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Page

Trade

Forecast

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I. INTRODUCTION

1.1 PURPOSE OF THE STUDY

The Lima Declaration and Plan of Action on Industrial Development and Co-operation adopted in March 1975, calls for an increase of the share of the developing countries to at least 25 per cent of total world industrial production by the year 2000.

This mandate poses two practical problems: one, to explore the participation of each industrial sector in contributing to achieve at least 25 per cent of total world industrial production by 2000 and two, to appraise the magnitude of the resources needed for its attainment.

This report relates to the study of both problems in the fertilizer sector and is part of an ongoing process whose ultimate aim is to encourage the implementation of practical measures for the attainment of the Lima goal. In 1976 developing countries produced 15 million tons of the three main fertilizer nutrients, or 15 per cent of world production, and consumed 22.5 million tons, or 23 per cent of world consumption, thus requiring them to import about one third of their fertilizer needs. Therefore this sector may become one of the more important contributors to achieving the Lima goal.

1.1.1 Background information

To carry out the Lima mandate, UNIDO underwent a major re-organization that created, among other measures, the International Centre for Industrial Studies (ICIS) late in 1975. Among the priority sectors selected for study in 1976, fertilizer was chosen as the first sector for study in view of its vital importance to boost agricultural production necessary to feed fast-growing populations. Additionally, as many developing countries are endowed with abundant supplies of raw materials for fertilizer manufacture whose local availability is critical to help solve their manifold agricultural problems, the fertilizer sector was also chosen as the subject for opening up the sectoral consultations process. The first draft world-wide study of the fertilizer industry 1975-2000 was published in December 1976. Its initial purpose was to identify the main opportunities for the advancement of the fertilizer industry and to assess the potential contribution of this sector could make to the attainment of the Lima goal. The study was intended as a decision-making tool for persons involved in investing in the fertilizer industry.

A preparatory meeting was held in mid-November 1976 to discuss the draft report and recommend issues for the Consultation Meeting on Fertilizers. The First Consultation Meeting on Fertilizers was held from 17-21 January 1977 to discuss the issues recommended by the Preparatory Meeting, and to recommend the follow-up subjects to be studied more in depth for the next consultation meeting. As this consultation meeting was the first ever held by UNIDO, it was deemed important to appraise its results and expectations in order to better gauge the needs of participating countries and amend the sectoral studies accordingly.

The results of the appraisal can be summed up as follows:

(a) As the draft was technically oriented, the participants concentrated mainly on substantive matters related to more immediate and pressing problems. that were mainly of a technical character. Thus the primary aim of the Lima mandate, to explore long-range ways to increase the developing countries' share in total world production by 2000, as pertains to the fertilizer sector, needs to be given more emphasis in the revised study and future consultations.

(b) The main comments and constructive criticism given on the draft study were twofold:

  (i) Criticisms on the forecasting factors and methodology.

  (ii) Requests for specific technical data and in-depth knowledge of technical matters.

Therefore the results of the appraisal showed the urgent need to amend the approach and scope of the study to re-focus the long-range aim of the Lima mandate.

1.1.2 Assessment of the new type of study required

It was felt that ICIS studies in this field should meet two criteria:

(a) To explore ways for increasing the developing countries' share in world fertilizer production by 2000 by enabling policy-makers and decision-makers in developed and developing countries to appraise the world fertilizer industry from their own viewpoints. In this way the study would help sharpen their awareness of the sector's opportunities and constraints, thus paving the way for further concrete dialogues that might result in specific international co-operation schemes.

(b) The studies should complement, without duplicating current work of other international organizations, and should provide useful contributions to enhance the world knowledge of the fertilizer industry, especially as regards its medium- and long-term prospects.

Presently there are several organizations active in the fertilizer field that provide data and information on the past, present and medium-term future of this industry. The two more internationally accepted authoritative sources of information on fertilizers are: FAO, concerning the past and present situation; and the FAO/UNIDO/World Bank Working Group on Fertilizers in collaboration with FIAC and the major fertilizers producers, concerning the medium-term future.

In order to find out the type of study needed, a morphological analysis was carried out as follows:

Characteristics/ Approaches (*)	Functional	Structural	Policy
Business			
Technical Assistance			
Policy			X

(*) For the purposes of this report, the studies were classified according to their approaches and their characteristics.

