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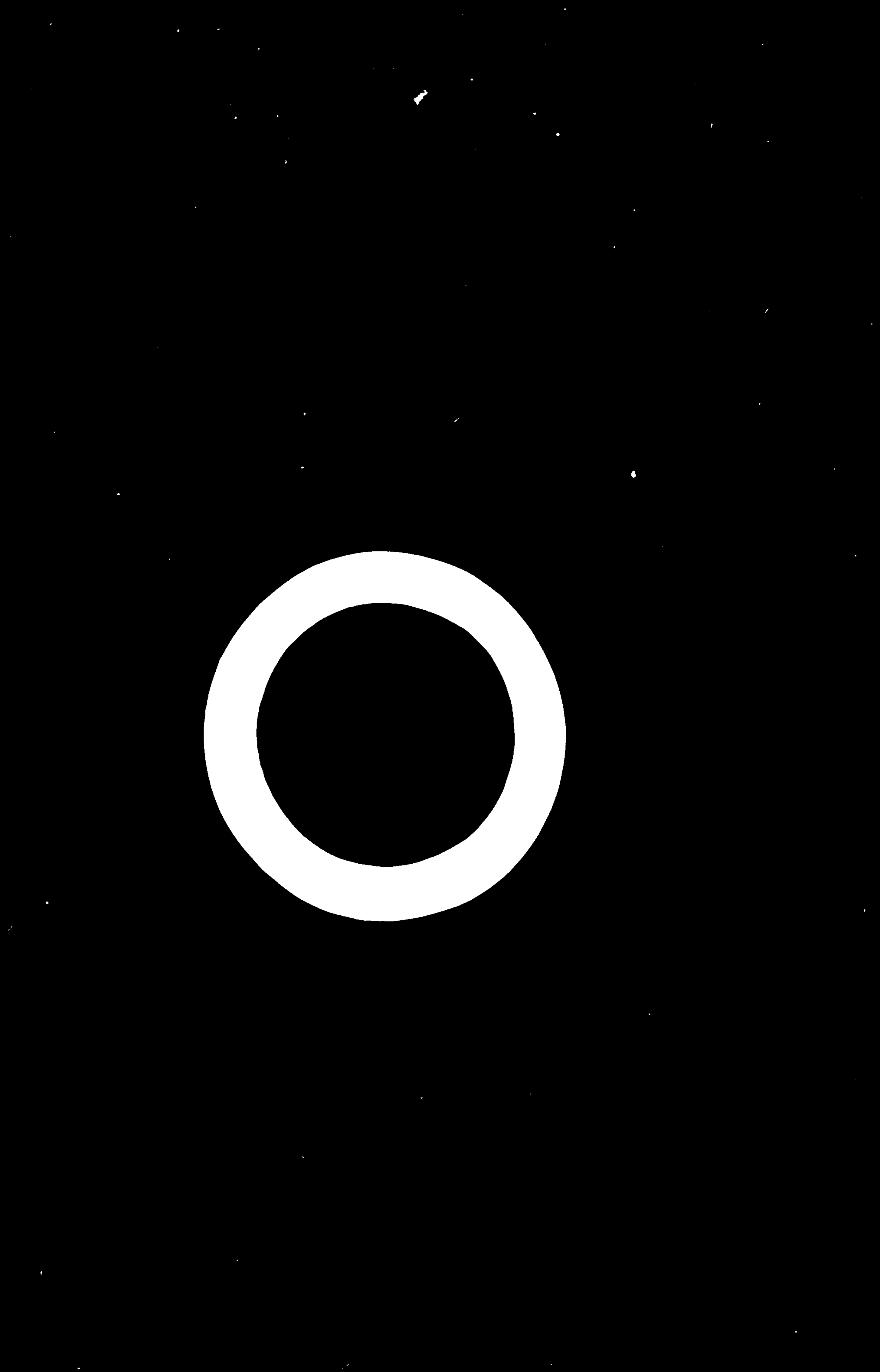
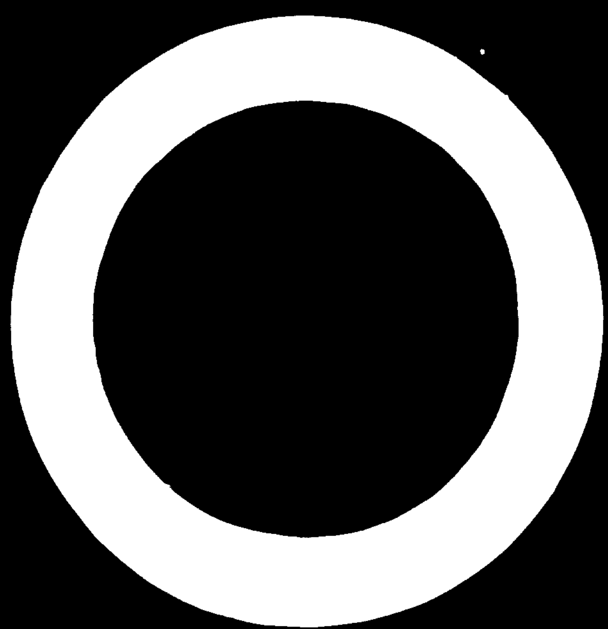
UNIDO MONOGRAPHS ON INDUSTRIAL DEVELOPMENT

Industrialization of Developing Countries: Problems and Prospects

FERTILIZER INDUSTRY

UNITED NATIONS





FERTILIZER INDUSTRY

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
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UNIDO MONOGRAPHS ON INDUSTRIAL DEVELOPMENT

Industrialization of Developing Countries: Problems and Prospects

MONOGRAPH NO. 6

FERTILIZER INDUSTRY

Based on the Proceedings of the International Symposium on Industrial Development (Athens, November–December 1967)

UNITED NATIONS
New York, 1969

ID/40/6

UNITED NATIONS PUBLICATION

Sales No.: E.69.II.B.39, Vol. 6

Price: $U.S.0.50 (or equivalent in other currencies)

Printed in Austria

Foreword

The International Symposium on Industrial Development, convened by UNIDO in Athens in 1967, was the first major international meeting devoted exclusively to the problems of industrialization of the developing countries. It followed a series of regional symposia on problems of industrialization held in Cairo, Manila and Santiago in 1965–1966 under the sponsorship of UNIDO and the United Nations regional economic commissions, and a similar symposium held in Kuwait in 1966 under the sponsorship of UNIDO and the Government of Kuwait.

The Athens Symposium was attended by some 600 delegates from 78 countries and by representatives of various United Nations bodies, international organizations and other interested institutions in the public and private sectors. It provided a forum for discussion and exchange of views on the problems and prospects of the developing countries which are engaged in promoting accelerated industrial development.

The Symposium devoted special attention to possibilities for international action and for co-operative efforts among the developing countries themselves, and explored the scope, means and channels for such efforts.

Studies and papers on a wide range of problems relating to industrialization were presented to the Symposium—by the UNIDO secretariat and by participating Governments, international organizations and observers. An official report, adopted at the Symposium, has been published by UNIDO.[1] Based on this documentation and the discussions in the meeting, the present series of monographs is devoted to the 21 main issues which comprised the agenda of the Symposium. Each monograph includes a chapter on the issues presented, the discussion of the issues,

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[1] *Report of the International Symposium on Industrial Development, Athens 1967* (ID/11) (United Nations publication, Sales No. 69. II. B. 7).

and the recommendations approved by the Symposium. Some of the monographs deal with specific industrial sectors; some with matters of general industrial policy; and others with various aspects of international economic co-operation. An effort has been made to make the monographs comprehensive and self-contained, while the various economic, technological and institutional aspects of the subject matter are treated within the context of the conditions generally prevailing in the developing countries.

Since economic, technological and institutional aspects are described with particular reference to the needs of the developing countries, it is felt that the monographs will make a distinct contribution in their respective areas. They are intended as a source of general information and reference for persons and institutions in developing countries concerned with problems of industrialization, and particularly with problems and issues of international co-operation in the field of industrialization. With this in view it was considered that an unduly detailed technical presentation should be avoided while at the same time enough substantive material should be offered to be of value to the prospective reader. For a more elaborate treatment of the subject, the reader is referred to the selected list of documents and publications annexed to each monograph.

The annexes also contain information on the areas in which UNIDO can provide technical assistance to the developing countries on request; a selected list of major UNIDO projects in the respective fields; and a list of meetings recently organized by the United Nations.

It is hoped that the monographs will be particularly useful to Governments in connexion with the technical assistance activities of UNIDO and other United Nations bodies in the field of industrial development.

This monograph was prepared by the secretariat of UNIDO.

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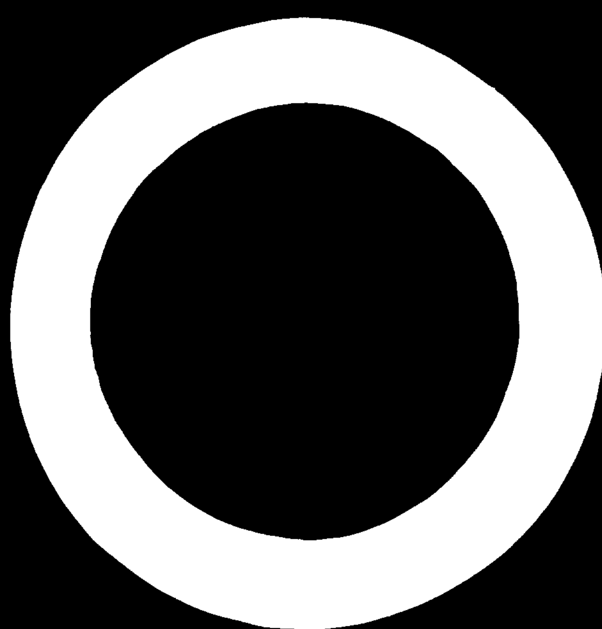
EXPLANATORY NOTES

Billion refers to thousand million.
Dollar ($) refers to US dollar unless otherwise indicated.
One hectare (10,000 m^2) equals 2.471 acres.
One mill equals $0.001.
Ton refers to metric ton (1,000 kg) unless otherwise indicated.

The following abbreviations are used in this monograph:

AID	United States Agency for International Development
ECAFE	Economic Commission for Asia and the Far East
FAO	Food and Agriculture Organization
GATT	General Agreement on Tariffs and Trade
IBRD	International Bank for Reconstruction and Development
TVA	United States Tennessee Valley Authority
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNIDO	United Nations Industrial Development Organization
WHO	World Health Organization



INTRODUCTION

The fertilizer industry holds a unique position in developing countries because it is linked both with agricultural development and industrialization. Many developing countries have serious food shortages and most of them obtain very low yields from agriculture. Since fertilizers are the key to increasing agricultural production, their importance to developing countries is evident. Experience in many developed countries as well as field trials conducted by the Food and Agriculture Organization (FAO) in developing countries have shown that the application of one ton of fertilizer can increase the yield of food grains by five to ten tons.

The economic growth of many developing countries is being retarded because food production has failed to keep pace with the growth of population. The problem is aggravated by the fact that areas deficient in food are the very areas with the highest population growth rates. Targets for food production should take into account not only the need to meet the present low levels of consumption but also the need to raise nutritional standards; as income levels in developing countries rise, the *per capita* demand for food also rises. Thus in many developing countries the annual food demand is increasing even faster than the annual population growth would lead one to expect.

Many countries with insufficient agricultural production have little unused land on which to grow additional food. Developing countries that do have unused land often do not have the resources to bring it into production fast enough to keep up with the increasing demand for food.

Thus, food needs over the next decade will have to be met largely by increased production from land at present under cultivation. This means that agricultural production must increase more rapidly than at any time in history. If the world population doubles between now and the end of the century the production of food must be doubled long before that in order to avert famine; this fact was brought out by the FAO Third World Food Survey, which also stresses that the developing regions, particularly the Far East, must increase their food supply at a much faster rate than the world as a whole.

Five inputs are necessary to increase agricultural productivity: fertilizer, improved seed varieties, water, pesticides and farm machinery. Of these, fertilizer is probably the most important. In recent years some developing countries have been widely using improved seed varieties, which require more fertilizer than the indigenous varieties.

In the early stages of agricultural development, the transition from traditional methods towards new technology is frequently slow and difficult to achieve. Poorly educated farmers with limited resources are understandably hesitant to change their traditional ways. A decisive factor in overcoming this inertia is to persuade farmers to accept one or more methods that can be carried out easily and produce visible results quickly. The use of fertilizers is such a method.

Although agriculture is its principal customer, the fertilizer industry has links with many other industries. The oil and natural gas industries supply hydrocarbons as raw materials to the fertilizer industry. The mining industry supplies phosphate rock, potash minerals and sulphur. The ammonia produced by the fertilizer industry has many industrial applications. Ammonium nitrate is used as an industrial explosive, particularly in coal mining. Urea is used in making urea-formaldehyde plastics. Phosphoric acid has many industrial uses. Ammonium phosphate is used as a fireproofing agent. Ammonium chloride, which is important in the manufacture of dry batteries, and soda ash are made as joint products in a process used in several Asian countries. Thus in many developing countries fertilizers provide the nucleus for a broadly-based chemical industry.

Chapter I gives some statistical evidence of the great growth in world production and consumption of fertilizers. Production in developing countries is increasing more rapidly than in the developed ones, but estimates show that even by 1976 the developing countries will produce only 14 per cent of the world's supply of nitrogen fertilizers, 10 per cent of phosphates and 5 per cent of potassium, which will be inadequate to supply their needs. Production in the developed countries, on the other hand, is greatly in excess of their requirements. There have been great changes in the relative demand for different types of fertilizers. Before 1955, nitrogen fertilizers were the least used; since 1966, they have become the most popular. During recent years there has also been a switch to liquid fertilizers. A table is given showing desirable targets for fertilizer use in developing countries in relation to population.

Chapter 2 analyses some of the government policies affecting the growth of a fertilizer industry. They include the imposition of heavy duties on imports of equipment, spare parts and raw materials, and severe limitations on the repatriation of profits by foreign investors. Some form of insurance is required against capital losses by investors as well as sufficient control over managerial policy to ensure that the plant is being efficiently operated. The industry needs utilities at fixed tariffs on which it can rely. It will be necessary to subsidize fertilizers in some way to make their use viable. Credit facilities must be made available to farmers, and an active sales promotion of fertilizers, including free technical advice, must be carried on.

Chapter 3 describes the manufacture of nitrogen fertilizers, which is now mostly based on the use of anhydrous ammonia. The main source for ammonia is natural gas, which is processed in large single-stream plants using centrifugal compressors. The price of feedstock and the size of plant are the factors determining the price of ammonia, which has been nearly halved by the use of the new technology.

Greater use of natural gas resources in the Middle East, North Africa and elsewhere and the building of new ammonia plants have introduced new trading patterns. Large plants for producing ammonia and solid derivatives, principally for export, are being constructed in some of those gas-rich areas. This has been made possible by recent improvements in methods of bulk transport for refrigerated ammonia and natural gas for which the necessary finance and technology were provided under various international and bilateral programmes.

Chapter 4 deals with phosphates, for which phosphate rock is the essential raw material. It is a bulky material because the best grades contain only 15 per cent phosphorus. A more economic modern procedure is to transport the intermediate material, elemental phosphorus, after the rock has been processed in large-scale plants near the mine. Two commercial processes for the manufacture of phosphoric acid are commonly used: the wet process, using sulphuric acid, and the thermal process, using an electric furnace. There is also a new process using hydrochloric acid. The critical factor in the wet process is the cost of sulphur: world production of sulphur was inadequate in 1967, but according to recent estimates there will be sufficient supplies by 1969/1970. Some tables are included showing the comparative costs of the two processes. The modern trend is towards higher-analysis products, which are often used in mixed fertilizers. A description is given of the four processes of manufacturing nitrophosphates.

Chapter 5 describes potash fertilizers. There are considerable potash reserves, mostly in developed countries. Potash fertilizers are now the least used of the three types. Potassium chloride accounts for 94 per cent of the supply and is mostly used in bulk blending. It takes from three to six years to build a potash complex, which presents serious engineering problems. Its operation requires considerable equipment and a skilled labour force. Difficulties of this sort have delayed the exploitation of mines in Ethiopia.

Chapter 6 enumerates the technical issues to be faced when a fertilizer industry is to be established. Few countries have the range of raw materials required to produce all three types of fertilizer. It is now possible, however, to import highly concentrated intermediates, such as ammonia and phosphorus, which should be used in preference to low-grade local materials. Developed countries have flourishing fertilizer industries based on imported materials. The industry must be planned as an integrated whole to provide the multinutrients that suit local agricultural conditions. It may be found economic to build large plants, but the foremost need is to make full use of existing capacity by employing skilled management. The possibility of setting up fertilizer industries on a regional basis should be explored.

