least in the field of heavy industry, considerably more advanced than the Austrian.)

As in the United States and Japan, in Austria the needs of national defence provided the strongest impulses for the development of the first small chemical plants. For the manufacture of gunpowder and explosives a sulphuric acid plant is a prerequisite, and sulphuric acid has proved to be the key product that leads to a succession of chemical products. Under the Austro-Hungarian monarchy, installations for the production of sodium sulphate for the glass industry, of aluminium sulphate for the paper industry, of copper sulphate for viniculture, of hydrochloric acid and of other heavy chemicals centred around the first sulphuric acid plants. But above all, large-scale units for the production of superphosphate were erected in three different localities in spite of the small marketing area. Up to 1942, superphosphate was the only mineral fertilizer made in Austria in mass production that met the demand; all other chemical fertilizers had to be imported. Even today the production of phosphate fertilizers is carried out by three different companies, each of which owns at least

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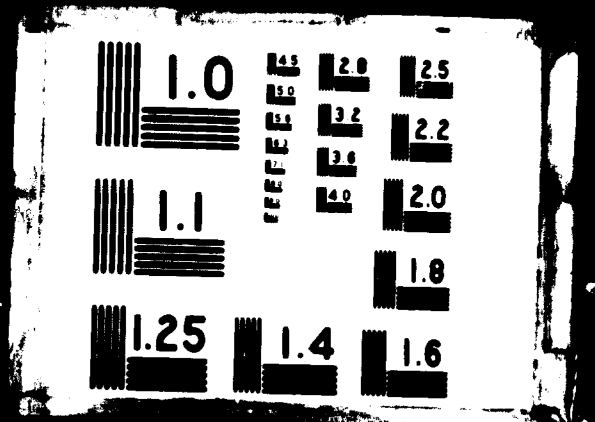

one sulphuric acid plant; there is a certain co-ordination of the production programme, but free competition with respect to quality and price. Superphosphate still holds its dominant position, but in comparison with the two- and three-component, phosphate-containing mixed fertilizers, its production is decreasing. In the manufacture of complex fertilizers two tendencies are becoming more pronounced: the trend towards a higher nutrient content owing to transport and wage costs, and the trend towards granulated fertilizers, more uniform in their grain size, a consequence of the mechanization of agriculture. The necessity for raising the nutrient content of complex fertilizers also increases the need for phosphoric acid, the production of which yields by-product gypsum. The Austrian chemical industry has been developing a process for the utilization of this by-product as a raw material for the manufacture of sulphuric acid and cement or ammonium sulphate.

A potassium fertilizer industry could not be established because of the lack of raw materials. Projects, such as the recovery of potash by incineration and the subsequent leaching of residues of the sugar industry, well developed in Austria, and the production of conversion saltpetre, which is not only needed for the production of black powder but is also a comparatively concentrated complex fertilizer, were soon abandoned for economic reasons. A recently developed Austrian process using imported potassium chloride deserves attention. Pulverized potassium chloride is converted with nitrogen tetroxide to elementary chlorine and a concentrated potassium nitrate solution, which, more effective than potassium chloride or potassium sulphate, can be added as the nitrogen-potash component of complex fertilizers. This process should be of particular interest to developing countries, since it supplies the key chemical chlorine—the basic material, among others, for plastics and solvents—at an unusually low price without making heavy demands on electric power.

There is no doubt that the indigenous development of the Austrian nitrogen industry would not have been possible during the period between the two World Wars. Only during the Second World War was the Austrian nitrogen industry established, and then it was set up along with an up-to-date steel combine and other factories as part of the German effort to develop heavy industry in Austria using German excess capital.

The Austrian nitrogen industry has expanded continuously through the investment of self-produced capital and occasional loans far beyond the capital required originally for its production of calcium-ammonium nitrate. In 25 years it has become a chemical combine with an extensive production programme and gross sales amounting to six times the original figures. For two thirds of this time the existing installations were merely enlarged and improved, and new processes, such as those for the production of plastics, were acquired under licence. During the past eight years, however, its own research and development programme, organized some time ago, at last began to produce results that have been used partly within the company and partly licensed to others. This entry into the processing trade, a rapidly expanding and important business, indicates progression from a developing to a developed country.