Chapter 7 deals with the financing of fertilizer projects. It is usually possible to find capital for well conceived projects, although even here there are often serious difficulties. There is little local private capital available in developing countries; the main sources of private capital are foreign companies and private development corporations. Public financing may come from the national Government, which can provide funds for the site and construction of the plant or from foreign Governments, which can guarantee suppliers' credits or grant loans, usually in non-convertible currency. Assistance can also be obtained from international organizations like the International Bank for Reconstruction and Development (IBRD); IBRD has recently become interested in furthering fertilizer projects. If other sources fail, there is the possibility of assistance from the United States Agency for International Development (AID) or other agencies from countries with market-oriented economies as well as countries with centrally planned economies.

Chapter 8 discusses the issues presented at the International Symposium on Industrial Development, the discussion of the issues, and the recommendations approved. *Chapter 9* deals with assistance available to the fertilizer industry from the United Nations and from bilateral aid programmes.

Chapter 1

TRENDS IN THE WORLD FERTILIZER INDUSTRY

GENERAL REVIEW OF CONSUMPTION AND PRODUCTION TRENDS

Since 1905, the growth of world production and consumption of chemical fertilizers has been spectacular. World consumption increased from about 2 million tons in 1905 to 48 million tons in 1966/1967. Except for the war periods, 1914–1918 and 1940–1945, production and consumption have doubled or tripled in each decade, as shown in table 1.

A number of factors point to a continuing increase in the world use of fertilizers. In the next fifteen years there will be 1.5 billion more people in the world to feed. At the same time, living standards are rising in developed and developing countries alike, portending improved diets. Under these circumstances it is evident that all Governments give a higher priority to agriculture, requiring more intensive agriculture and greater use of fertilizer. Farmers will draw increasing profit from their investment in fertilizer, the cost of which will decline in relation to that

TABLE 1: TRENDS IN WORLD FERTILIZER CONSUMPTION
(million tons)

	Nitrogen (N)	*Phosphates (P_2O_5)*	*Potash (K_2O)*	*Total*
1905/1906	0.366	1.047	0.515	1.928
1913/1914	0.702	2.137	1.022	3.861
	Decline during First World War			
1919/1920	0.757	1.729	1.070	3.556
1938/1939	2.670	3.637	2.904	9.211
	Decline during Second World War			
1946/1947	2.568	4.368	2.677	9.613
1960/1961	10.200	9.845	8.465	28.510
1965/1966	17.390	14.525	12.120	44.035
1966/1967	19.820	15.500	12.940	48.260

of machinery, land and labour. At the same time it will be generally realized that man must stop taking more nutrients out of the soil than he is putting back into it if it is not to become completely depleted.

Changes in consumption pattern

The three main nutrients in chemical fertilizers are nitrogen (N), phosphorus (P_2O_5) and potash (K_2O). Their relative use has changed in recent years. Table 1 shows that nitrogen was the least used of the three in 1946/1947, whereas in 1966/1967 it was already forging far ahead of phosphorus and potash. This trend will probably continue. Before 1960, most fertilizers were solids of relatively low nutrient content, and some of the fertilizers were produced as by-products from other industries. Until the late 1950s ammonium sulphate was the principal nitrogen fertilizer, and normal (single) superphosphate, the principal phosphate fertilizer. They generally contained 20 per cent or less of plant food. Most products, with the exception of some of the nitrophosphates produced in Western Europe, were pulverized and of low nutrient content. Very little was shipped overseas.

Changes in production

The world picture has changed rapidly in the last five years, and even more rapid changes are expected in the next five years. Low-analysis materials are being replaced by higher-analysis materials. Ammonium sulphate and sodium nitrate are losing ground to ammonium nitrate and urea and, in some areas, to anhydrous ammonia and nitrogen solutions. Normal (single) superphosphate is being replaced partly by concentrated (triple) superphosphate and to a greater extent by high-analysis complex fertilizers of the nitrophosphate or ammonium phosphate type. Anhydrous ammonia has become the basic building block for nitrogen fertilizers, while wet-process phosphoric acid is becoming the major source of phosphate fertilizers. Little change has taken place in the processing of potash, and potassium chloride has remained the principal type of potash fertilizer. Table 2 gives projections of production and consumption of fertilizers for 1970/1971 and 1975/1976.

Table 2 shows clearly the higher growth rate in the developing as compared with the developed countries. Even in 1975/1976, however, production in the developing countries will still represent only 14 per cent of the total world production of nitrogen, 10 per cent of the world

TABLE 2: ESTIMATED PRODUCTION AND CONSUMPTION OF FERTILIZERS BY REGION, 1970/1971 AND 1975/1976

(thousand tons of nutrients)

	Developed areas	*Developing areas*	*World[a] total*
Projection for 1970/1971			
Production	63,300	5,800	69,100
Consumption	56,000	9,500	65,500
Surplus/(Deficit)	7,300	(3,700)	3,600
Projection for 1975/1976			
Production	88,500	10,700	99,200
Consumption	79,000	16,150	95,150
Surplus/(Deficit)	9,500	(5,450)	4,050

[a] Excluding China (mainland), North Korea and North Viet-Nam.

production of phosphate and 5 per cent of the world production of potash. In that year the developed countries will still be surplus producers of all three nutrients, while the developing areas will have larger deficits of all three than they have now.

These conclusions are based on a graphical analysis of past trends of production and consumption. There should be ample world capacity to produce the quantities of plant nutrients shown in table 2. The United

TABLE 3: ESTIMATED WORLD FERTILIZER CAPACITY COMPARED WITH PRODUCTION, 1970/1971

(thousand tons)

Fertilizer	*Production*	*Capacity[a]*
N	30,400	43,000
P_2O_5	20,700	28,000
K_2O	18,000	26,000
TOTAL	69,100	97,000

[a] Excluding China (mainland).

States Tennessee Valley Authority (TVA) in its report ***Estimated World Fertilizer Production Capacity as Related to Future Needs***[1] gives capacities for 1970 as shown in table 3. The estimates of capacity reported by TVA

[1] For full reference see annex 3 under "Other sources".

represent only a statement of intentions for 1970 by Governments and industrial firms, so that these capacities may or may not actually come into existence.

TABLE 4: 1975 TARGETS FOR FERTILIZER CONSUMPTION IN DEVELOPING COUNTRIES COMPARED WITH ACTUAL 1966/1967 CONSUMPTION

	Probable population, 1975 (millions)	*Fertilizer consumption (tons)*			
		Suggested minimum targets for 1975		*In 1966/1967*	
		N[a]	*P_2O_5*[b]	*N*	*P_2O_5*
India	609	6,090,000	3,045,000	830,200	274,600
Pakistan	138	1,380,000	690,000	170,000	30,500
Indonesia	134	1,340,000	670,000	110,000	5,500
Brazil	113	1,130,000	565,000	71,200	91,600
Nigeria	81	810,000	405,000	4,600	1,800
Mexico	58	580,000	290,000	320,000	97,100
Philippines	46	460,000	230,000	65,000	41,200
Turkey	42	420,000	210,000	95,900	90,700
Thailand	42	420,000	210,000	36,000	17,800
United Arab Republic	40	400,000	200,000	250,000	55,000
South Korea	36	360,000	180,000	239,700	124,800
Burma	31	310,000	155,000	6,000	1,000
Iran	30	300,000	150,000	30,000	15,000
Argentina	27	270,000	135,000	30,000	12,000
Ethiopia	26	260,000	130,000	n.a.[c]	n.a.
Colombia	24	240,000	120,000	45,000	51,800
South Africa	24	240,000	120,000	108,000	215,000
Republic of Viet-Nam	22	220,000	110,000	45,200	24,700
Afghanistan	20	200,000	100,000	n.a.	n.a.
Congo (Dem. Rep. of)	19	190,000	95,000	1,300	400
Morocco	19	190,000	95,000	25,300	19,900
Algeria	17	170,000	85,000	20,300	15,900
Sudan	17	170,000	85,000	40,000	700
Ceylon	16	160,000	80,000	45,000	1,000
Peru	16	160,000	80,000	80,000	16,000
Malaysia	15	150,000	75,000	43,500	6,500
China (Taiwan)	15	150,000	75,000	155,300	36,800
Venezuela	13	130,000	65,000	31,000	10,000
United Republic of Tanzania	13	130,000	65,000	5,000	1,300

[a] Calculated on basis of 10 kg *per capita*.
[b] Calculated on basis of 5 kg *per capita*.
[c] Not available.

Fertilizer targets for developing countries

It is important that developing countries set definite and increasing targets for fertilizer consumption, for it is demonstrable that higher fertilizer use results in higher production. A given quantity of fertilizer will yield, within limits, a certain amount of additional food or other agricultural product more or less independently of the area on which the fertilizer is used. From the standpoint of economic planning, *per capita* fertilizer consumption is therefore a very significant factor. The low *per capita* fertilizer consumption in Africa, Asia and Latin America, for example, is clearly correlated with the low nutritional levels and the low rate of agricultural and economic development in those areas.

It is therefore suggested that all developing countries should begin to plan now for the following *per capita* fertilizer consumption by 1975: 10 kilograms N, 5 kilograms P_2O_5, and 2.5 kilograms K_2O. These are, of course, very rough minimum targets, which would have to be modified considerably for individual countries depending on types of crops, rainfall, soil analysis etc. Table 4 shows the suggested targets for all the developing countries with a population of over 13 million in 1975, excluding China (mainland), North Korea and North Viet-Nam.

FACTORS THAT INHIBIT THE DEVELOPMENT OF A FERTILIZER INDUSTRY

An analysis of fertilizer use in developing countries indicates that 75 per cent of these countries fall into the category of very low consumers (0 to 5 kg *per capita*); 10 per cent into the category of low consumers (6 to 10 kg *per capita*); 10 per cent into the category of moderate consumers (11 to 25 kg *per capita*); and only 2 per cent into the category of high consumers (26 to 50 kg *per capita*). Seventy per cent of the developed countries fall into the categories of moderate or high consumers.

The conclusion may clearly be drawn 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 needed for both domestic consumption and export.

Since sufficient quantities and types of fertilizer are available on the world market, any developing country with sufficient foreign exchange can import fertilizers for its needs. In some instances fertilizers may be delivered to a developing country at a lower price than the price would be if the same fertilizer were produced within the country. However, even when this is the case, many of the developing countries decide to establish their own fertilizer industry to conserve foreign exchange or to be independent of foreign supplies.

There are many prerequisites for the successful establishment of a fertilizer industry in a developing country. The industry is capital-intensive: it requires a considerable amount of local capital for domestic expenditure as well as foreign exchange to import machinery and equipment. "Know-how" must be acquired. There must be a readily available source of adequate and inexpensive raw materials, sufficient utilities and adequate storage and distribution facilities. Personnel must be available to be trained as operatives and maintenance workers and for marketing and managerial positions. Finally, there must be an assured local market or assured markets for exports.

In developing countries the lack of suitable infrastructure is frequently at the root of delays in implementing large-scale industrial projects. For example, the Government whose policy encourages an increase in crop yields through the use of fertilizer may find at harvest time that crops cannot be moved fast enough to the market because of inadequate roads or freight-handling facilities. It has by now become axiomatic that it is not sufficient to import machinery and use up-to-date processes if the necessary supporting infrastructure is lacking.

If a country imports fertilizer in the initial phases of its development in order to build up an agricultural market, while it uses its capital resources to create an infrastructure until such time as the market and the infrastructure can support a fertilizer plant of economic size, a fertilizer project has a good chance of success. Investors can under certain conditions help in the development of essential transport and distribution facilities. In most instances, however, it may be in the best interest of the country as a whole for the Government itself to undertake this work.

Some developing countries with a large domestic consumption and others with abundant and cheap natural resources have planned sharp increases in fertilizer production. Their targets for 1970, 1975 and 1980 will be difficult to attain unless the factors that impede the development of the industry are identified and national and international action is taken to remove them in time.

Fiscal policy

Imports and import duties

Many developing countries have hampered the establishment of an indigenous fertilizer industry by levying heavy import duties (ranging as a rule from 10 to 30 per cent) on the cost, insurance and freight (c.i.f.) value of equipment imported for the industry, even when the equipment is financed by a loan. In effect, this means that the developing country is siphoning off part of the loan given for purchase of equipment into its internal revenues.

Some developing countries also impose import duties on spare parts or other supplies and raw materials for fertilizer production, thereby adding to the cost of production. These import duties are frequently levied even when there are no comparable spare parts, supplies or raw materials available within the developing country. When this occurs in the public sector, the cost of production goes up; when it happens in the private sector not only does the cost of production go up but the inducement for future investment is correspondingly reduced.

In fact, in some countries a paradoxical situation exists in which imported fertilizers and food grains are free of import duty, while the equipment and machinery imported to produce fertilizers and increase food grain production are subject to import duties.

Taxes and excise duties

Many developing countries are now adopting the policy of exempting certain important categories of plant and equipment in addition to materials and finished products from both customs and excise duties and sales and other taxes. In the past such levies created an atmosphere of uncertainty which was unfavourable to investment. For example, in a developing country with a large number of well established fertilizer plants a contract had been drawn up for naphtha to be delivered at a certain price from an oil refinery, and more than ten miles of pipeline had been laid to transport it. The production cost of fertilizers had been worked out on the basis of the delivered cost of the raw material. When the plant started production, the local state government imposed a 10 per cent sales tax on naphtha. Although this sales tax could be absorbed without difficulty, plans for expanding production based on the use of naphtha were subsequently dropped.

Finally, in many developing countries the tariffs for the industrial use of power, water and other utilities are unreasonably high. Concessions granted for the industrial use of utilities represent an added attraction for investors in developing countries. In one case, the price of electricity for a new fertilizer plant became subject to a surcharge, although the rate had been negotiated at the planning stage. Uncertainties about taxation and prices are bound to limit the expansion of the fertilizer industry, and will in the long run produce an unfavourable atmosphere for industrialization in general.

INCENTIVES FOR FOREIGN INVESTORS

Experience indicates that lack of capital—foreign capital in particular, but also domestic capital—is the basic factor limiting the establishment and expansion of the fertilizer industry in developing countries. This problem is further discussed in chapter 7.

Developed countries cannot be expected to put their resources into projects in regions lacking a favourable investment climate. Returns on investment should whenever possible be at least equal to that available in the developed countries It is also of primary importance that the producer be allowed to exercise a high degree of control for some time over the marketing of the products. While the risk factor is present in any investment, every attempt should be made to keep it to a minimum.

The developed countries have demonstrated that they are willing to undertake assistance programmes. The developing countries should do everything possible to encourage them to do so. Many Governments understand that their policies must be clearly geared to assisting industry if fertilizer projects are to be quickly carried out either in the public or private sector or when the Government is executing a project in collaboration with private firms. A difficulty with joint sponsorship is that the Government sometimes takes too long to issue necessary permits or letters of intent, or to decide on its share of participation or its managerial or marketing responsibilities.

When foreign investors from countries with a market economy are involved, a realistic attitude must be taken towards the repatriation of profits to repay the investment; when a favourable climate for investment exists, however, outside investors are as a rule willing to use much of their profits to expand their plants. It is therefore in the interest of developing countries to make their policies relating to foreign private investment as attractive as possible.

Until such time as trained and experienced personnel can be recruited, local and foreign investors will expect firm assurance that they will have some control over the staffing of a new plant in order to ensure successful operation. In this connexion, it may be noted that many developing countries have issued regulations that interfere unduly with management and thus with the scope of operations. Private investors in developed countries are usually unwilling to participate in loans to developing countries that have a reputation for interference.

In bilateral and multilateral assistance projects, particularly those with capital participation, the investment is guaranteed by the recipient Government. Of course, the greatest assurance is the policy pursued by the Government and its past performance. Mutual understanding and adjustments are necessary to make capital participation successful.

CREDIT, PRICING AND SALES

In many developing countries, one of the major factors retarding the growth of fertilizer consumption is that credit facilities for the farmers are inadequate and that it takes too long to obtain credit. This is not so much because the authorities concerned fail to appreciate the problem but rather because the problem is complex and funds are scarce. The resources of the fertilizer producers and traders themselves are inadequate. For financial and administrative reasons, the commercial, private and state banks barely touch the problem.

As a rule the fertilizer industry is willing to co-operate by extending credit to farmers, but at the same time it looks to the Government to put into operation a realistic policy whereby credit is made available at a reasonable rate of interest and in a manner that suits the agricultural cycle.

As with any commodity, there must be an incentive to sell fertilizers. Restrictions on profits may reduce the incentive of the dealer to try to sell more.

If the farmer must travel a long distance to obtain his fertilizer, he may decide it is not worth the effort. Depots and warehouses must be established so that the farmer is never more than a few hours' travelling distance from the nearest supply point.

In many developing countries, mainly as a result of government effort, progress has been made through co-operatives and other institutions. Credit facilities in some countries are also extended to the farmers through certain government departments.

Sales promotion and pricing

Experience in countries using large amounts of fertilizer has shown that the services offered by the sellers of fertilizer are often as important as the price of fertilizer in increasing sales.

An integrated sales promotion programme that includes distribution, sales, servicing and consumer education must be evolved. Besides guaranteeing fair prices, credit facilities must be extended in certain cases to dealers who can in turn pass on the credit to the farmers. Free technical service, which includes soil analysis, prescribing doses of fertilizers to be applied and advice on farm management problems relating to seed, pesticides, drainage, irrigation etc., should also be provided to the farmer.

Fertilizers must be treated as a capital input in the agricultural economy. The prices paid for fertilizer and those obtained for farm produce must have a relationship to each other which allows the farmer to make an increasing profit as he uses increasing amounts of fertilizer. up to the point of diminishing returns. In some developing countries, this can only be ensured when the Government sets the prices both for fertilizer and for farm produce.

In some 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 giving the farmer a bonus 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 certain price for his produce regardless of the market price. On the other hand, countries like Australia and the United Kingdom provide price subsidies on certain classes of fertilizers that meet government specifications. Apparently, price support at some stage is necessary if farmers are to be stimulated to increase their productivity.

NITROGEN FERTILIZERS

GENERAL REVIEW OF CONSUMPTION AND PRODUCTION

Before 1954, nitrogen was the least used of the three plant nutrients, but since then its use has increased very rapidly. The production of nitrogen is not only the fastest growing but also the most rapidly changing sector of the fertilizer industry.

Unlike the phosphate and potash fertilizer industries, where there are relatively few products produced, the nitrogen industry is characterized by a wide range of products varying in their content of nitrogen from 11 per cent in the case of monoammonium phosphate to 82 per cent for the increasingly used modern synthetic, anhydrous ammonia. Before the Second World War, most nitrogen fertilizers were natural products, such as Chilean nitrate (sodium nitrate with a 16 per cent nitrogen content) and coke-oven ammonia. Since then the switch to the production of synthetic ammonia has been so marked that by 1964 synthetic ammonia accounted for nearly 94 per cent of the world ammonia market. Among the nitrogen fertilizers most widely used at present are ammonium nitrate (35 per cent nitrogen content), anhydrous ammonia, and urea (46 per cent nitrogen content). It will be noted that these are all high-analysis nutrients.

World production of nitrogen totalled 6.37 million tons in 1955. By 1965, this had almost tripled to 16.63 million tons—an annual compound growth rate of over 10 per cent.

In 1955, Western Europe and North America were the only major areas producing nitrogen fertilizers. Since that time, Eastern Europe has increased production until it now accounts for 20 per cent of world production. These three developed areas contributed 84 per cent of the world production of nitrogen in 1965.

World production of nitrogen fertilizers is expected to reach 30.4 million tons by 1970/1971, and 46.6 million tons by 1975/1976. Of these world totals, the developing countries are expected to account for 3.4 and 6.6 million tons, respectively (compared with some 1.5 million tons in 1965). Production is thus expected to grow at a faster rate in the developing than in the developed countries, but the output of the developing countries would still represent less than 15 per cent of world production in 1975/1976.

FEEDSTOCKS FOR NITROGEN FERTILIZERS

Ammonia is produced by combining under high pressure and temperature 3 volumes of hydrogen with 1 volume of nitrogen, by the use of a catalyst. Nitrogen is obtained from the air. The early technology of ammonia production employed only refinery or coke-oven gas to supply hydrogen. With present-day technology, however, almost any economical supply of hydrogen, as from electrolysis of water or from solid, liquid or gaseous hydrocarbons, can be used for ammonia production.

Natural gas has become an important source of hydrogen for ammonia production, and many areas, both developed and developing, have large supplies of this feedstock. In some cases, but not all, natural gas is associated with crude oil production. Coal once was an important source of hydrogen in developed countries, but it has been largely superseded by natural gas where adequate supplies exist.

Countries with oil refineries can use by-product tail gas or naphtha for ammonia production. Those with no suitable local feedstock can import naphtha or liquefied natural gas. Thus in the future raw materials for nitrogen fertilizer production should not limit the location of plants or their anticipated production levels.

Since most nitrogen fertilizers are based on anhydrous ammonia made from natural gas or liquid hydrocarbons, raw material availability, on the basis of current ammonia technology, must be examined in terms of those feedstocks, since it may be assumed that ample atmospheric nitrogen will always be available.

Based on the total world agricultural and industrial needs for ammonia, the annual nitrogen requirements will be about 125 million tons by 1985. On the assumption that half of this amount is made from natural gas and half from liquid hydrocarbons, this total corresponds to about 2 per cent of the present known natural gas reserves and a negligible proportion of proved world petroleum reserves. Thus no raw material shortage for nitrogen fertilizers is foreseen, even without taking into consideration the enormous reserves of coal, lignite and oil shale.

Effect of type and price of feedstock on the cost of ammonia

The choice of raw materials for nitrogen production depends upon price and availability. In many developing countries, raw materials like naphtha and fuel oil are available at reasonable prices from refineries because they are not in great demand owing to the scarcity of motor vehicles and the low level of industrialization. In developed countries, the situation is just the reverse. Naphtha is much in demand because it is a valuable raw material for petrochemical production.

The type of feedstock affects both the plant cost and the production cost of ammonia (because solids or heavy fuels require more complex gasification and purification equipment). The effect on production cost is shown in table 5. The composite data are for plants employing electric-driven prime movers with capacities of 365 tons per day and for a power cost of 7 mills ($0.007) per kWh.

These figures are intended to show comparative costs only. Actual costs depend on investment costs, plant location, accounting procedures, taxes and various other local factors.

TABLE 5: EFFECT OF FEEDSTOCK TYPE AND PRICE ON THE COST OF AMMONIA

Type of feedstock	*Production price of feedstock per million Btu, higher heat value*				
	0.10	*0.20*	*0.30*	*0.40*	*0.50*
	Ammonia cost per ton ($)				
Reformer hydrogen	22.0	24.2	26.7	29.7	32.5
Natural gas	25.8	29.7	34.1	38.5	42.3
Naphtha	28.6	33.0	37.5	41.7	43.2
Heavy oil	33.0	37.4	41.7	47.3	51.7
Coal	38.5	44.0	49.5	55.0	60.0

TREND TOWARDS LARGE-SCALE AMMONIA PRODUCTION UNITS

As regards nitrogen fertilizers, the most important advances have been made in the production of ammonia, though there have also been important process improvements in the production of nitric acid and urea. The "new technology" for the production of ammonia is one of the most striking technological changes in recent years. It is the culmination of a series of developments from the hydrocarbon feedstock to ammonia synthesis. The essence of the new technology is the concept of large capacity, single-stream plants equipped with centrifugal compressors.

During the period 1967—1970, 35 new large ammonia plants will be built in the United States, 22 in Western Europe, 9 in Southeast Asia and 6 in Latin America. "Large" plants are defined as single-stream plants producing 600 short tons[2] a day or more of ammonia.

The trend towards construction of such large units is largely confined to organizations and companies in the industrialized part of the world that have had experience either with smaller ammonia plants or with large petrochemical plants and have abundant capital resources at their disposal. The necessary infrastructure and services also exist in industrialized countries.

For the operation of such large single-stream plants, both the operating and the maintenance departments must have at least a hard core of able and well trained men. A well manned repair shop is essential for maintenance work and repairs during scheduled shutdowns, as well as very detailed sets of instructions and checks for the operation and the control of the plant. Experience in the operation and maintenance of the critical and most susceptible parts of the equipment is vital.

Several years of experience in constructing and operating a small plant will make it easier to construct, operate and maintain a single-stream ammonia plant producing 600 to 1,500 tons per day. But specialized knowledge of water-purification systems, reforming furnaces, heat exchangers and centrifugal compressors will also be necessary. Because of the know-how required, the construction and operation of large-scale ammonia plants in developing countries will present problems that should be taken into account during the planning stage.

Effect of plant size on ammonia cost

The capital cost of large plants that produce between 600 and 1,500 tons daily using centrifugal compressors is nearly 50 per cent less than it would be for plants of the same size using the old technology. Capital cost reduction of this magnitude is very rare in industry, and all producers of ammonia have begun to consider building the new large plants.

The relative ammonia production costs using reciprocating compressors or steam-turbine-driven compressors under United States

[2] One short ton equals 2,000 lb.

TABLE 6: AMMONIA PRODUCTION COSTS ACCORDING TO SIZE OF PLANT

Plant capacity (short tons/day)[a]	*200*	*300*	*400*	*600*	*1,000*	*1,500*
Compressors and drives	*Reciprocating—compressor*			*Centrifugal steam-turbine-driven compressor*		
Investment ($ per short ton)	*4,300,000*	*5,500,000*	*6,500,000*	*8,500,000*	*12,300,000*	*15,750,000*
	Production cost in dollars per short ton of ammonia					
Cost of raw materials and utilities						
Natural gas ($0.20 per million Btu)	6.00	6.00	6.00	6.46	6.40	6.30
Power ($0.007 per kWh)	4.37	4.37	4.37	0.21	0.21	0.21
Boiler feedwater make-up ($0.25 per 1,000 gallons)	0.14	0.14	0.14	0.14	0.14	0.14
Circulating cooling water ($0.02 per 1,000 gallons)	1.00	1.00	1.00	1.00	1.00	1.00
TOTAL	11.51	11.51	11.51	7.81	7.75	7.65
Other costs						
Catalyst and chemicals	0.40	0.40	0.40	0.40	0.40	0.40
Operating labour (4 men and 1 supervisor—$3/h)	1.80	1.20	0.80	0.60	0.36	0.24
Plant overhead (100% of operating labour)	1.80	1.20	0.80	0.60	0.36	0.24
Maintenance (3% of capital investment)	1.84	1.57	1.37	1.22	1.05	0.90
Taxes and insurance (2% of capital investment)	1.23	1.05	0.91	0.81	0.70	0.60
Interest (5% on capital investment)	3.07	2.62	2.28	2.02	1.76	1.50
Amortization (10% of capital investment)	6.15	5.24	4.57	4.05	3.52	3.00
TOTAL PRODUCTION COST	27.80	24.79	22.64	17.51	15.90	14.53

[a] One short ton equals 2,000 lb.

conditions based on natural gas at $0.20 per million Btu would be approximately as given in table 6.

Many large ammonia plants employing centrifugal compressors are in operation now, and most of them are designed for use of natural gas as the feedstock. When the new plants are in full operation and all modifications have been completed, the actual capital and operating costs will probably differ somewhat from the estimated data given in table 6. Therefore, direct comparison between tables 5 and 6 cannot be made. The comparative data in each table will, however, provide useful guidelines when ammonia projects are under construction.

Capital and financing charges are generally on the increase. The installation costs vary appreciably from country to country so that to cite investment costs for any given plant may be misleading. Estimates should be obtained from experienced contractors.

Costs of production can be considerably reduced by increasing plant capacity and finding low-cost feedstocks. For example, the cost of manufacturing ammonium nitrate can be cut by a third if plant capacity is increased from 200 to 1,000 tons per day. Similarly, assuming that other costs remain constant, the cost of manufacturing will be doubled if the price of ammonia increases from $20 to $80 per ton. Plant sizes have increased several fold in recent years, and the installation of big plants in places such as Alaska, Algeria, the Caribbean, Iran and Saudi Arabia is evidence of the locational pull towards economically priced feedstocks and ammonia. It is also clear that the reduction in the costs of production becomes progressively smaller as plants get larger; hence, there are economic limits beyond which the slight additional cost savings may be outweighed by risks and other factors.

Shipment of ammonia

In the past few years, United States producers have gained much experience in shipping anhydrous ammonia in refrigerated barges and ocean-going vessels. Bulk ammonia is now being transported from the Caribbean to distant points in Canada, Finland, Great Britain and the United States. In some cases, such shipments have replaced obsolete plants or are taking the place of projected installations in the recipient countries. The special-purpose tankers can also carry other cargoes such as liquefied petroleum gas (LPG) or various petrochemicals. More ships of this type are being built.

The availability of such transport creates new opportunities for many developing countries. For example, those with natural gas and other low-cost feedstock sources within access of the coast may be in a position to produce and sell liquid ammonia. At the same time, developing countries with no low-cost feedstock sources and/or with insufficient markets to support a large, economically sized ammonia plant can purchase low-cost ammonia transported by refrigerated tankers. This arrangement also helps to build up regional and interregional trade between developing areas.

Although each case must be evaluated separately, an example is quoted where ammonia produced from a large unit at $21 per ton could be shipped 5,000 miles for about $16 per ton (based on $10 freight costs and $6 terminal charges), bringing the total cost to $37 per ton. Comparable production costs from a smaller naphtha-based plant would be about $46 per ton, which makes the imported ammonia distinctly cheaper. In addition, the capital saved by not building the smaller ammonia plant could be used to benefit the developing countries in other ways. An end-product plant employing indigenous expertise may be built using imported ammonia and phosphoric acid, and later primary ammonia and phosphoric acid facilities may be added.

Chapter 4

PHOSPHATE FERTILIZERS

Production of raw materials

Phosphate rock

Phosphate rock is the essential raw material for the manufacture of phosphate fertilizers. It occurs in either igneous or sedimentary deposits in many parts of the world, but it is commercially exploited in relatively few. The composition, structure and accessibility of the deposits vary considerably. Many deposits are unsuitable for commercial exploitation.

For most fertilizer processes, which are based on acidulation, the ore must have a very low content of common impurities, particularly iron and aluminium. The physical structure of the ore affects the cost of grinding, the ease with which it flows through process equipment and the rate of the chemical reaction. Even the richest phosphate rock contains no more than 15 per cent phosphorus; thus, the economics of transport are often a decisive factor in determining commercial possibilities. Generally speaking, although very low-grade deposits are exploited by certain countries for internal use, the growing use throughout the world of more highly concentrated fertilizers means that the higher grades are increasingly required. It is possible to "beneficiate" the crude ore by means of flotation and calcination, but the cost of such upgrading must then be taken into account.

Output of phosphate rock in 1966/1967 reached a new peak of 60.6 million tons, 11 per cent higher than in the previous year. World supplies of phosphate rock continue to be in excess of demand. Production has started at El-Hasa (Jordan), while deposits in Australia, Peru and the Spanish Sahara are not expected to contribute to world supply until after 1970. There will be no shortage of this raw material in the world in the near future.

In fact, indicated reserves exceed 46,000 million tons—enough to last over 400 years at the 1971 rate of use. Of this total, over half (24,000 million tons) is in Africa; 13,500 million tons are in North

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America and 7,500 million tons in Eastern Europe. Deposits in other areas are small.

There is extensive world trade in phosphate rock, since many countries have no known usable deposits. Nearly half of the phosphate rock produced enters into world trade, with Europe (excluding the USSR) being the largest market. European imports totalled about 16 million tons in 1965. Australia, India and Japan are the largest importers outside Europe.

Although the industrial uses of phosphorus are increasing and its importance in agricultural crop production and human nutrition is well known, there is a tendency in many developing countries to reduce the use of phosphorus (P_2O_5) relative to nitrogen. This may be harmless in soils rich in phosphorus, but in others the continued use of nitrogen without P_2O_5 will soon exhaust the supply of phosphorus in the soil and disastrous crop failures may ensue. The world consumption of nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O) in 1966 was in the ratio of 1 to 0.8 to 0.7.

Production capacity

The estimated capacity of the world phosphate industry is expected to increase to 33.5 million tons in 1971. This figure includes an assumed USSR capacity of 3.6 million tons of P_2O_5 and an arbitrary allowance for China (mainland). It does not include phosphate rock used directly on the soil after being finely ground but without being chemically processed.

In 1965, 5.8 million tons of ground phosphate rock were used, which is the equivalent of about 1.8 million tons of P_2O_5. FAO figures for P_2O_5 consumption showed an average annual increase of 6.6 per cent over the period 1964—1967, with consumption reaching 15.5 million tons by 1967. It is estimated that consumption will rise in the developed countries to 17.5 million tons in 1971 and to 23 million in 1976. Corresponding figures for the developing countries will be 2.8 tons in 1971 and 4.6 million tons in 1976.

Actual world production in 1965 and 1967 and estimated capacity in 1971 are shown in table 7.

The growth rate of the world phosphate fertilizer industry in recent years has been about 12 per cent per year. As with the nitrogen fertilizers, the estimates show that the developed countries will have a greater production capacity than they need to cover their consumption. The developing countries, however, will have a deficit even though their production capacity is rising steadily.