The Austrian heavy chemical industry, however, still receives its strongest impulses for development through partial amalgamation with foreign chemical companies superior in size and scientific productivity. This is done by founding affiliated companies in which each of the two partners has a 50 per cent share so that only unanimous decisions can be taken. This is not the case with the fertilizer industry, which needs no foreign affiliation; but in the field of petrochemistry important co-operative production units are already working at full capacity or are under construction.

The experience of the Austrian fertilizer industry in its nearly 50 years of existence, indicates that:

(*a*) As long as industrial potential is low, phosphate fertilizer production based on sulphuric acid is cheap, comparatively easy to set up and an effective first step; it also promotes the development of other useful yet comparatively simple chemical products.

(*b*) A nitrogen industry should be started only after establishing a suitable infrastructure and preferably in partnership with an experienced nitrogen fertilizer manufacturer; it, too, will stimulate research and development and, in addition, produce new capital.

(*c*) Even countries without potassium salt deposits can build up chemical industries by importing this irreplaceable fertilizer component.

Summary

The standard of living of the developed countries is 10 to 50 times higher than that of the developing countries. Austria is a small country and its production is not greatly favoured by external circumstances. The production of American capital, the number of inhabitants of mainland China or the area of Brazil exceeds the respective Austrian factors approximately 100 times; yet, Austria, which has had to reconstruct its economy twice during the past 50 years, stands today among the developed countries with a high standard of living. The reason for this may be found in the sociological-economic-intellectual condition of the economy, which may be considered as Austria's infrastructure. A good infra-structure can accelerate development on a large scale and is more stable and efficient than economic values determinated by book-keeping.

In spite of optimal planning and commercial efficiency, it will not suffice to import machinery and the most up-to-date processes if the infrastructure needed for them is lacking. To a certain extent, however, infrastructure may be imported. If this is achieved by setting up industries in the developing countries, and if the difference in the infrastructure between the countries is too large this will lead to colonialism. The middle course to be recommended, therefore, seems to be the entrepreneurial partnership.

For the industrialization of the developing countries, politicians, businessmen, engineers and scientists are required. Politicians aspire to power and are occupied

with distributing functions; businessmen look for economic profit; engineers take care of production and its smooth operation; while scientists consider cause and effect relations. Scientists, therefore, should be entrusted with the chief responsibility for making decisions. Industrialization, however, exercises such a great fascination on various professions that this recommendation may be difficult to follow.

GREIF SANDER,
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Ruhr-Stickstoff AG

REMARKS OF THE CONSULTANT FROM THE FEDERAL REPUBLIC OF GERMANY

GENERAL PROBLEMS

The need of the developing countries for fertilizers is acute. This problem was faced at an early stage by the West European nitrogen industry, which had been supplying fertilizers to developing countries for many years. As early as the mid-1950s the industry of the Federal Republic of Germany launched several programmes to promote the demand for fertilizers, for example, in India and Pakistan. These projects were not limited to ensuring the supply of fertilizer proper but were concerned also with the transport, storage and methods by which the application of fertilizer could become profitable to farmers in the developing countries. From 1961 on the industry has co-operated closely with the Food and Agriculture Organization (FAO) in the Freedom from Hunger Campaign (FFHC) Fertilizer Programme, which has in the meantime carried out some 120,000 fertilizer trials and provided training for several thousand local fertilizer experts. This international effort could not have been successful without the assistance of the recipient countries themselves. Their number has now risen to 23.

One of the foremost tasks in agriculture for the developing countries is to improve and spread a knowledge of the use of fertilizers to farmers by setting up proper marketing organizations. In the future there will be an ample supply of fertilizers of all three plant nutrients, N, P_2O_5 and K_2O, from factories that are in operation or planned in both developed and developing countries.

The main problem will be to find markets for this increasing supply and to ensure its correct handling and application. This includes the distribution of the increasing agricultural output in the domestic markets of the developing countries. In addition, the increase in agricultural productivity brought about by the use of fertilizers will allow a saving in foreign exchange, at present required to pay for the import of food, and will be available for export.

Unless a method can be found to persuade a growing number of farmers to try fertilizer for the first time or to increase their application of it and to ensure a means of disposing of the growing agricultural output, fertilizer production will be unprofitable. This fact should be borne in mind when establishing priorities in fertilizer planning.

DEVELOPMENT OF PRODUCTION CAPACITIES

Large investments are being made at present in fertilizer production facilities for all three major plant nutrients. Table 1 below supplies figures for nitrogen production capacity (March 1968).