TABLE 7: PHOSPHATE PRODUCTION IN 1965 AND 1967 AND ESTIMATED CAPACITY IN 1971

(million tons of P_2O_5)

Region	*Actual production*		*Estimated capacity for fertilizer and industrial uses*
	1965[a]	*1967*	*1971*
Africa	0.30	0.55	1.71
Asia[b]	1.02	1.29	3.61
Europe			
Eastern[c]	2.81	3.17	5.94
Western	4.34	4.9	7.72
Latin America	0.18	0.21	2.31
North America	4.02	5.14	10.29
Oceania	1.13	1.28	1.91
TOTAL	13.80	16.54	33.49
Possible fertilizer production capacity < 0.90 × 0.85[d]			25.62

[a] Fertilizer year ended 30 June 1965.
[b] Including an allowance for China (mainland).
[c] Including the USSR.
[d] Assuming 90 per cent production and 85 per cent of phosphate used for fertilizer.
SOURCE: United States Tennessee Valley Authority survey 1965.

Sulphur

Sulphur, while not considered a primary plant nutrient, is closely associated with fertilizer production in that sulphuric acid acidulation of phosphate rock forms the basis of today's phosphate industry. The recent rapid expansion in the phosphate industry caused an equally rapid rise in the demand for sulphur. As a result, sulphur prices rose and supplies were short in many areas of the world. This touched off a world-wide expansion of sulphur production and large-scale exploration for new supplies, leading to some sources that could not have been developed economically at the lower price levels. In fact, estimates show that, although consumption outstripped production in 1967, production should again exceed consumption by 1971.

Elemental sulphur production using the Frasch method and recovery from sour gases is located primarily in North America and Europe, and the major expansion of sulphur capacity will occur in these regions. Substantial increases in recovered sulphur are expected in Asia as the countries of the Near East develop their sour gas sources. Little expansion in the production of other forms of sulphur appears likely except in North America.

The alternative sources for elemental (Frasch) sulphur are pyrites and gypsum. During the last few years, owing to the shortage and high price of elemental sulphur, developing countries have been exploring alternative sources and investigating fertilizer production processes that reduce the use of sulphur, such as the nitric acid process discussed earlier.

Economic pressure will favour increased use of pyrites and other forms of sulphur and of fertilizer processes that do not require sulphur.

Phosphate fertilizer consumption

Major phosphate fertilizers include normal (single) superphosphate (16 to 20 per cent P_2O_5), basic slag (16 per cent P_2O_5), and concentrated (triple) superphosphate (32 to 46 per cent P_2O_5). The other major sources of P_2O_5 are complex fertilizers containing various amounts of nitrogen and phosphate, and, in many cases, potash. These products include ammonium phosphates (64 per cent P_2O_5) and other materials made by ammoniating phosphoric acid, and nitrophosphates (40 per cent P_2O_5), which is produced by acidulating phosphate rock with nitric acid.

Normal (single) superphosphate

In North America and Western Europe, the production of normal superphosphate has not increased since 1960. In 1965, world production of normal superphosphate actually decreased. North America and Western Europe have excess capacity to produce this material. However, many of the plants are over ten years old, and some have been converted to produce complex fertilizers. Higher analysis products are replacing normal superphosphate, which is expected to have only 30 per cent of the market by 1971.

As the trend towards higher analysis materials continues, normal superphosphate will continue to lose ground, perhaps even faster than indicated by the estimates of capacity in 1971 shown in table 8.

Basic slag

Basic slag is a by-product of steel production, and thus its production growth rate is determined by the growth of the parent industry. It is a major phosphate fertilizer in Europe, but little is produced in other regions. Basic slag was second only to normal superphosphate as a phosphate fertilizer as recently as 1955. Its production has increased very slowly, however, and its share of the market decreases each year. By 1971, basic slag should account for only 6 per cent of all phosphates.

Concentrated superphosphate

The future growth of concentrated superphosphate is uncertain. Although it is the most concentrated straight phosphate produced commercially, it is equalled in phosphate content by some of the ammonium phosphates. This tends to put concentrated superphosphate at some disadvantage as regards transportation and handling costs, since ammonium phosphates also contain nitrogen.

A small expansion in concentrated superphosphate capacity is expected in North America and Western Europe. Africa, Asia, Eastern Europe and Latin America are scheduling relatively large increases in capacity. Since both concentrated superphosphate and ammonium phosphates are based on phosphoric acid and conversion of plant facilities from concentrated superphosphate to diammonium phosphate is in some cases technically and economically feasible, it is expected that some concentrated superphosphate capacity will be converted to the production of complex fertilizers of the ammonium phosphate type.

Complex fertilizers

The major change in the phosphate industry in the last ten years has been the shift from acidulation of phosphate rock with sulphuric acid to the production of phosphoric acid from sulphuric acid and phosphate rock and the use of this product as the major building block for concentrated phosphate fertilizers. As the demand for higher-analysis materials increases, the use of phosphoric acid and the finished fertilizer materials that can be produced from it will increase in importance.

The phosphate fertilizer industry is expected to change rapidly in the next ten years. Complex fertilizers based on phosphoric acid will probably continue to replace the lower-analysis products, perhaps at a more rapid rate than indicated by the estimates of future capacity.

Higher-analysis products

There is a strong trend in the world towards high-analysis phosphate fertilizers. The developing countries, should, whenever possible, adopt this trend because it reduces the bagging, transport and storage costs per unit of P_2O_5. In 1955, the lower-analysis materials, normal (single) superphosphates and basic slag, represented about 81 per cent of the world's phosphate fertilizers. By 1965, these products constituted only 58 per cent of the total. Between 1955 and 1965, the increase in normal superphosphate production was approximately 20 per cent, whereas production of concentrated superphosphate nearly doubled and production of complex, or multinutrient, fertilizers (mainly ammonium phosphate and nitrophosphate) quadrupled. Table 8 shows the estimated distribution in 1971 of phosphate fertilizer capacity among major types of products.

The most popular of the concentrated fertilizers are concentrated superphosphate and ammonium phosphate. Both are mainly manufactured from wet-process phosphoric acid, which in turn requires sulphur.

TABLE 8: WORLD[a] CAPACITY FOR PRODUCTION OF MAJOR TYPES OF PHOSPHATE FERTILIZER

as per cent of estimated 1971 total world production of all phosphate fertilizers

Fertilizers	*Percentage of world P_2O_5 capacity*
Normal superphosphate	30.2
Concentrated superphosphate	18.9
Complex fertilizers[b]	30.0
Basic slag	5.7
Other and unspecified phosphate fertilizers[c]	15.2
TOTAL ESTIMATED 1971 PRODUCTION, ALL TYPES	100.0

[a] Excluding USSR and China (mainland).
[b] Includes ammonium phosphate, 20 per cent; nitrophosphates, 6 per cent; and unspecified types of complex fertilizers, 4 per cent.
[c] Includes phosphoric acid, for which no specific outlet has been determined.

Increased use of multinutrient fertilizers

Farmers in developed countries increasingly tend to use phosphate in the form of multinutrient fertilizers rather than as a single nutrient. In developing countries, the farmer has to be educated to this approach. Some developing countries prescribe certain mixtures containing different N, P and K combinations, taking into account the analysis of soil and type of crops to be grown. Mixtures were formerly made using straight fertilizers, such as superphosphate, ammonium sulphate and potassium chloride. Often these ingredients were manufactured by different companies and dispatched to a mixing plant where they were mixed and sometimes granulated. Such mixing and granulation entail additional expense. The modern practice is to manufacture mixed fertilizers in integrated plants. As a result mixed fertilizers are not necessarily more expensive than straight fertilizers and may even be cheaper. Developing countries should adopt the integrated approach so that the farmer receives in a single bag all the nutrients needed for the particular crop under particular soil conditions. This also saves the farmer time and labour.

MANUFACTURING PROCESSES FOR PHOSPHATE FERTILIZERS

Trend towards large-scale production units

There is a general trend in the phosphate fertilizer industry towards large-scale production units, which has resulted in a substantial reduction in cost per unit of output. Whereas ten years ago a wet-process phosphoric acid plant producing 200 tons of P_2O_5 per day was regarded as a large plant, present plants are in operation capable of producing 600 tons per day in a single train of reactors, filter and evaporator. Nitrophosphate plants capable of producing 1,500 tons per day are today part of a complex producing ammonia, nitric acid and straight nitrogen fertilizers. Electric-furnace phosphorus units of 50,000 kW capacity can produce 75 tons of phosphorus per day, which is equivalent to 175 tons of P_2O_5.

Developing countries with large internal consumption should take advantage of the economies of scale in production. Where internal consumption is small, several countries in a region could co-operate to achieve these economies. Increasing the scale of operation, however, should always be weighed against the cost of distribution of the product over wider market areas. There are also advantages in locating production facilities at the phosphate mine, since high-analysis phosphate fertilizers weigh less than the rock from which they are made.

Manufacture of phosphoric acid

There are two basic methods in commercial use for the production of phosphoric acid—the wet process, usually using sulphuric acid, and the electro-thermal process. It is estimated that the world capacity for production of wet-process phosphoric acid (54 per cent P_2O_5) will increase from 5.4 million tons P_2O_5 in 1965 to 14.7 million tons P_2O_5

in 1971. Thermal-process capacity is expected to increase also. Because of the higher purity of thermal acid, it is used extensively in the production of phosphates for detergents and other high-value products. Thus only 19 per cent of the thermal acid produced in the United States was used for fertilizers, as compared with 93 per cent of the wet-process acid. Much of the wet process acid is used for the manufacture of triple superphosphate and ammonium phosphate. However, in recent years wet-process phosphoric acid has become a more marketable commodity because the quality of the acid has been improved so that its handling and transport are less difficult.

The hydrochloric acid process for making phosphoric acid is attracting attention, and small plants based on this process have been built where hydrochloric acid is in surplus. Hydrochloric acid is used instead of sulphuric acid to dissolve the phosphate rock, and the phosphoric acid formed is separated from the calcium chloride by using an organic solvent, preferably normal butanol or isoamyl alcohol. The solvent is separated from the acid and recycled to the process. This process was developed by the Israel Mining Industries. A similar process was developed by the Dow Chemical Company, using tributyl phosphate as the solvent. Whether this process is economic depends on the cost of hydrochloric acid. In the United States it is obviously uneconomic because hydrochloric acid costs around \$70 per ton, and nearly 2 tons of chlorine are required to make a ton of P_2O_5. But where cheap by-product hydrochloric acid is available, the process has advantages.

In view of the high cost of sulphur and the world shortage, the production of thermal acid in places where low-cost electricity is available has become important. Tables 9 and 10 show capital costs and production costs of thermal-process and wet-process phosphoric acid at a hypothetical plant in Florida. Similar cost data would apply to plants in Morocco, the United Arab Republic or other areas having phosphate rock and low-cost electric power.

The capacity of the plants is assumed to be 544 tons of P_2O_5 per day, or about 185,000 per year. The wet-process plant consists of facilities for receiving and storing molten sulphur, producing sulphuric acid, producing phosphoric acid in a single train extraction-filtration unit, and concentrating the acid to 54 per cent P_2O_5. Supporting facilities include rock grinding, gypsum disposal, plant utility systems, maintenance shop, laboratory, office and auxiliary facilities. No facilities are provided for clarifying the acid, which would be needed if the acid were to be transported.

The thermal plant consists of three 45,000 kW furnaces together with charge preparation equipment and auxiliary facilities comparable with those in the wet-process plant. It is assumed that all of the phosphorus will be converted to phosphoric acid at the plant, although it is more likely that the elemental phosphorus would be shipped to market areas for conversion to fertilizers. Three phosphoric acid units capable of

TABLE 9: CAPITAL COSTS OF PLANT PRODUCING 185,000 TONS OF P_2O_5 PER YEAR
(thousand dollars)

	Thermal-process acid plant	*Wet-process acid plant*
Battery-limits plant	22,260	9,429
Other equipment and site	4,343	3,100
Engineering	5,320	2,506
Contractor's fee and overhead	3,192	1,504
TOTAL	35,115	16,539

TABLE 10: ESTIMATED PRODUCTION COSTS AT PLANT PRODUCING 185,000 TONS OF P_2O_5 PER YEAR
(dollars per ton of P_2O_5)

	Wet-process acid plant	*Thermal-process acid plant*
Sulphur	37.04	
Phosphate rock[a]	21.69	
Phosphate matrix[b]		13.64
Coke	—	2.88
Electricity	—	11.02
Other items	2.17	17.63
Salaries and wages	4.50	6.75
Maintenance	4.02	6.20
Depreciation over 15 years	5.37	7.96
	5.96	12.60
TOTAL DIRECT COSTS	80.75	78.68
Overhead	4.96	7.17
Taxes and insurance	1.79	3.79
Credit for sale of by-products	—	—5.51
GRAND TOTAL	87.50	84.13

[a] Dry, uncalcined, 31.4 per cent P_2O_5 rock.
[b] Undried phosphate matrix, 24 per cent of P_2O_5 serves as a source of silica.

producing acid of any desired strength, including superphosphoric acid containing up to 80 per cent P_2O_5, are included in the estimate.

It will be seen from table 10 that the estimated costs for phosphoric acid from the two processes are about the same—\$84.13 per ton of P_2O_5 by the thermal process and \$87.50 per ton by the wet process, using a cost of \$42 per ton of sulphur delivered.

Ammonium polyphosphate

Reaction of ammonia with superphosphoric acid yields a mixture of ammonium ortho-phosphate and pyro-phosphate, which is commonly called ammonium polyphosphate. Triammonium pyro-phosphate, $[(NH_4)_3HP_2O_7]$ is the principal polyphosphate, although other pyro-phosphates and tripolyphosphates are likely to be present.

The only known large-scale production of solid ammonium polyphosphate is in the plant operated by the United States Tennessee Valley Authority. The grade of the TVA product is 15—60—0. It is made by reaction of thermal superphosphoric acid with anhydrous ammonia under high pressure and temperature (3 atm and 210 °C). The product is discharged from the reactor as a fluid melt and is granulated in a pugmill. Since no moisture is present, drying is unnecessary. The pugmill product is cooled and screened; the oversize is crushed, and fines are recycled.

Ammonium polyphosphate of 12—60—0 grade has been made experimentally from wet-process phosphoric acid. As in the case of ammonium ortho-phosphates, the polyphosphate may be combined with urea, ammonium nitrate, or ammonium sulphate, and potash salts may be added to make a variety of multinutrient fertilizers.

Ammonium polyphosphate solutions are produced by several firms in the United States and Europe by ammoniation of superphosphoric acid and concurrent addition of water. The solutions are used in the preparation of liquid mixed fertilizers.

Nitrophosphate

If phosphate rock is acidulated with nitric acid, the product will contain calcium nitrate and monocalcium and dicalcium phosphates. The hygroscopicity of calcium nitrate precludes general acceptance of this product. Nitric acid serves two purposes: it makes the phosphate soluble and it provides nitrogen as a plant nutrient. In the Odda process, the calcium nitrate is removed by filtration. The calcium nitrate may be used as such or converted to ammonium nitrate. Other variants of this process are attracting considerable attention because they do not require sulphur. Processes using sulphuric acid or phosphoric acid in conjunction with nitric acid and those using ammonium sulphate or carbon dioxide addition have also become attractive. The relative costs of the two nitrophosphate processes—the Odda process and the phosphonitric process—and of the two processes based on ammonium phosphate were compared by making estimates of the production costs in hypothetical plants situated in southeastern United States near Memphis, Tennessee.

The cost study compared the estimated wholesale price (production costs plus return on investment and sales expense) of the following granular fertilizers containing nitrogen and P_2O_5 in 1 : 1 ratio:

(*a*) Odda Smeltwerke process—nitrophosphate;
(*b*) Mixed acid nitrophosphate with nitric and phosphoric acid;
(*c*) Ammonium phosphate nitrate;
(*d*) Urea ammonium phosphate.

The study shows that the wholesale price of the Odda product is the lowest. It gives nitrophosphate at $114 per ton, as compared with $128 per ton for urea ammonium sulphate, $133 per ton for nitrosulphate by the phosphonitric process, and $135 per ton for ammonium phosphate nitrate. The economic advantage of the Odda process is due mainly to the savings in the cost of raw materials and intermediates. Unlike the other processes, the Odda process does not require sulphur but the disposal of the resulting calcium nitrate presents difficulties. Several new processes have been developed recently to make higher percentages of water-soluble P_2O_5 by the nitric acid acidulation of phosphate rock such as the chemo-project—Kallinbach, Norsk Hydro and Dutch State Mines.

COSTS OF TRANSPORTING PHOSPHORUS

A major advantage of the thermal process is the high concentration of the intermediate product, elemental phosphorus. Phosphorus is readily transported in mild steel tank cars, and shipment by river barges or seagoing vessels is feasible. A consignment of 1 ton of elemental phosphorus would supply the same amount of P_2O_5 as about 7.5 tons of phosphate rock plus 2.2 tons of sulphur for use in the wet process.