Table 1

ESTIMATED NITROGEN FERTILIZER PRODUCTION CAPACITIES FROM 1966/1967 TO 1970/1971
(Thousand tons of nitrogen)

Region	*1966/1967*	*1967/1968*	*1968/1969*	*1969/1970*	*1970/1971*
Africa	350	550	700	900	1,000
Asia	4,800	5,600	6,200	7,900	9,200
Eastern Europe	5,600	6,550	7,650	8,150	10,300
Western Europe	9,100	10,750	12,650	13,800	14,400
South America	800	1,050	1,450	1,650	1,850
North America	9,650	12,600	14,450	15,850	15,850
Oceania	100	100	300	500	500
World total	30,400	37,200	43,400	48,750	53,100
Total for developing countries	3,150	3,950	5,300	6,900	8,250

Source. Development Assistance Committee (DAC) of the Organisation for Economic Co-operation and Development (OECD).

These figures indicate an increase of 22.7 million tons of nitrogen, or 75 per cent in world nitrogen production capacities over a period of four years making an average increase of over 5.5 million tons of nitrogen per year. This development is well under way and is rapidly changing the situation with respect to raw materials required for the manufacture of ammonia. About 53 per cent of world ammonia production in 1970/1971 will be based on natural gas and another 20 per cent on naphtha.

During the same period, the number of ammonia plants in production and in the planning stage will increase from 395 to 448 by 1970/1971, and the total number of nitrogen plants, including by-product facilities, will increase from 664 to 703. This limited increase in the number of plants, compared with the development of total capacity, is the result of a considerable increase in the average size of the modern ammonia plant. Whereas in 1960, in industrialized countries a plant with a capacity of 300 tons per day was the optimal size, today plants with a capacity of 1,000 tons per day are common. In addition, a number of 1,500-tons-per-day plants are being built; one recently went on-stream in the United States, and others are being considered for locations in Europe and Latin America. For developing countries a 100,000-tons-per-year nitrogen plant should be a minimum requirement.

However, giant-size ammonia plants may still be the exception. A modern ammonia plant requires a market with a high level of domestic demand, and probably not more than 30 per cent of fertilizer production will be for export. Generally, nitrogen plants have to rely on the conversion of ammonia to nitrogen products for technical use in the plastic, fibre, metal and mining industries.

Investment problems and utilization of capacity

Investment in ammonia production has been studied recently by a number of private and international institutions. The OECD Development Centre, for example, has quoted for a case model an investment cost of $477 per ton of nitrogen at a naphtha-based plant with an annual capacity of 123,000 tons of nitrogen in South-East Asia. This figure includes urea and ammonium nitrate production facilities. According to this source, investment costs for the manufacture of nitrogen, including financing, but excluding import duties on equipment will be about 30 to 45 per cent higher in developing countries than in developed countries.

The erection of chemical complexes in the fertilizer field today, with improved technological processes and the requisite infrastructure, requires a heavy outlay of capital. Additional capital is needed for maintenance during and after start-up, that is, from 12 to 36 months, until full capacity is reached. In developing countries a number of nitrogen plants have been built recently where market conditions make production at rated capacity difficult. A production rate below 80 per cent of capacity will create considerable financial problems, and a rate of 70 per cent or lower will present a very serious situation. The OECD Development Centre, taking into account all nitrogen plants existing or planned, has estimated a production relative to capacity in developing countries in 1970 as 62 per cent for nitrogen, 59 per cent for P_2O_5 and 74 per cent for K_2O.

World trade in mineral fertilizers

World trade in mineral fertilizers has increased rapidly since 1956, as indicated in table 2 with respect to nitrogen fertilizers.

Table 2

World imports of nitrogen fertilizers in recent years

(Thousand tons of nitrogen)

	Total	*Ammonium sulphate*	*Urea*	*Complex fertilizers*
1956/1957	2,043	863	166	107
1961/1962	3,088	1,066	523	204
1962/1963	3,178	1,955	563	235
1963/1964	3,429	1,075	744	306
1964/1965	3,749	1,157	845	405
1965/1966	4,121	1,352	951	496

Estimates for 1966/1967 show that the world total of nitrogen production has grown to over 5 million tons.