One ton of elemental phosphorus is equivalent to the phosphorus content of 5 tons of triple superphosphate or diammonium phosphate derived from wet-process acid. Thus, when the market is far from the phosphate rock mine, a substantial saving in transport costs can be made by shipping elemental phosphorus to the market area for conversion to fertilizer.

Although the estimate for the hypothetical thermal plant in Florida, mentioned above, assumes that all of the elemental phosphorus is converted to phosphoric acid on site, it is much more likely that most or all of the phosphorus would be consigned to one or more conversion plants located in market areas. If the Florida plant only produced elemental phosphorus and did not convert it, the investment would be reduced by about \$5 million, to \$30 million, and the production cost would be about \$178 per ton of phosphorus, which is equivalent to \$78 per ton of P_2O_5. (See tables 9 and 10.)

In markets where the transport cost of phosphate rock is \$15 per ton, the cost of transporting elemental phosphorus would be about \$6.60 per ton of P_2O_5 as compared with \$32.60 per ton of P_2O_5 from phosphate rock. Under these conditions the thermal process would have a clear advantage when a 20 per cent return on investment is included, as shown in the following tabulation.

TABLE 11: COST OF PRODUCING ONE TON OF P_2O_5 AS AMMONIUM PHOSPHATE FROM IMPORTED ELEMENTAL PHOSPHORUS COMPARED WITH COST OF INDIGENOUS MANUFACTURE BY THE WET PROCESS

Process	*Cost per ton of P_2O_5 (\$)*
Thermal process	
Cost of elemental phosphorus (3 mills per kWh)	78.00
Return on investment (20 per cent/yr on \$30 million)	32.40
Transportation of phosphorus	6.60
Conversion to fertilizer	10.00
TOTAL	127.00
Wet process	
Cost of wet-process acid	87.50
Return on investment (20 per cent/yr on \$16.5 million)	17.84
Conversion to fertilizer	8.00
Transportation of fertilizer	32.60
TOTAL	145.94

In the above comparison it is assumed that the fertilizer product is ammonium phosphate and that the cost of ammonia in the market area is the same as at the phosphate mine, so no allowance is made for the cost of transporting the nitrogen content of ammonium phosphate.

TABLE 12: COST OF PRODUCTION OF ONE TON OF P_2O_5 AS PHOSPHORIC ACID IN INDIA FROM IMPORTED ELEMENTAL PHOSPHORUS AS COMPARED TO THE COST IF RECEIVING THE P_2O_5 IN THE FORM OF SUPERPHOSPHORIC ACID MANUFACTURED BY THE WET PROCESS

Process	*Cost per ton of P_2O_5 ($)*
Thermal process	
Cost of elemental phosphorus (3 mills per kWh)	78.00
Return on investment (20 per cent/yr on $30 million)	32.40
Freight to India (0.44 ton at $18)	7.92
Conversion to phosphoric acid in India	10.00
TOTAL	128.32
Wet process	
Cost of wet-process acid (including $38.50 for sulphur)	87.50
Conversion to superphosphoric acid	8.00
Return on investment (20 per cent/yr on $18 million)	19.40
Freight to India (1.39 tons at $15)	20.90
TOTAL	135.80

Another possibility is to ship elemental phosphorus overseas to make fertilizers locally in developing countries. Ocean transport costs for shipment of fertilizer from the United States to India are in the range of $12 to $15 per ton. Thus, shipment of triple superphosphate costs $26 to $33 per ton of P_2O_5. Ocean freight rates for elemental phosphorus are not available; at an assumed cost of $18 per ton, however, the freight charge per ton of P_2O_5 equivalent would be $8, and the savings as compared with shipping triple superphosphate would be $18 to $25 per ton of P_2O_5.

Comparison of the cost of shipping elemental phosphorus to India with the cost of shipping phosphate rock and sulphur is more difficult, as rock and sulphur are not commonly shipped there from the United States. However, recent prices of phosphate rock and sulphur delivered at ports in India were $23 and $60 per ton, respectively. Thus, the raw materials for making wet-process phosphoric acid in India would cost $133 per ton of P_2O_5. The cost, including allowance for a 20 per cent return on investment, of elemental phosphorus delivered in India from the hypothetical Florida plant with 3 mills per kWh is calculated to be less.

It has been proposed that wet-process phosphoric acid be concentrated to superphosphoric acid for shipment to India or other developing countries. A rough comparison gives shipping elemental phosphorus to India a cost advantage over wet-process superphosphoric acid.

The conclusion may be drawn that where electricity is available at or near 3 mills per kWh and sulphur costs are as high as $38.50 per ton, the thermal method should be considered for phosphate fertilizer production. The usefulness of thermal acid for industrial phosphates weighs in its favour, as well as the fact that the process can use low-grade rock, the product can be used to make unusually high grade fertilizers, and savings on transport can be realized by shipping elemental phosphorus.

Chapter 5

POTASH FERTILIZERS

Production of potash

Potash reserves

Potash is an important commodity today. Some 90 to 95 per cent of the world production of potassium salts is used as fertilizers. However, potash was not used as a commercial fertilizer in large quantities until early in the twentieth century. Its primary industrial use before then was in dyeing and tanning and the manufacture of glass, fireworks, explosives, soap and other chemical products.

Although there are many potash-bearing minerals, most of the world's known reserves are in sylvite, carnallite, kainite, langbeinite, nitre and polyhalite. Most potash is produced from sylvite and carnallite.

Germany controlled the world production of potash from the 1860s until the early 1930s, when demand stimulated the development in the United States of the Carlsbad deposits in New Mexico. Production rose in the Carlsbad district to meet the increased demand during and after the Second World War. World demand has increased since the middle 1940s by 8 per cent per year.

The growing demand for potash on the world market has stimulated the development of the Saskatchewan deposits in Canada. At the present time, three companies are producing potash there, and five other companies are developing properties. Several other major companies are making feasibility studies.

Potash is being recovered in over 140 operations in the world, including both brine and mining operations. Currently fourteen other deposits are being developed.

Potash production from deposits in Eastern and Western Europe and in North America will reach almost 27 million tons by 1971. Known reserves total nearly 83.000 million tons. They are situated mainly in developed areas; three quarters of the reserves are in Europe. Some developing countries, however, may become major producers.

The world potash fertilizer industry

The growth in the production of potash fertilizers has been slower than that of nitrogen fertilizers and about the same as that of phosphate fertilizers. Potash is the least used of the three primary plant nutrients contained in fertilizers. This is partly because many soils contain relatively high amounts of K_2O, which have not been depleted by crop production. As crop production increases, however, it is expected that greater amounts of potash will be used and potash consumption will equal phosphate consumption.

Since 1955, potash production has increased at a compound rate of 6.2 per cent per year. The increase in 1965 alone exceeded 1 million tons as several large Canadian mines came into production. World potash production in 1967 was 14.526 million tons of K_2O. Production is forecast to rise in the developed countries to 17.3 million tons by 1971 and to 23.5 million tons by 1976. In the developing countries, production is forecast to rise to 700 thousand tons by 1970 and to 1.2 million by 1976. As with nitrogen and phosphate fertilizers, this gives a deficit compared with estimated consumption, which is put at 1.5 and 2.55 million tons, respectively.

Although potash reserves have been found in all areas of the world with the exception of Oceania, production has been confined to a relatively few countries in Eastern and Western Europe and North America. Israel recently began production of potash, and Chile and Peru are producing potash from their guano deposits.

Production is divided fairly equally among Eastern Europe, Western Europe and North America, with Western Europe leading by a small margin. Figures indicate, however, that by 1971, North America will be the major producer with 40 per cent of the total. Eastern Europe will then contribute 30 per cent of world production and Western Europe 22 per cent.

New production units are being planned in several African and Latin American countries, and Israel is planning to double its output in the next few years. However, the production from these sources continues to be only a small part of total world production.

Potash fertilizer consumption

Potassium chloride (muriate of potash) is by far the most widely used of the relatively few types of potash fertilizer. Another potash fertilizer is potassium sulphate, one of the least hygroscopic of the common fertilizers. It is preferred for tobacco, potatoes, citrus and some other crops sensitive to chloride. Potassium sulphate accounts for only about 8 per cent of total potash consumption, and its share of the market will continue to decline.

Another non-hygroscopic, non-chloride form is potassium nitrate (saltpetre, nitre). The technical grade (99 per cent) is used in explosives and the 95 per cent material (13 per cent N, 44 per cent K_2O) is usually described as fertilizer grade. Limited supplies and high unit costs have largely restricted its use to specialized mixtures or direct soil application, and its consumption is not expected to rise much.

Experts in the United States are becoming interested in water-soluble potassium metaphosphate. Semi-commercial quantities of the technical grade material (57 per cent P_2O_5, 37 per cent K_2O) are being produced in Scotland, and some is reportedly being made in Israel.

During the past few years, the general trend has been towards producing more concentrated fertilizers of all types. Sixty per cent muriate, for example, has been steadily gaining ground over the traditional 20 to 45 per cent concentrations.

Most of the potash produced today is incorporated into mixed or complex fertilizers before application to the soil.

Bulk blending—the physical mixing of straight fertilizers—has helped to boost the demand for granulated, concentrated fertilizers. (Granulation minimizes the segregation of the constituents, reduces caking and dusting and facilitates the distribution of the nutrients in the soil.) Owing to the increase in bulk blending, a coarser form of potassium chloride is now in greater demand.

World potash consumption in 1967 was about 13 million tons, an increase of 7 per cent compared with 1966. An average annual increase of about 6.3 per cent is expected up to and including 1980.

Development of a potash complex

Costs of manufacturing potash are directly related to grade, depth of mine and capacity. If the other costs to be borne by a producer in a developing country are considered as part of manufacturing costs, then manufacturing costs are also directly related to investments in distributing facilities (railroads, roads, port facilities), housing, schools and hospitals, and basic utilities (water, power, fuel).

Mining costs per ton of finished product vary according to the ore content. Obviously a high-grade ore containing little waste, such as salt, is much more productive per ton mined than one of low grade. For example, in Canada (Saskatchewan), the ore contains 26 to 28 per cent K_2O, whereas some of the low-grade Carlsbad ores contain only 12 to 14 per cent K_2O. For a given tonnage of potash, this means that a Canadian producer has to mine less than half the amount of ore mined by a Carlsbad producer.

Refinery costs also vary according to the grade of ore, although not nearly so much as mining costs, since the separation and disposal of waste occur early in the circuit and from then on costs are similar regardless of grade. Mining costs rise as the depth of the mine increases. This is due to three factors: a deeper shaft is a more costly investment; hoisting costs are proportional to distance lifted; and underground recovery (amount of ore removed per unit of penetration) is inversely proportional to depth. Shaft costs are also affected by the geological formations through which a shaft is sunk. Depth is not the only factor influencing cost. In Canada, a shaft is over 3,100 feet deep and costs (fully equipped) approximately $10 million. This is nearly 6.5 times as much as in Carlsbad and reflects not only the depth but the treacherous geological formations that must be traversed to reach the Canadian ore.

Economies of scale are also important. A high-capacity mining operation invariably has lower unit costs than a low-capacity one. This is particularly true of operations with high fixed investment and operating costs. In the refinery, staff are needed to man certain controls regardless of the volume processed. In Canada, a conventional mining operation will have $20 million invested in shafts alone. If to this are added underground equipment, a refinery, and office and laboratories all built to withstand the severe Canadian winters, the investment will be of the order of $50 per ton annually.

Construction costs at the world's potash mines may vary from $30 per ton of annual capacity to as much as $70 per ton. Moreover, construction costs have been rising by 5 to 6 per cent per annum over the last five years, and similar increases are probably to be expected in the future.

In developing countries, where labour is readily available at a very low cost, a producer will find it more advantageous to hire many men than to invest in complicated equipment that is difficult to operate and may exceed the capabilities of the local labour force. In this case, unit costs will not change much with volume. However, the labour available is unskilled and inexperienced, and this means that extensive training programmes have to be undertaken. Even though Canada is a developed country, the rural location of some of the potash mines has made it necessary to institute highly organized training programmes to teach farmers to operate mining and refining equipment.

The development of potash deposits from discovery to actual production has, in some instances, taken several decades, depending on the market prospects. The actual construction of mine and plant facilities has taken from three to six years, depending on the particular deposit. To be economically feasible, a potash operation should have adequate reserves to sustain operations for 25 to 50 years and must produce a fairly high tonnage. This in turn demands an adequate power supply to operate the underground equipment, refinery and other equipment; an adequate water supply for plant processing, brine make-up, dissolving and flotation; a source of natural gas or fuel-oil for the power plant and production of steam; a reliable supplier of repair parts and supplies or the equivalent in plant inventory; and a labour force. In developing countries, the complications are aggravated by lack of industrialization, transport, competent labour, utilities, housing, foreign exchange, and sometimes rigid government regulations.

An example of the difficulties developing countries face may be seen in Ethiopia, which has within its borders a very large deposit of potash. The results of early investigations were not sufficiently encouraging to attract potential producers, and to date the deposit is still not being exploited. The factors that discouraged early investigators include:

Remote location: extensive development of roads, port facilities and sources of energy is required;

Climatic conditions: severe surface temperatures in excess of 130°F make operations difficult and expensive;

Lack of water: a considerable quantity of water is required for processing potash to modern standards of quality;

Lack of skilled labour: personnel must be brought in and housing facilities built;

Ore quality: although of high potash content, it contains impurities that make processing complex and expensive.

In evaluating the Ethiopian project, geologists and mining engineers investigated water sources, mining conditions, native customs and site locations, port requirements, transport facilities, living conditions, availability of equipment and other factors. An economic study was made, the attitude of the Government and the tax position were determined, and capital requirements worked out. Some day this deposit will undoubtedly be commercially mined. There is a natural market for this raw material that is large enough to make the operation economic in spite of the high costs.

Unfortunately, most of the world's largest producing deposits of potash are located 200 to 1,000 miles from the sea and are serviced by complex transport systems. The transport of bulk products has received increasing consideration during the last five years. Companies entering bulk markets, such as phosphate rock, potash, sulphur and others, will find that much time and money have been expended on developing the lowest possible distribution costs. The first step is to decide on the cheapest form of transport to the port, where adequate loading facilities must be available. Choosing a vessel of the right size is also important; larger vessels offer lower freight rates, but there may be difficulties about discharging bulk carriers in the ports of developing countries.

Specialized bulk carriers are desirable, though over-specialization may make it difficult to obtain return cargoes. The delays in shipping, however, have been eased by the increase in shipments of dry solids, which rose from about 300 million tons in 1950 to over 700 million tons in 1965.

Chapter 6

ECONOMIC ISSUES TO BE FACED IN DEVELOPING A FERTILIZER INDUSTRY

As a general rule, four distinct and progressive steps may be seen in the development of a country's fertilizer industry:

Imports of food to stave off famine while fertilizers are being introduced and demonstrated to create a market;

Imports of finished fertilizers to meet growing demand until a domestic industry is justified;

Building of local production facilities with the aid of imported know-how;

Self-sufficiency of production and operation, with imports limited to raw materials not available locally.

The first stage at best is a short-run solution to supplying food needs. Developed regions cannot be expected to produce and furnish in excess of their own needs the quantities needed to meet very large demands in developing areas. In fact, if such a practice is continued it can lead to even greater food problems.

The developed countries should not continue to supply all the finished fertilizer products needed by the developing countries. This would require the outlay of large amounts of foreign exchange that the developing countries do not possess. The developing countries should be encouraged to use their own resources, both human and material, whenever this can be economically justified.

The step-by-step development of the fertilizer industry will vary from country to country. Each country must attempt, however, to achieve the most efficient use of all its available resources.

The developed countries can help the developing countries by investing capital and furnishing technical know-how. The developed countries have considerable experience in constructing, operating, managing and maintaining fertilizer plants. They can also assist with the development of efficient distribution and marketing systems.

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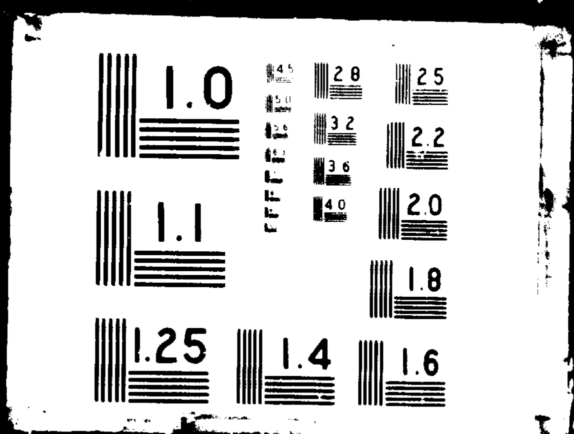

PHASING IN A DOMESTIC FERTILIZER INDUSTRY

Correct selection of imported fertilizers

Use of imported fertilizers to create a market is a necessary prelude to establishing an indigenous fertilizer industry. Careful consideration should be given to the kind of fertilizers imported with respect to cost, suitability and compatibility with future development plans. When a fertilizer industry is being planned, imported materials should be similar to those that will later be produced. Imports of mixed fertilizers or the use of imported straight fertilizers in a mixing plant should be considered.

Use of indigenous raw materials

The usual raw materials required for a fertilizer industry are:

Natural gas or naphtha (from indigenous oil refineries), coal and lignite;

Phosphate rock;

Potash minerals;

Sulphur.

Many developing countries have one of these raw materials; some have two; very few have three; and none, with the possible exception of Peru, has all four, in contrast to the Soviet Union and the United States, which have all four raw materials in abundance. Such information as is available indicates that China (mainland) may also have the four required materials but only in limited quantities.

All countries naturally wish to make use of whatever indigenous raw materials they have. However, insistence on using indigenous raw materials of unsuitable quality or excessive cost, such as low-grade, high-cost phosphate rock that cannot be beneficiated at a reasonable price, is a poor policy. Such a policy leads to the excessive cost of phosphate fertilizer, and this will discourage its use and retard agricultural development. The result may be more damaging to the country's economy than importing fertilizers or raw materials. Developing countries should search diligently for raw materials, but they should carefully evaluate the economics of using them.

Use of imported intermediates

When domestic raw materials are inferior in quality or overpriced, the importation of fertilizer intermediates such as ammonia, phosphoric acid and elemental phosphorus should be considered. Relevant factors in this connexion are:

A drop in the price of liquid ammonia in many areas as a result of the new low-cost ammonia technology;

Availability of liquid ammonia in shipload quantities from various sources:

Availability of liquefied natural gas and liquefied petroleum gas in shipload quantities;

Availability of phosphoric acid in shipload quantities;

Future availability of elemental phosphorus and superphosphoric acid in shipload quantities;

New, improved processes for the production of nitrophosphate fertilizers.

These possibilities may prove attractive in some cases and should be evaluated carefully. For example, Achorn and Walkup[3] found in 1966 that the developing countries could import urea-ammonia solution and process it into complex fertilizer at a saving of from \$0.92 to \$5.31 per ton of product compared with making the same grades of complex fertilizer by using imported anhydrous ammonia and solid urea.

Similarly, if a country already has a nitrogen industry, imports of phosphoric acid to make ammonium phosphate fertilizers should be considered. Another possibility is to import bulk triple superphosphate (non-granular) for use in producing a mixed fertilizer by ammoniation-granulation techniques.

Imports of intermediate materials by the developing countries may prove to be a major step towards establishing a domestic fertilizer industry. Plants processing intermediate materials into finished products do not require as large an investment as plants producing the basic raw materials. Savings may be realized through purchasing the intermediates from countries with lower production costs than would be possible in a country in which production is on a small scale. Savings in transport costs are possible by importing high-analysis intermediates rather than finished products with relatively low plant nutrient content. Flexibility and the ability to meet changing demand are, however, maintained.

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[3] For full reference see annex 3 under "Other sources".

The experience of the developed countries has shown that it is best to import only the necessary raw materials, provided that the demand is sufficient to support an economic scale of operation. Examples of countries that have built up a large phosphate industry based mainly or entirely on imported raw materials are Australia, Belgium, China (Taiwan), the Federal Republic of Germany, Japan, the Netherlands, New Zealand and the United Kingdom. Many other countries import their phosphate rock but use indigenous supplies of sulphur or pyrites. Several countries make extensive use of nitrophosphate processes requiring no sulphur.

The examples mentioned above indicate that lack of indigenous raw materials does not preclude the establishment of a flourishing phosphate industry. In fact, some of the countries export a substantial amount of fertilizers containing phosphates.

Advantages of long-term contracts

Another aspect of the importation of fertilizers, fertilizer raw materials or intermediates by many developing countries is that purchases are effected on a spot tender basis. Generally, such tender offers coincide with the period during which the manufacture of fertilizers is most intensive for internal use in developed countries, which themselves also bid on these tenders. Consequently, many of the bids are unduly high because the suppliers are not interested in taking on additional business at the time of the tender offer. Therefore, if developing countries entered into long-term contracts for fertilizers and fertilizer raw materials and intermediates, they might be able to get better terms and assure themselves of steady supplies for a reasonable period in the future.

ECONOMIC USE OF PLANT

Plant size

Statistics given in chapter 3 showed that plant size and the cost of natural gas have a decisive influence on the cost of manufacturing ammonia. As a result of these economic factors, there is a tendency to favour very large ammonia plants producing between 1,000 and 2,000 tons daily and which are built near gas fields or seaports. Ammonia (and derivatives) made under these conditions can frequently be transported in special ships and delivered to consumer points thousands of miles distant at prices competitive with, or lower than, nitrogen fertilizer made locally in a small or medium-sized plant using relatively high-cost feedstocks. Therefore every possibility of making nitrogen fertilizers must be carefully examined on its merits. As previously explained in chapter 3, the large-scale plants are so new that there is relatively little experience in operating them. Furthermore, highly skilled personnel is required.

Full utilization of existing capacities

One of the most serious problems of developing countries is their failure to operate fertilizer plants at a level near their rated capacity. The economic success of modern fertilizer plants usually depends on sustained operation at or near capacity. Each plant has a "break even" operating rate, below which the operation is uneconomic. The break-even rate may vary considerably from one plant to another, but 70 per cent may be a typical value. Modern plants should be capable of an output of at least 90 per cent of rated capacity, even with allowance for maintenance work and occasional major repairs. In fact, it is not unusual to achieve a sustained output above rated capacity. Many developing countries are operating their fertilizer plants at only 50 to 60 per cent of capacity, even when higher output is urgently needed and fertilizer is imported to make up the deficit.

The reasons for this poor record include shortages of raw materials, inadequate storage and transport, lack of operating or maintenance skills, and difficulties in obtaining spare parts and other maintenance supplies. Most of these difficulties could be overcome if the Government of the country concerned would assign a high priority to achieving maximum production in existing facilities. In many countries the supply of fertilizer is so vital to the country's economy that top priority would be fully justified. There is a regrettable tendency to attach more importance to establishing new plants than to making the best use of existing ones.

Training of operating and maintenance personnel for a plant is a difficult problem. Most construction firms provide a start-up service, but this is often inadequate for thorough training, since these firms lack the personnel to train the plant operators sufficiently to ensure sustained, full-capacity operation. Good results have been achieved by employing a supervision team from an experienced operating firm for one or two years.

Short-sighted policies of restricting imports of raw materials, spare parts, or services of foreign technologists may be responsible for many of the poor records of performance. Complicated, time-consuming procedures for obtaining approval for imports may be as damaging as outright prohibition. Heavy taxes on imports may also be a handicap. These questions have already been discussed in chapter 2.

Marketable by-products

Any marketable by-product, such as fluosilicic acid produced during the manufacture of superphosphate or phosphoric acid, helps to lower the cost of the main product. Another example is by-product gypsum from the wet-process manufacture of phosphoric acid, which can be used in the manufacture of wall plaster and building products. In other cases, gypsum is used as a fertilizer for groundnuts. It can also be used as a raw material for a process combining the manufacture of sulphuric acid and cement.

ORGANIZED PLANNING AND REGIONAL CO-OPERATION

Planning for local fertilizer needs

Developing countries often establish a nitrogen fertilizer industry first, followed by a phosphate fertilizer industry and finally, a mixed fertilizer industry. This sequence has some disadvantages, since it is likely to make installation of the total industry more expensive, and it makes it more difficult to give the farmer the balanced fertilizer that he needs. It would be better to begin by providing the farmer with the grades of fertilizer he needs rather than setting up separate industries. In countries where farmers are well educated and where there are many well trained agricultural advisers and ample facilities for soil analysis, the farmer can make wise use of straight fertilizers. Even so, farmers often prefer multinutrient fertilizers. In developing countries farmers are often illiterate, well trained advisers are few, and soil-analysis laboratories may be lacking. In such cases it would seem best to provide farmers with mixed fertilizers compounded on the basis of the best information available for the crops and soil of the area and with due regard to cost.

If farmers are supplied with straight nitrogen fertilizers, the results may be good for a few years, but the phosphorus content of the soil is likely soon to become depleted. The farmers will then be disappointed in the results of using fertilizer.

When nitrogen and phosphate fertilizer facilities are planned separately, problems may arise that could be avoided by an integrated approach. For instance, if urea is chosen for nitrogen fertilizer and superphosphate for phosphate fertilizer, an attempt to mix the two materials will result in a wet, sticky, unusable mixture. Also, money may be wasted in granulating two materials in separate plants when the two could be combined and granulated in a single plant.

Examples of inadequate project planning

The planning of a fertilizer industry is a complicated problem that each country must solve for itself. A matter of primary importance is the cost of the finished fertilizers delivered to the farmer. The actual manufacturing costs often are no more than half of the final cost. Handling, bagging, transport, storage and distribution costs make up a large percentage of the final cost. For these reasons, a thorough economic evaluation usually favours high-analysis products, although there are exceptions. When the nature of the crops and soils is such that sulphur is needed in fertilizer, some compromise must be reached between sulphur content and the concentration of the primary nutrients.

New fertilizer projects require expertise of a high order from the conception of a project to the start-up phases. Many projects have been located near the sources 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 where all conditions were desirable except for a good source of process water. Sometimes Governments of developing countries have wanted a project in a special area in order to initiate industrialization in that area with no regard to the availability of markets, utilities or manpower.

The success of a project depends upon mutual agreement between the Government of the developing country and the planning group responsible for the project. Experts coming from developing countries themselves would probably be valuable in ensuring this.

Many developing countries do not realize that they pay too high a price for projects if they insist on overly 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.

The net result is to limit the amount of fertilizer available to the farmer and to increase the cost of the fertilizer that is produced. A country with a good record in making full use of the facilities it has will inspire confidence in investors when new plants are needed. Conversely, where previously financial aid or investment has been poorly utilized, there is little reason to suppose that more capital will be forthcoming.

Linkage with other industrial sectors

Inter- and intra-industry linkage offers developing countries advantages over the unassociated industrial operations of many older economies. When the industrial framework of a developing country is being planned, opportunities for such linkage may arise. This is particularly true for the fertilizer and certain other heavy chemical industries. For example, docks, roads, plant sites, housing can in many cases be shared and perhaps constructed simultaneously, with substantial savings in capital and operating costs.

Sometimes one product is needed by several industries, as, for example, sulphuric acid for fertilizers, steel pickling and chemical manufacture; or oxygen for steelmaking, for gasification of feedstocks to make ammonia synthesis gas and for production of chemicals. Oil refining may yield gases and liquid hydrocarbons, like naphtha, used for ammonia production, while ammonium nitrate made from the ammonia can find use as a fertilizer and as an industrial explosive. Opportunities also exist for sharing utilities, water treatment, waste gas and effluent disposal.

Possibilities of regional co-operation

Not all countries should aim at establishing a full-fledged fertilizer industry. Many countries are too small or lack the agricultural potential to furnish a market for a fertilizer plant of an economic size. In such cases regional planning can be helpful. For instance, a country with low-cost natural gas could produce ammonia for itself and other countries of the region. Another country may have phosphate rock, a third may have sulphur or low-cost electric power, and a fourth may have potash.

Careful planning is needed to determine where production facilities should be located and what products or raw materials should be shipped.

Simple economics dictate that if Country A has phosphate rock and Country B has cheap natural gas, it will be mutually advantageous to have Country A manufacture phosphate fertilizers for itself and for Country B, while Country B manufactures ammonia and/or nitrogen fertilizers for itself and Country A. With the wider market, each country can build plants that take advantage of economies of scale. If each country insisted on having both a nitrogen and a phosphate plant the result might be the failure of both projects in both countries.

The advantages of regional planning and co-operation are not confined to small countries. Adjacent portions of large countries may benefit also. For instance, the northwestern part of the United States and the southwestern part of Canada constitute a region in which phosphate rock, potash and finished fertilizers move freely across the border, with substantial advantages to both countries.

Chapter 7

FINANCING OF FERTILIZER PROJECTS IN DEVELOPING COUNTRIES

The financing of large-scale projects in developing countries is always a difficult problem. Yet, a viable fertilizer project will as a rule be able to attract the necessary capital from private or government sources of financing.

PRIVATE FINANCING

Unfortunately, savings are limited in most developing countries, and local individuals or companies can rarely be counted on to be a significant source of investment capital. For example, in developed countries the consumers of fertilizers are a potential source of private capital, but this is not the case in most developing countries because farmers and even co-operatives simply do not have sufficient savings. Local producers of equipment, if indeed there are any, do not have the means to assist the financing of equipment purchases even over short periods. Outside financing is, therefore, needed for fertilizer projects in most developing countries. The principal sources of foreign exchange capital in the past have been Czechoslovakia, the Federal Republic of Germany, France, Italy, Japan, the United Kingdom, the Union of Soviet Socialist Republics and the United States.

The most prolific source of foreign exchange equity capital in the years ahead will most likely be foreign private firms. A significant recent development has been the broadening of the extended risk guarantee programme of the United States Agency for International Development (AID) so as to permit United States pension funds, life insurance companies and other types of institutional investors to participate in projects abroad; previously this was not possible.

The public sale of shares or stock is another potential source of private capital for financing new fertilizer plants. However, most developing countries do not have efficiently functioning stock markets, and public stock issues may therefore frequently be a difficult way to raise additional capital.

Private development corporations, of which there are a large number, are another potential source of financing. Many development corporations have been organized in recent years with funds from government sources, usually from developed countries. Although some of these development corporations charge high rates of interest, they do offer a source of capital as well as a source of project analysis, which can be helpful in raising additional capital.

Suppliers of equipment represent another important private source of capital, and credits from suppliers can be very important in the financing of new fertilizer plants. However, virtually all such credits are related to government programmes; few suppliers are prepared to arrange private financing without some government guarantee. In many cases, after a supplier in a developed country has obtained a firm financial commitment from a private bank in his country to permit him to extend credit for a project in a particular developing country, the Government of the developed country has withheld its guarantee and the transaction has fallen through.

The lack of private capital as an investment source for new fertilizer plants in developing countries is not surprising, since fertilizer projects must compete with many other industrial projects for investment funds. The relative risks of these competing projects are weighed by investors as are also the repayment terms and profits. Private capital may find that profits are frequently lower from such projects than in developed countries.

Developing countries wanting to create or expand fertilizer industries may be well advised to make their policy on foreign private investment as attractive as local conditions and their particular economic, social and political philosophies permit.

Government financing

As a rule local government sources of capital are available for the construction of fertilizer plants, particularly as far as local currency components are concerned. The foreign exchange component will in most instances be much more difficult for a developing country to supply from its own resources. Yet some Governments in developing countries have put up the entire foreign exchange and local currency components for the building of fertilizer plants, a clear indication of the high priority given to these projects. Fertilizer projects are often financed and owned jointly by Government and private industry

Loans by foreign Governments are another important source of capital for the fertilizer industry in developing countries. Most of these loans are non-convertible, however, and this is a disadvantage because of the length of time it may take to get certain equipment from a particular country or because such equipment may cost more in one country than in another. Sometimes too, the lender will not permit the design to be prepared and the engineering to be done in the developing country even though it has adequate design and engineering facilities.

Another source of government capital is inter-governmental financing such as is made available by the World Bank Group, which includes the International Bank for Reconstruction and Development (IBRD), or World Bank, and its affiliates, the International Finance Corporation (IFC) and the International Development Association (IDA). There are also regional development banks. Perhaps the most encouraging sign for potential manufacturers of fertilizers has been the great interest in the fertilizer industry shown by IBRD in recent years. IBRD is now actively considering a wide range of fertilizer projects. IBRD loans may be granted to a Government, to an autonomous government agency, or to private corporations. However, its loans cover only the foreign exchange needs of a project.

Lastly, an important source of funds for project loans is the United States Agency for International Development (AID). However, AID will not compete with private capital. In turning to AID, the investor must convince AID that he has tried without success all other sources, such as IBRD and the Export-Import Bank or, if the investment is to be made in Latin America, the Inter-American Development Bank. Before AID will assist it must be satisfied that money cannot be raised from other sources. The terms of assistance from AID are generous but are generally geared to conditions in the recipient countries so as to avoid upsetting the domestic money market.

Chapter 8

THE INTERNATIONAL SYMPOSIUM ON INDUSTRIAL DEVELOPMENT: ISSUES, DISCUSSION AND RECOMMENDATIONS

The issues, the discussion and the recommendations approved by the Symposium are presented in this chapter.