The share of the developing countries in the total imports of nitrogen fertilizers in percentage is as follows:

1956/1957	*1961/1962*	*1962/1963*	*1963/1964*	*1964/1965*	*1965/1966*	*1966/1967 estimated*
47	51	51	48	46	43	45

In 1966/1967 as in 1956/1957, about 24 per cent of world consumption of nitrogen fertilizer was imported, and there is little doubt that this percentage will increase in the future. Table 3 gives additional information on trade development over this period showing the relative importance of different types of nitrogen fertilizers.

Table 3

SHARE OF SELECTED NITROGEN FERTILIZERS IN TOTAL WORLD IMPORTS
(Per cent)

	1956/1957	*1965/1966*
Ammonium sulphate	42	33
Ammonium nitrates	24	17
Urea	8	23
Complex fertilizers (N-P N-K N-P-K)	5	12

Out of the total increase in imports of nitrogen fertilizers throughout the world, 1965/1966 relative to 1956/1957, the percentage share attributable to each continent is shown in table 4.

Table 4

INCREASE IN WORLD IMPORT OF NITROGEN FERTILIZERS, 1965/1966 RELATIVE TO 1956/1957: PERCENTAGE SHARE OF EACH CONTINENT

	The Americas	*Asia*	*Africa*	*Europe*	*Oceania*
Ammonium sulphate	18	53	23	5	1
Ammonium nitrate	1	9	8	80	2
Urea	14	68	8	9	1
Complex fertilizers (N-P, N-K, N-P-K)	12	26	3	58	1

With few exceptions, the years up to and including 1966/1967 have shown a supply of nitrogen fertilizers sufficient to meet the demand from every importing country, including the developing countries; this situation will certainly continue in future years. Exporters from developed countries, particularly in Europe, have acquired the know-how of fertilizer marketing that, together with national and international technical and capital aid, will assure their ability to meet such a demand. This will enormously aid the developing countries to satisfy their growing fertilizer requirements.

Prices for nitrogen fertilizers on the world market have been favourable for the developing countries. The average annual export price, for example, for ammonium sulphate f. o. b. North Sea port (based on index 1956 = 100), decreased in 1966 to 76 points and in 1967 to 60 points.

With the exception of certain areas that were affected by the Middle East crisis of 1967, the trend in freight rates has also been advantageous to importing countries in recent years.

The number of nitrogen fertilizers, including complex fertilizers, available for import has increased considerably. For example, the nitrogen industry in the Federal Republic of Germany has a total of eight different nitrogen fertilizers and twenty complex fertilizer grades of the N-P, N-K and N-P-K-type for export. This wide range of fertilizers will ensure that even special requirements by farmers in importing countries can be met. In many cases, the introduction of particular types of nitrogen fertilizers to the market of a developing country helps pave the way for indigenous production at a later stage.

FERTILIZER MARKETING IN DEVELOPING COUNTRIES

An excellent example of an improved marketing set-up for fertilizers has been planned recently by experts for Ceylon. The basic facilities for a distribution system for fertilizers already exists there. These include a state buying organization in addition to private trading companies; a special branch of the Ceylonese Agricultural Department for the handling of fertilizer credit and subsidies; a co-operative and an approved private-dealers scheme at the village level; a fair amount of storage facilities throughout the channels of distribution that extend to the village level, for which special standard designs have been developed; and an extension service able to adapt advice to local conditions. Suggested improvements include:

(*a*) Provision of better credit facilities by making it possible for farmers to obtain loans through local banks (credit only in kind);

(*b*) Adaptation of standard storage designs to meet local requirements;

(*c*) Introduction of bag sizes suitable for normal needs on small plots;

(*d*) Offering incentives for transporting and selling fertilizer to the farmer;

(*e*) Establishment of uniform consumer price quotations throughout the country regardless of the distance of the farmer from the port of entry of the fertilizers;

(*f*) Adjustment of the time of supply of fertilizers to the twofold seasonal demand of local agriculture.

Although the problem of fertilizer distribution will probably differ from one developing country to another, studies for the initial set-up and improvement of existing systems deserve high priority. The example given for Ceylon takes into consideration a number of areas where there is room for improvement, and this may point the way to a solution to the fertilizer problem in other developing countries.

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Agricultural Division,
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STATEMENT OF THE CONSULTANT FROM THE UNITED KINGDOM

To improve the economics of fertilizer manufacture in the developing countries detailed technical and engineering problems will have to be solved. The factors to be considered in the case of even a single fertilizer complex are numerous, but in the case of a region, country or continent, they may be innumerable. Some specific problems relevant to the import of intermediates and the under-utilization of capacity may be singled out for discussion.

Sources of phosphate and potash are relatively few. For any plant location under consideration sufficient information is likely to be available so that the optimum methods of supplying these plant nutrients can be computed.

In contrast, the situation regarding nitrogen is in a state of flux, owing to the utilization of cheap sources of natural gas, the introduction of refrigerated tankers for ammonia and the scale of operation in the industry. The provision of nitrogen represents a significant proportion of the foreign currency requirements, be it imported or manufactured locally. The cost of imported ammonia is likely to remain at its present price of $50 to $60 per ton delivered to the battery limits of a conversion plant located at the port. This assumes that ammonia is transported in 10,000-ton tankers and includes a cost of up to $10 per ton to cover the capital and operating costs of a 15,000-ton refrigerated ammonia storage installation. The cost of locally produced ammonia varies considerably from region to region, and outside factors can have little influence on the cost of raw materials in these various regions; nor can the size of the market arbitrarily be increased. If other factors are examined in order of importance, it is found that the total production and the time distribution of this production over the first six to eight years of the project have a profound influence on the cost of local production. In a study of the investment and production costs of ammonia in a developing country recently published by the Organisation for Economic Co-operation and Development (OECD) the assumed output levels were:

Per cent of rated capacity	*Year of operation*
25	4th
40	5th
60	6th
80	7th

Thus, depending on location, imported ammonia can often be shown to be the cheapest source of nitrogen for all but the biggest fertilizer complexes. If, on the other hand, the performance of an average European ammonia plant is taken as the basis of calculation, then even medium-size ammonia plants with a capacity of 300 to 400 tons per day can compete effectively with imported ammonia. Taking intermediate performance figures between those of Europe and the ones assumed in the OECD study, such plants may remain competitive if the foreign exchange element alone is taken into consideration.

The lengthy period between the date of order and production can be reduced by appropriate actions being taken by the Government and local authorities of the developing countries. The recent vigorous approach of the Indian Government to this problem will help achieve good results at Indian Explosives Limited, Kanpur.

The output of the plant in its first, second and third year of operation has a fundamental effect on the net cash flow and profitability. In this field room for great improvement at relatively low cost in human effort, capital and time can be seen. Ammonia technology has been changing rapidly since about 1960. Only in 1968 has a stage been reached when consolidation of the present technology is beginning to take place and operators and contractors alike have accumulated sufficient experience to permit them to remove the elements of high risk that were accepted in the designs of 1963 to 1965.

The past few years have seen the construction of some excellent ammonia plants, some that have caused considerable loss to their operators, and a large number whose performance has fallen well below the average of chemical plants in the process industries as a whole. This is now general knowledge and is the cause for the widely held belief that modern ammonia plants are inherently more complex and less reliable than other chemical plants. As previously mentioned, the experience is now available together with the necessary technology that has enabled Imperial Chemical Industries and others to determine what constitutes a good, reliable and economic design. In retrospect, it is possible to see what went wrong. The client and contractor are perhaps to be blamed equally.

The prospects of very cheap ammonia afforded by the new technology created a boom in the industry. As a result of this a large number of contractors entered the field, and intensive competition rapidly developed. Clients, not being in the possession of the necessary experience and know-how to check, specify and select the right plant, tended to purchase on the basis of price. This resulted in a steadily declining cost of plants; and finally it reached a stage when contractors, sometimes unknown to themselves, entered into contracts at unrealistically low prices, which resulted in no profit or even a loss to their company. Inevitably, this competitive situation resulted in "engineering down to a price". To a marginal extent this affected the quality of the equipment provided. To a much more significant extent it meant that not enough money was spent on design, and, consequently plants were designed that were barely operable.

Neither the contractor nor the operators have fully appreciated the nature of the new generation of ammonia plants. Everyone was preoccupied with capital cost, the over-all heat balance, fuel consumption per ton of ammonia, etc. Later, it was realized that any one of a hundred minor instruments or other faults could shut down the plant, which would then take four to five days to start-up. Unfortunately, most of the hard won experience regarding conventional plants was also ignored, with the result that some small and medium-size plants built in the past three or four years perform no better than their big brothers.