THE ISSUES[4]

Acceleration of the economic growth of many developing countries is being retarded because of the failure of food production to keep pace with the increased growth of population. Five important agricultural inputs are necessary to increase agricultural productivity: fertilizer, improved seed varieties, water, pesticides and farm machinery. Of these, fertilizer is probably the most vital input. Some countries, such as the United States and Japan, have estimated that approximately one half of the increase in agricultural yields they have attained can be attributed to greater use of fertilizers. Experience in many developing countries, as well as field trials conducted by the Food and Agriculture Organization (FAO) under the Freedom-from-Hunger Campaign has shown that an application of one ton of fertilizer can increase the yield of food grains by five to ten tons.

The fertilizer industry provides the nucleus in many developing countries for a broad-based chemical industry. To illustrate, the production of acids such as sulphuric, nitric and phosphoric acid, is an integral part of the fertilizer industry. These acids are used by and are the starting materials for diversified chemical production. Synthetic ammonia, one of the largest single chemicals in the world from which almost all of the nitrogen fertilizers are made, is the backbone of a large variety of chemical products. Chemical fertilizers derived from ammonia, such as urea, ammonium sulphate, ammonium nitrate and ammonium phosphate, in addition to being used as fertilizers, are used in many industries, e.g., plastics, explosives, food industries and pesticides. They have linkages also to steel, heavy chemicals and petrochemical industries.

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[4] From Issues for Discussion: Fertilizers, Pesticides and Insecticides Industry, 1967, ID/Conf. 1/A. 8 (mimeo.).

The issues presented to the International Symposium had previously been raised and discussed by four regional symposia on industrial development, held in 1965 and 1966:

Symposium on Industrial Development in Africa (ECA), Cairo, 1966, (ID/CONF. 1/R.R. 1 — E/CN. 14/347);

Asian Conference on Industrialization (ECAFE), Manila, 1965, (ID/CONF. 1/R.R. 2 — E/CN. 11/719);

Symposium on Industrial Development in Latin America, Santiago, 1966, (ID/CONF. 1/R.R. 3 — E/CN. 12/755/Rev. 1);

Symposium on Industrial Development in the Arab States, Kuwait, 1966, (ID/CONF. 1/R.R. 4 — E/C. 5/135/Add. 4).

Disparities in production and consumption levels: world fertilizer programme

Total world production of fertilizers ($N + P_2O_5 + K_2O$) in 1965/1966 is estimated at about 48.1 million tons. Of this, the developing countries [Asia (including Africa and mainland China) and South America] produced only 5.67 million tons. This means that the developing countries produced only 11.8 per cent of world production. If mainland China, North Korea and North Viet-Nam are excluded, the production of $N + P_2O_5 + K_2O$ in developing regions was 3.72 million tons, while consumption totalled 4.43 million tons. In 1966/1967, consumption in these areas is expected to amount to 6.15 million tons. By 1970/1971, it is estimated that they will need an additional five million tons of $N + P_2O_5 + K_2O$ to increase agricultural production by 10 per cent.

Current trends indicate that fertilizer production will run ahead of consumption in advanced countries, while it will lag considerably behind consumption in developing countries. The latter countries experience serious foreign exchange difficulties in covering their deficits by imports. Foreign exchange shortages also hamper their attempts to build plants for domestic production, even when other factors favour such a course of action.

To increase their fertilizer production capacity, the developing countries could revise their fiscal policies affecting the fertilizer industry. International financial organizations could also revise their policies and treat fertilizer projects as "infrastructure" investment and extend capital to build fertilizer plants on a "soft-credit" basis. Since irrigation projects and dams are treated in this category, it can be argued that the full effect of such projects is not attained without matching the input of fertilizer to the soil. In this connexion, a suggestion is made for the establishment of a "world fertilizer development programme", taking into account the full needs of the developing countries and setting national and regional targets.

Economies of scale and new technologies

New technology in ammonia production is reducing capital and production costs. There is a tendency for large single-stream plants to be located close to cheap natural gas and to transport ammonia to their markets. Similarly, in phosphate production, the tendency is to produce phosphoric acid or highly concentrated phosphate (P_2O_5) and ship it out. In the case of potash production, it has to be in locations where potash exists.

It is advisable, therefore, that studies be conducted to ascertain the operating experience of the "new breed" ammonia plants based on the new technology, for transfer to developing countries. Countries possessing natural gas and oil resources may give a high priority to the utilization of their natural and financial resources for the manufacture of nitrogen fertilizers.

Countries which have a deficit in fertilizers and do not possess natural gas may consider investing in fertilizer production facilities in areas rich in natural gas. They may thus give serious consideration to regional co-operation. Attention may also be drawn to the possibilities of importing liquid ammonia or phosphoric acid for conversion to solids as alternatives to producing ammonia at high cost or to importing phosphate rock and sulphur.

Sulphur shortage

An associated problem is the world-wide shortage and the correspondingly high price of sulphur. Phosphate (P_2O_5) production using sulphuric acid is being carried out in many developing areas. Consideration should also be given to:

(*a*) Production of sulphuric acid from raw materials other than sulphur;

(*b*) The use of ammonia and other liquid fertilizers directly on the soil;

(*c*) Reducing or avoiding the use of sulphur in fertilizer production;

(*d*) The recovery of sulphur from "sour" gases.

Alternative sources of sulphur and potash could also be developed with pilot installations.

Pesticides and insecticides

At present, the developing countries have to import more than 90 per cent of their requirements of insecticides and pesticides from developed countries, but there is a need for the developing countries to establish facilities for their manufacture. Some of the required concentrations in terms of active ingredients in insecticides and pesticides are quite low so that imports of ready-to-use materials involve heavy freight on inert products that could be found locally or brought in from a nearby source and blended at a formulation plant. Establishment of such formulation plants may be the first step towards complete manufacture by developing countries of their insecticide and pesticide requirements. The manufacture of the active ingredients themselves may be a practical proposition in certain developing countries.

The discussion

In view of the serious food situation in many developing countries, the view expressed by the Symposium was that the development of the fertilizer, pesticides and insecticides industries had become urgent and vital.

There was general agreement that in intensive agriculture, although many inputs were necessary, such as fertilizers, pesticides, better seeds, water and farm machinery, the most noteworthy results were to be achieved through the use of fertilizers. The importance of fiscal policies, infrastructure (transportation and storage capacity), professional training, education of farmers and other prerequisites for the development of the fertilizer and pesticides industries was recognized. Generally speaking, it was concluded that the use and production of fertilizers must be considered as essential factors in a comprehensive agricultural promotion plan.

It was also pointed out that the installation and operation of a fertilizer plant was perhaps the easiest part of the whole network. Marketing, efficient distribution, the organization of farmers' credit and the education of the farmer for the rational use of fertilizers, presented more complicated problems. In that context, the need was stressed for thorough agro-economic feasibility studies to be made in advance before planning and implementing any project.

It was felt that throughout the world there was a serious imbalance in regard to the production, availability and consumption of fertilizers as between the developing and the industrialized countries, and that the correction of this imbalance was perhaps the most urgent task for the developing countries to undertake in solving their food problem.

In view of the shortage of foreign exchange in the developing countries and their real need for fertilizers over the medium term, the Symposium considered that imports alone were not enough to correct the imbalance and that the countries in question must set up and develop fertilizer industries on their own soil, with the backing of the developed countries and with help from international organizations.

Stress was laid on the need for regular, adequate data on the present and future consumption, production and capacity of fertilizer plants and the desirability for information to be made available on the measures taken to adjust production to requirements.

The necessity for effective co-operation and co-ordination between the various agencies of the United Nations family, especially between UNIDO and FAO, in studying the fertilizer sector and helping developing countries to promote the use of fertilizers and to implement fertilizer projects was brought out during the discussions.

The Symposium also considered it necessary, in so far as it has not already been done, to determine for any given country or region the most suitable types of fertilizer, bearing in mind soil conditions and crops now grown or to be grown. The role of FAO in this area was well known; UNIDO should handle questions relating to the production of fertilizers in close co-operation with the United Nations regional economic commissions.

The World Food Program in its turn might provide food for the workers during the construction and erection of fertilizer plants.

It was noted that UNDP, with the co-operation of UNIDO, was at present considering many pilot projects in the fertilizer and pesticides sphere. Preliminary studies carried out by UNDP and UNIDO on the problem of the gradual backward integration in the fertilizer industry have shown that in an African country not possessing the raw materials required, an N-P-K plant could nevertheless be built at a reasonable cost. Many delegates stressed the importance of demonstration and pilot projects to be set up in certain areas of developing countries.

Regarding technologies, the Symposium was informed that one country which had started with plants for the electrolysis of water and for coal gasification was now basing its output mainly on gas and petroleum products, using the reforming process. Approximately 80 per cent of its production of 1.2 million tons of nitrogen was produced in this way.

With regard to end products, while many countries began by producing ammonium sulphate and superphosphate, the tendency now was to produce high-analysis products such as urea, triple superphosphate, diammonium phosphate and high-grade multinutrient fertilizers.

On the question of the substitution of raw materials and manufacturing processes, the discussion brought out the need for adopting processes which reduce or avoid the use of sulphur. In view of the world shortage of sulphur and its high prices, alternative raw materials for the production of sulphuric acid, such as sulphur-containing ores, gypsum and anhydrites, should be thoroughly investigated by developing countries. The use of ground rock phosphate directly in the soil and the use of calcined phosphates should likewise be investigated to determine their effectiveness. Processes using hydrochloric or nitric acid or carbon dioxide for the extraction of P_2O_5, instead of sulphuric acid seemed also to indicate a solution.

Developing and developed countries must give high priority to the development of new sulphur resources, and especially to the recovery of sulphur from sour gases and petroleum products. It was proposed that a world study be made of short- and medium-term demand, supply and prices of sulphur.

Grave concern was expressed about under-utilization of existing productive capacities in developing countries. It was pointed out that this was mainly due to non-availability of sulphur, spare parts, suitable markets and skilled personnel, and it was recommended that studies be undertaken to determine the causes of this under-utilization of existing capacity and suggestions made for remedial measures.

Stress was laid on the importance of regional and interregional co-operation for the development of the fertilizer industry. An example was cited in the ECAFE region, where there were countries with large available resources of gas and oil but only small markets, while neighbouring countries had large populations and market potentialities but lacked cheap and abundant raw materials. Efforts were now being made to bring these countries together so that the former could develop a basic chemical and fertilizer industry and supply intermediate products like ammonia and phosphoric acid to the latter for conversion into fertilizers.

Attention was drawn to the importance of the manufacture and use of liquid fertilizers. According to some, the use of high-analysis liquid fertilizers and anhydrous ammonia would enable farmers to obtain the fertilizer elements at the lowest cost. At the same time, since the use of liquid fertilizers implied storage and distribution arrangements and special facilities for their use, it would be necessary to set up demonstration projects in that field in developing countries. Several areas of the underdeveloped world seemed to be strategically suited for such pilot installations.

The discussions brought out the importance of the manufacture and use of pesticides to reduce food losses, and also of other auxiliary chemicals employed in agriculture, such as growth-control agents. A demonstration project in the production of DDT (dichloro-diphenyl-trichloro ethane) and BHC (benzene hexachloride) in a developing country was quoted as an instance of the interest displayed in the problem by UNDP and UNIDO. Reference was made to the irradiation of cereals as a means of preventing insect damage. Although this method had been approved and put into practice by one industrial country, the first pilot plant set up in a developing country had given rise to a number of problems to which solutions were being sought. It was felt that this method of cereal conservation had a promising future.

RECOMMENDATIONS APPROVED[5]

(1) In order to establish national development programmes for the fertilizer and pesticides industry, those responsible for these sectors at the national and international levels must possess up-to-date information about the world market and trends in the fertilizer industry. For this purpose, it is desirable that UNIDO take action:

(a) To improve and extend the collection, distribution and utilization of statistics concerning production and existing or planned productive capacity;

(b) To organize an efficient system for the exchange of information between developing and developed countries concerning their respective needs and possibilities;

(c) To provide opportunities for those concerned with the development of these industries to meet at regional or world sectoral symposia to compare their programmes for possibilities of co-ordination.

(2) In order to guide further developments in the fertilizer industry, UNIDO should endeavour to draw up a strategy on a world scale for the production and use of fertilizers based on the food and agricultural requirements in accordance with the recommendations made by FAO and WHO in this field.

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[5] From *Report of the International Symposium on Industrial Development, Athens, 1967* (ID/11) (United Nations publication, Sales No.: 69. II. B. 7).

(3) In view of the magnitude of the capital investment required in the fertilizer industry and the consequent need to make the best possible use of available capital:

(*a*) Thorough and exhaustive techno-economic studies should be carried out before any funds are invested. UNIDO, upon request, should assist in carrying out these studies as appropriate.

(*b*) Every advantage must be taken of economies of scale and all the pertinent conclusions must be drawn, especially in so far as regional co-operation is concerned. UNIDO, in co-operation with the relevant economic commissions, should assist and promote activities in this field;

(*c*) A high rate of utilization of productive capacity is desirable. A study should be made by UNIDO of the causes of the under-utilization which is too often a feature of developing countries, and of the means of correcting it;

(*d*) A study should be made by UNIDO of the causes of the wide differences in total capital costs of fertilizer projects between developed and developing countries;

(*e*) The World Bank and other appropriate international institutions should consider the possibility of treating the fertilizer industry, from the credit standpoint, as infrastructure on a par with projects such as irrigation and transportation. UNIDO should take follow-up action for the implementation of this recommendation with the World Bank.

(4) Regional, and indeed interregional, co-operation is even more necessary in the fertilizer industry than elsewhere, and should be encouraged by all means. It is particularly feasible between countries producing intermediate products (ammonia, phosphoric acid, etc.) cheaply and countries which consume large quantities of fertilizers.

(5) The role of mineral raw materials is decisive. It is therefore necessary:

(*a*) To continue and extend geological surveys of sulphurous material, phosphate rock and potash deposits;

(*b*) To follow closely movements on the sulphur market and make a careful study of the short- and medium-term trends of that market;

(*c*) To study the economic possibilities of any techniques calculated to reduce the consumption of sulphur.

UNIDO should undertake, assist or promote these activities.

(6) Equally important is the training of farm and factory workers and the task of accustoming them to the new products and methods. It is therefore desirable:

(*a*) To continue and expand training programmes;

(*b*) To install pilot plants and equipment, particularly for the production and application of liquid fertilizers, pesticides and formulation plants for pesticides and growth-control agents.

UNIDO, UNDP and other appropriate bodies should assist and promote such activities.

(7) It is recognized that there may be many obstacles to the extension of the fertilizer and pesticides industry in developing countries such as customs and fiscal policies, lack of qualified staff, insufficient markets and inadequate infrastructures. UNIDO should co-operate with UNCTAD, GATT and other appropriate organizations for systematic studies of these obstacles.

(8) In so far as the above-mentioned activities, studies and measures fall within the responsibility of international organizations:

(*a*) It is essential that these bodies should work in close co-operation and co-ordinate their activities in accordance with their respective technical and regional spheres of competence. Since fertilizers are of importance to both agriculture and industry, it is particularly important that UNIDO's activities in regard to this industry and the industrial production of fertilizers should be conducted in full co-operation with FAO, UNDP and other appropriate international bodies;

(*b*) It is no less essential that full, effective and systematic use should be made of all projects and studies carried out at present or in the recent past so that the appropriate conclusions may be drawn and duplication avoided. UNIDO should consider this question and issue an annual "Digest" of all the papers issued, work carried out and developments in the fertilizer sector by all United Nations agencies and other international organizations.

UNITED NATIONS AND OTHER ACTION TO PROMOTE THE FERTILIZER INDUSTRY IN DEVELOPING COUNTRIES

Through various forms of international co-operation a great deal of work has been done to promote the fertilizer industry in developing countries. This chapter on United Nations action to promote chemical fertilizers gives some examples of specific activities concerned with the establishment of new industries in developing countries, and also with problems of rationalization and extension of existing industries. A few examples of bilateral assistance from developed to developing countries are also given.

United Nations action

The work involves the continuing review of approved and newly developed technological processes and their economic application in specific industrial branches and provision of support to technical assistance activities in developing countries. To this end, seminars, expert group meetings and study groups are organized to disseminate technological information on industries of particular importance to the developing countries, manuals and reports are prepared on industrial technology and processes as well as industrial branch reports for the use of developing countries.

The programme of UNIDO for the development of the fertilizer industry is financed under various United Nations operational programmes in which UNIDO participates. These are: the Regular Programme of technical assistance devoted to industry and financed from the United Nations budget (RP); the Special Fund component of the United Nations Development Programme (UNDP/SF); and the Technical Assistance component of the United Nations Development Programme (UNDP/TA). UNIDO receives, in addition, voluntary contributions from Governments for the financing of the Special Industrial Services programme (SIS), a programme limited largely to urgent short-term missions.