It could be said that these are details. However, details of this very kind have turned many seemingly profitable ventures into failures and put the industry almost into disrepute. These details should be examined in order to establish, at the technological level, the best that can be done for the developing countries and, for that matter, for the industry as a whole.

The conventional, medium-size ammonia plant technology has not stood still either. The cost of the ammonia plant with a capacity of 300 to 500 tons per day has decreased considerably in the past few years as equipment manufacturers have installed modern facilities to produce the equipment required for these plants; they are now able to produce high-pressure vessels, compressors, heavy pipework, etc., at low cost. Furthermore, the process efficiency of these plants need not be significantly different from the efficiency of large plants. Steam drives, which have in certain locations been the key to low production costs, can equally well be employed in conjunction with reciprocating compressors. Imperial Chemical Industries and others in Europe have used steam turbines and gearboxes to drive reciprocating compressors for at least ten years. They have proved as reliable as any alternative arrangement.

Conventional ammonia plants operated by the main fertilizer manufacturers have normally achieved an on-stream time of 92 to 95 per cent of capacity by the third or fourth year of operation, and sufficient "de-bottlenecking" has been carried out to increase the ultimate output of the plant to 100 per cent and sometimes up to 130 per cent of nominal capacity. The annual output of these units, therefore, has often exceeded the nominal annual capacity calculated on 100 per cent on-stream time. There is no reason to believe that plants constructed today should not also benefit from the removal of bottlenecks. The on-stream time of a single-stream "total energy plant" is unlikely to be higher than 85 per cent. Reasonable output forecasts for an ammonia plant in an industrialized country in Europe can be:

Year after engineering completion	*Per cent of capacity*
1st	60
2nd	75
3rd	80
4th	90

For a developing country using a well-proved design, the following targets may be proposed:

Year after engineering completion	*Per cent of capacity*
1st	40
2nd	60
3rd	70
4th	80
Subsequent years	80

To ensure with reasonable certainty that a given plant will achieve the assumed performance, the capital cost will increase by an estimated 4 to 5 per cent above the minimum prices currently quoted. The increase in capital cost would consist of a very substantial increase in the total design costs and represent 2 to 2.5 per cent of the capital cost, the balance being a slight increase of 2 to 2.5 per cent in the cost of the hardware. The software costs, that is, the design and engineering costs that are necessary to arrive at an economical design, also include a small allowance for a consultant's fee.

There is often a marked reluctance in the developing countries to pay for know-how and experience, however. Paying for perhaps inferior hardware and engineering has, unfortunately, become generally accepted. Extra design cost and capital expenditure will go a long way towards ensuring that one buys the most economical and profitable plants and allows one the liberty of being able to select the plant not on the basis of price alone. It cannot be emphasized enough that the knowledge is available to build good, profitable, medium-size ammonia plants, but it is necessary to pay for it.

The task of this Group meeting was "to identify the causes and suggest remedies" for factors inhibiting the indigenous growth of the fertilizer industry in developing countries. In the case of ammonia, the causes are now identifiable. The remedy to under-utilization of capacity lies in using the most up-to-date experience with established processes. Better utilization will reduce the production costs and the foreign currency investment cost per ton of ammonia. In many cases these cost reductions will make it more attractive to build plants in, rather than import ammonia to, the developing countries.

Annexes

ANNEX 1

OPENING STATEMENT BY MR. N. K. GRIGORIEV, DIRECTOR, DIVISION OF INDUSTRIAL TECHNOLOGY, UNIDO

I take great pleasure in welcoming all of you to UNIDO for this meeting of the *Ad Hoc* Expert Group from Fertilizer-Deficit Countries. Some of you are old friends of the United Nations and have assisted us on various occasions with your valuable contributions. Others who are new to our work in UNIDO will, I hope, enjoy working with us and continue to assist UNIDO in its future programme.

UNIDO is essentially a catalytic agent and an international servicing institution to assist developing countries in their efforts towards rapid and successful industrialization. When requested by member countries to do so, UNIDO provides them with the services of experts in trouble-shooting in existing industries, assists them to make location and feasibility studies, and to plan new industries, etc. UNIDO executes Special Fund projects for demonstration purposes and organizes pilot plants for fertilizers, pesticides and petrochemicals. The Rwanda pyrethrum-extraction plant and the United Arab Republic pesticides projects are examples of such aid. Under Special Industrial Services (SIS), UNIDO acts as a fire-brigade to help countries to solve urgent industrial problems.

Although field operations, such as the provision of technical experts, making available information on methods of modern technology, and giving advice on the most economical size of plant applicable, are the main task of UNIDO, we carry out a number of supporting activities, such as research, conducting seminars, workshops and expert group meetings. This meeting is thus an essential part of our work programme in the development of the fertilizer industry.

We are meeting to discuss and recommend measures to be adopted to overcome obstacles to the rapid growth of the fertilizer industry in developing countries. Imports of fertilizers necessary for agricultural production to meet the demands of an increasing population are consuming large blocks of foreign exchange. Some developing countries plan to import up to $350 million worth of fertilizers annually for the next few years; this is in addition to the expansion of their indigenous production capacity. If the process can be expedited and some of the bottlenecks removed, dependence on imports can be reduced, and the savings in foreign exchange used for further industrialization. The building up of design and engineering know-how, the manufacture of indigenous equipment and the production of necessary machinery are essential to this process.

I hope your deliberations will be fruitful and that your work with us and your visit to this beautiful city of Vienna will be rewarding and enjoyable. You have left positions of responsibility to attend this meeting, and I thank you for being here today.

ANNEX 2

LIST OF PARTICIPANTS

Expert Group from fertilizer-deficit countries

Gastao Vitor CASPER	Brazil	Senior Processing Engineer Petroleo Brasileiro S. A. DEPIN-Petrochemical Industries Division
Abdalla FADLALLA	Sudan	Director, Department of Industry Ministry of Industry and Mining
José Garcia LUNA	Mexico	Chief, Planning and Development Petrochemical Division Petroleos Mexicanos
M. K. K. NAYAR	India	Managing Director Fertilizers and Chemicals, Travancore, Ltd.
Taha ZAKY	United Arab Republic	Chairman and Managing Director Egyptian Chemical Industries (KIMA)

Consultants from fertilizer-surplus countries

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M. C. VERGHESE	Chief, Section for Fertilizers, Pesticides, and Petrochemicals Industries
F. SAGER	Senior Interregional Adviser
O. CZIVIS	Senior Industrial Development Officer
F. T. NIELSSON	Senior Industrial Development Officer
M. HONDA	Industrial Development Officer
V. Rao VANGALA	Industrial Development Officer

ANNEX 3

AGENDA

Election of Chairman
Aims and purpose of the *Ad Hoc* Group
Statement by experts from India and Mexico
Statements by experts from the Sudan, Brazil and the United Arab Republic
Statements by consultants from the United States, Japan, Austria, United Kingdom and the Federal Republic of Germany
Discussion of factors inhibiting the indigenous growth of the fertilizer industry in developing countries and recommended solutions
Discussion of difficulties experienced in importing the required quantities and types of fertilizer and suggested remedies
Consideration of report and recommendations

ANNEX 4

List of discussion papers

1.	The influence of infrastructure on fertilizer industries	*Gastao Vitor Casper* *Abdalla Fadlalla*
2.	The fertilizer industry in India	*M. K. K. Nayar*
3.	The trend towards ammonia plants with capacities of over 1,000 tons per day	*José Luis Garcia Luna*
4.	The fertilizer industry and financial factors inhibiting its development	*Taha Zaky*
5.	Production of sulphuric acid from anhydrite	*Hans Hohn*
6.	Fertilizer projects: technical considerations with particular reference to ammonia plants	*V. Varga* *T. Suzuki*
7.	Financing of fertilizer plants in developing countries	*Raymond Ewell*
8.	Present and future development of fertilizers in developing countries	*Raymond Ewell* *Greif Sander*
9.	Sulphur shortage: processes reducing the use of sulphur and the transport of sulphur and phosphorus	*M. C. Verghese*
10.	Proposed UNIDO assistance in dealings with engineering contractors	*F. Sager*
11.	Direct application of liquid fertilizers in the soil	*F. T. Nielsson*
	Economic advantages of the ammoniation of superphosphates	*F. T. Nielsson*
12.	Production of nitrophosphates using processes developed by Kaltenbach/SCHZ-Chemoproject and Norsk Hydro Elektrisk Kvaelstof AS	*O. Czivis*

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