Some projects may also be financed from funds in trust, deposited by Governments for specific projects, or other direct voluntary contributions. In all these programmes assistance is given only at the request of the Government concerned.

In addition to helping solve technical and managerial problems of existing industrial enterprises and advising on the establishment of new industries, UNIDO missions have been sent to:

Bolivia, for a fertilizer project study;
The Democratic Republic of the Congo, on a fact-finding mission to investigate into the possible UNIDO assistance in fertilizers;
Indonesia, to advise the Government on existing fertilizer projects;
Iran, to assist with chlorine-based and phosphorus-based pesticides;
Jordan, to prepare a fertilizer industry feasibility study;
Madagascar, to investigate the market for nitrogen fertilizers (particularly urea);
Rwanda, to initiate a project for the extraction of methane dissolved in the waters of Lake Kivu for fertilizer production;
Syria, to analyse tenders for a fertilizer project;
Togo, to discuss with the Government the proposed demonstration plant for the production of phosphatic fertilizers.

Exploratory field missions have also been carried out in Peru and Yugoslavia. Assistance has been given to many countries in production and in improvement and maintenance techniques in petrochemical and fertilizer industries.

UNIDO has served as executing agency for UNDP in implementing the following Special Fund projects:

The first phase of the Special Fund project in Algeria, dealing with industrial and marketing surveys on petroleum derivatives and natural gas was completed in February 1968.

A second phase of the Special Fund project, "Centre for Industrial and Technological Studies" in Algeria, has been initiated to provide further assistance to the Government in its efforts towards the most efficient utilization of the natural hydrocarbon resources.

A Special Fund project is in operation in Pakistan, on pre-investment studies for the promotion of fertilizers and petrochemical industries.

A Special Fund project has been initiated in Rwanda for a pilot plant for pyrethrum processing and for stimulation of industrialization.

Work is under way to implement a demonstration pesticides plant project in the United Arab Republic for the production of DDT, liquid bromine etc.
UNDP has recently sanctioned a project in Togo for the production of single superphosphate.

Supporting activities

To facilitate operational activities, a variety of supporting activities are undertaken, directed mainly towards the transfer and adaptation of modern production technology for use in developing countries. Such transfers and adaptations are carried out by the organization of seminars, symposia and expert group meetings, surveys and studies and the publication of documents.

Meetings

During 1968, expert group meetings were held in Vienna on various topics connected with the fertilizer industry. One such meeting brought experts together from fertilizer deficit countries and consultants from fertilizer-surplus countries, during which the following topics were discussed: availability of capital for purchase of plant and know-how; supply problems of raw materials; inadequacies; internal policies; cost of production and pricing policies; inadequate project planning and execution; and lack of effective regional co-operation. A list of meetings on the fertilizer industry is presented in annex 2.

Surveys and studies

Surveys and studies are undertaken by UNIDO to bring to the attention of developing countries new technologies and processes and also to identify the problems facing the industry in developing countries and to suggest solutions. The surveys and studies undertaken so far include: a compilation or directory of fertilizer production facilities; a critical study of various nitrophosphate processes; and a study of the utilization of by-product gypsum for the production of sulphuric acid.

Publications

The most useful surveys and studies are published. A list of UNIDO publications on the fertilizer industry is attached as annex 3.

Bilateral assistance

The following are some examples of bilateral assistance from the developed to the developing countries:

Austria

In co-operation with commercial firms, the Austrian Government has organized a large-scale insects and weeds destruction action in Tunisia in the years 1966—1968. The goal of this development programme is not only to increase agricultural production per hectare in Tunisia, but also to train experts to carry out agricultural flights, as this is an important development in the fight against weeds, insects etc.

Czechoslovakia

Technical assistance is provided by experts in the manufacture of nitrogenous fertilizers, phosphatic fertilizers and mixed fertilizers. Assistance is given in the preparation of feasibility studies, investment studies, projects, studies dealing with optimal capacity units etc., especially relating to the production of ammonia, nitric acid, urea and mixed fertilizers.

France

French technical and economic assistance relating to fertilizers has been directed to French-speaking African countries including Madagascar. It included promotion of use of fertilizers, agricultural extension work and supply of credit for agricultural development. It has been estimated that about 25 per cent of the activities of the specialized institutes was concentrated on solving the problems relating to the use of mineral fertilizers. The technical assistance, both direct and indirect, included employment of more than 300 experts in the countries concerned. The French Government and French private capital have financed market and feasibility studies leading to the establishing of two local fertilizer industries, one in the Ivory Coast and one in Senegal.

The Netherlands

In 1966, the Government of the Netherlands financed a feasibility study on the industrialization possibilities in the fertilizer sector in Indonesia. In 1968, an expert was placed at the disposal of the Indonesian Government for 18 months.

Sweden

Within the Swedish programme for assistance to developing countries bilateral or multilateral support has been given for increasing the agricultural production and the nutrition value of food products. During the next years it is proposed to extend assistance, which has hitherto been limited to shipments of fertilizers.

United Kingdom

The United Kingdom has sent a technical expert in mechanical composting to India and other experts to Jordan, Pakistan and Venezuela to conduct feasibility studies on various aspects of the fertilizer industry. It has also made grants or loans relating to the purchase of fertilizers or manufacturing equipment to Ceylon, India, Lesotho, Malawi, Pakistan and the Windward Islands.

United States

At the end of the fertilizer year 1967, there were 1,385 US technicians working in the food and agriculture field around the world. Probably no more than twelve to fifteen of these were devoting full time to fertilizers, although many of the technicians spent a considerable part of their time on them. To provide technical experts for fertilizers, the Agency for International Development maintains a general agreement with the National Fertilizer Development Center of the Tennessee Valley Authority (TVA) to second staff members for various duties. Work conducted under this agreement includes *inter alia* training, special studies, provision of technical teams, and maintenance of a working technical library. A contract with North Carolina State University provides assistance to Latin America for soil testing which is closely associated with the use of fertilizers. During 1968 AID approved a number of projects both for loans and for private investment guarantees.

Annex 1

UNIDO ASSISTANCE TO THE FERTILIZER INDUSTRY

A. Areas relating to the development of the fertilizer industries in which UNIDO is in a position to provide technical assistance

Over-all planning for the fertilizer and pesticides industries;
Feasibility and pre-investment studies;
Preparation of tender documents, analysis of bids and drawing up of contracts, supervision of construction, erection, start-up and operation of plant;
Establishment of pilot and demonstration plants;
Assistance to existing plants;
Projection and evaluation of projects;
Location studies;
Choice of suitable raw materials;
Improvement of production technology and evaluation of alternative technical processes;
Reduction of the use of sulphur in fertilizer production;
Procurement of know-how and techniques;
Taking steps to transfer technologies from developed to developing countries;
Training in operation, maintenance and management;
Marketing and distribution;
Evolution of policies for regional and interregional co-operation;
Updating of statistics regarding fertilizer production capacities;
Procurement of financial assistance.

B. Selected major technical assistance projects

The projects listed below relate to the activities of the United Nations Industrial Development Organization since its establishment in 1967. The list excludes projects carried out under the predecessor organizations of UNIDO (the former Division of Industrial Development up to 1962 and the Centre for Industrial Development up to 1967). Since the projects are listed for illustrative purposes, the names of countries have been omitted. The respective programmes under which the projects are implemented are shown as:

SIS	Special Industrial Services of UNIDO
UNDP/TA	United Nations Development Programme, Technical Assistance Component
UNDP/SF	United Nations Development Programme, Special Fund Component
RP	Regular Programme

(1) ***Projects implemented or under implementation by UNIDO in areas related to the development of fertilizer industries***

AFRICA

Urea and ammonium sulphate complex (SIS)
Exploratory mission for proposed ammonia and urea project (SIS)
Economics of sulphuric acid production from gypsum (SIS)
Study on bromine recovery and utilization (SIS)
Industrial and marketing surveys on petroleum derivatives and natural gas (phase 1), Centre for Industrial and Technological Studies (phase 2) (UNDP/SF)
Pilot plant for industrialization and pyrethrum production (UNDP/SF)
Demonstration plant for the production of phosphatic fertilizers and the complementary activities in fertilizer use and promotion (UNDP/SF)
Fertilizer production and marketing (RP)
Production of organic fertilizers (SIS)
Nitrogen fertilizers production and export possibilities (SIS)
Use of methane gas (SIS)
Ammonia and urea fertilizer plant specifications (SIS)
Fertilizer industry; investment and market arrangement (SIS)
Urea and ammonium sulphate project preparation (SIS)
Study on chlorine utilization for DDT manufacture (SIS)
Demonstration pesticides production plant based on chlorine and bromine resources (UNDP/SF)

THE AMERICAS

Formulation of projects for the production of nitrogen, phosphate and potash fertilizers (UNDP/TA)
Organic materials and compost fermentation for fertilizers

ASIA AND THE FAR EAST

Fellowships in fertilizer industry (UNDP/TA)
Pre-investment studies for the promotion of the fertilizer and petrochemical industries (UNDP/SF)
Problems of superphosphate plant operation (SIS)

EUROPE AND THE MIDDLE EAST

Centre for Industrial Development (UNDP/SF)
Exploratory mission for assistance to fertilizer projects under construction and proposed urea and triple superphosphate projects (SIS)
Fellowships in fertilizer industry (UNDP/TA)
Natural gas development (RP)
Possibilities of further assistance to the fertilizer industry (SIS)
Evaluation of tenders for a triple phosphate project (SIS)
Nitrogen fertilizer project (SIS)
Study of fertilizer requirements and urea production (SIS)

(2) *Projects in preparation or under discussion with Governments in areas related to the development of fertilizer industries*

AFRICA

Exploitation of methane gas (UNDP/SF)
Demonstration plant for the production of phosphate fertilizers (UNDP/SF)
Industrial and marketing surveys for fertilizers (UNDP/SF)
Study on the production of feed phosphates and urea-based cattle feed (UNDP/TA)
Proteinous food based on petroleum feed stocks (UNDP/TA)
Development of the fertilizer industry (UNDP/TA)
Fertilizers, pesticides and petrochemicals industries (UNDP/TA)
In-plant training group in fertilizer industries (RP)

THE AMERICAS

Pilot project for the production, storage and application of liquid fertilizers (UNDP/SF)
Study on feed phosphates and synthetic cattle feed (UNDP/TA)
Fertilizer, pesticides and petrochemicals industries (UNDP/TA)
In-plant training group in fertilizer industries (RP)

ASIA AND THE FAR EAST

Pilot projects for the production and application of ammoniated superphosphate and pesticides using excess chlorine (UNDP/SF)
Pilot plants for the recovery of sulphur from natural gas and crude oil (UNDP/SF)
Assistance in the preparation of feasibility studies for establishing a single superphosphate industry (UNDP/TA)
Petrochemical and fertilizer project (UNDP/TA)
Assistance to a urea fertilizer project (UNDP/TA)
Assistance in preventive and current maintenance of existing fertilizer plants (UNDP/TA)
Assistance in the establishment and operation of bulk blending fertilizer plant using solids and liquids (UNDP/TA)
In-plant training group in fertilizer industries (RP)

EUROPE AND THE MIDDLE EAST

Assistance in the production of potash (UNDP/TA)
Studies on the recovery of sulphur from high sulphurous crude oils (UNDP/TA)
In-plant training group in fertilizer industries (RP)

Annex 2

SEMINARS, MEETINGS AND WORKING GROUPS ORGANIZED BY UNIDO OR BY THE UNITED NATIONS PRIOR TO THE INCEPTION OF UNIDO

	Location	*Date*
1. Meeting of *Ad Hoc* Expert Group on Fertilizer Production	UN Headquarters, New York	December 1966
2. First Interregional Seminar on the Production of Fertilizers	Kiev	September 1965
3. Meeting of the *Ad Hoc* Expert Group from Fertilizer-Deficit Countries	Vienna	May 1968
4. Meetings for the Promotion and Development of Fertilizer and Pesticide Industries		
Africa	Rabat	October 1969
Asia	Tehran	October 1969
Latin America	Rio de Janeiro	September 1970*
5. Second Interregional Seminar on the Production of Fertilizers	Kiev	4th quarter 1971

* Proposed.

Annex 3

SELECTED LIST OF DOCUMENTS AND PUBLICATIONS ON THE FERTILIZER INDUSTRY

UNITED NATIONS

CENTRE FOR INDUSTRIAL DEVELOPMENT (PREDECESSOR OF UNIDO)

Report of the Interregional Seminar on the Production of Fertilizers, Kiev, 1965, 1966, ST/TAD/SER. C/78 (Sales No. 66.II.B.7).

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

Fertilizer Manual. 1967. ST/CID/15 (Sales No. 67.II.B.1).

Fertilizer Production, Technology and Use: Papers Presented at the United Nations Interregional Seminar on the Production of Fertilizers, Kiev, 1965, 1968, ID/2 (Sales No. 68.II.B.1).

Report of the Ad Hoc Expert Group on Fertilizer Production in Six Selected Countries with Good Natural Gas Resources, New York, 1966, 1969, ID/5 (Sales No. 69.II.B.5)

Factors Inhibiting the Indigenous Growth of the Fertilizer Industry in Developing Countries; Report of the Ad Hoc *Group of Experts from Fertilizer Deficit Countries, Vienna, 1968*, 1969, ID/13 (Sales No. 69.II.B.21).

Sectoral Studies: Fertilizer Industry, 1967, ID/CONF. 1/38 (mimeo.).

Trends and Prospects of World Fertilizer Production Capacity as Related to Future Needs, by D. L. McCune and E. A. Harre, 1967, ID/CONF. 1/B.22 (mimeo.).

Fertilizer Industry Series:

Chemical Fertilizer Projects: Their Creation, Evaluation and Establishment, by C. J. Pratt, ID/SER. F/1 (Sales No. 68.II.B.17).

Guide to Building an Ammonia Fertilizer Complex, by J. A. Finneran and P. J. Masur, ID/SER. F/2 (Sales No. 69.II.B.10).

The Reduction of Sulphur Needs in Fertilizer Manufacture, by C. J. Pratt, ID/SER. F/3 (Sales No. 69.II.B.26).

The Ammonium Chloride and Soda Ash Dual Manufacturing Process in Japan, by Shozaburo Seki, ID/SER. F/4 (Sales No. 69.II.B.20).

New Process for the Production of Phosphatic Fertilizer Using Hydrochloric Acid, by Y. Araten and R. Brosh, 1969, ID/SER. F/5 (Sales No. 69.II.B.23).

ECONOMIC COMMISSION FOR AFRICA

Investigation on Fertilizer and Chemical Industries in East Africa, 15 July 1965, E/CN. 14/INR/83 (mimeo.).

ECONOMIC COMMISSION FOR ASIA AND THE FAR EAST

Report of the Conference on the Development of Fertilizer Industry in Asia and the Far East (Bombay, 1963), 1963, E/CN. 11/18. NR/51 (mimeo.).

FOOD AND AGRICULTURE ORGANIZATION

Fertilizers: An Annual Review of World Production, Consumption and Trade, vols. 1946 to 1967 (Sales publications).

OTHER SOURCES

Achorn, F. W. and H. G. Walkup, *Cost Comparison of Ocean Shipment of Anhydrous Ammonia and Solid Urea vs. Shipment of Urea-Ammonia Solution*, Tennessee Valley Authority, Muscle Shoals, Ala., 1966.

Douglas, J. R., Jr., *US Fertilizer Industries: Opportunity in Fulfilling World Fertilizer Needs*, presented at the Annual Meeting of the National Fertilizer Solutions Association, Miami Beach, Fla., 1966.

Fisher, C. C., *Capital Sources for Fertilizer Plant Construction*, presented at the Annual Seminar of the Fertilizer Association of India, 1966.

McCune, D. L., T. F. Hignett and J. R. Douglas, Jr., *Estimated World Fertilizer Production Capacity as Related to Future Needs*, Tennessee Valley Authority, Muscle Shoals, Ala., 1966.

UNIDO MONOGRAPHS ON INDUSTRIALIZATION OF DEVELOPING COUNTRIES: PROBLEMS AND PROSPECTS

No. 1. Non-ferrous metals industry
No. 2. Construction industry
No. 3. Building materials industry
No. 4. Engineering industry
No. 5. Iron and steel industry
No. 6. Fertilizer industry
No. 7. Textile industry
No. 8. Chemical industry
No. 9. Food-processing industry
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No. 12. Standardization
No. 13. Industrial information
No. 14. Manpower for industry
No. 15. Administrative machinery
No. 16. Domestic and external financing
No. 17. Industrial planning
No. 18. Regional co-operation in industry
No. 19. Promotion of export-oriented industries
No. 20. General issues of industrial policy
No. 21. Technical co-operation in industry

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United Nations publication

69-3111—January 1970—4,300

Sales No.: E. 69. II. B. 39, Vol. 6

ID/40/6

74.09.12