(a) Business approach, concerns operations expected to produce economic results at the earliest. Its usual long-term horizon is five years.

(b) Technical assistance approach, concerns the solving of current problems be they of operational, planning, infrastructural etc. nature. It ranges from sectoral planning, project implementation to operational trouble-shooting. Its time horizon usually is that of the project duration.

(c) Policy approach, concerns the enabling of decision-makers and policy-makers to assess the short-, medium- and long-range impacts of decisions before they are taken, taking into account past and current events, future global developments and their own aims for the future. The time horizon may span 20-25 years.

Regarding their characteristics the studies have been analyzed as follows:

(d) Functional: the sector is divided into clearly defined functions such as production, consumption etc., which are then studied individually along a time axis.

(e) Structural: the sector is divided by functions which are then structurally correlated at specific time outlooks in order to show more clearly the sector's internal mechanisms and its dynamics.

(f) Policy: provides, in addition to the structural analysis, the practical factors and criteria required for establishing a fertilizer industry in developing countries.

Within the above context, the main comments on the draft study involve the following elements:

(a) Forecasting factors and methodology: we agree that a number of important factors influencing decisively the fertilizer industry are qualitative in nature. Therefore, methods including quantitative and qualitative factors should be developed. These methods involve simulation models and futures research techniques whose application to the fertilizer industry is relatively recent.

(b) Technical subjects: concerns a wide array of functions usually dealt with by techno-economic manuals and studies that focus on current problems. There are several organizations engaged in these very important activities that correspond to the business approach or technical assistance approach.

Based on the above analysis and the criteria for the study, we propose to carry out a study of the policy approach/policy type, emphasizing medium- and long-term forecasting using state-of-the-art methodologies simplified in sophistication and rigour, in order to facilitate end-user application to their specific conditions.

1.1.3 Scope of the study

The study concentrates on the three main nutrients N-P-K analyzed at world and regional levels according to FAO's country classification to ensure international comparison. It comprises an analysis of the past and current world situation based mainly on FAO's data sources, an analysis of the medium-term outlook to 1987 based on the UNIDO/FAO/IBRD working group on fertilizers' data, and a long-term outlook to 2000 using our own forecasting methods. Additionally, it includes a chapter on the establishment of the fertilizer industry based on practical experience in this sector.

To ensure a smooth methodological transition from current forecasting practices to futures research techniques that requires both familiarization with the methods and feedback from its users, we are following a two-tier approach: we have applied forecasting models for the fertilizer industry but we give a methodological overview of methods to be applied in further work.

1.2 FOOD, AGRICULTURE AND FERTILIZERS

1.2.1 Food and nutrition

Among the most prevalent and devastating ills affecting mankind are famine and malnutrition. The latter, although harder to define and overcome than the former, afflicts a very large proportion of population in developing countries. Its solution does not involve crisis mobilization but co-ordination of long-term comprehensive actions that entails socio-economic, nutritional and agricultural policies.

The existense of malnutrition is usually explained by four main causes: not enough food, lack of some essential nutrients in the diet, genetic or environmental prevention of adequate food digestion, and intake of too many calories or overconsumption of some essential components of the diet. The combination of the first three causes characterizes the situation in developing countries. The spectrum of protein-calorie malnutrition is the most widespread form of malnutrition due to lack of food. Moreover, the health of man depends basically on three factors: the variety of edible products he lives on, adequate food availability, and food of biological quality. At present mankind relies on 11 plant species for about 80 per cent of its food supply out of several thousands of edible plants; food availability is dependent on crop yield, new land supply and domesticated edible plants; the biological quality depends on its nutritional value.

The simplest food cycle is to grow plants and eat parts of them, thus achieving the highest efficiency in transferring protein and energy to man. However, as food consumption patterns differ widely from one region to the next, farmers have adapted their food production systems accordingly. Since the protein content of edible plants varies from about 6 per cent to more than 20 per cent of dry matter, agricultural systems based on plants with relatively lower protein content give the farmer a greater total yield of food per hectare or man hour because the amino-acid production of plants involves energy-expensive biochemical processes fueled by carbohydrates that otherwise would accumulate as food. Therefore agriculture has evolved on the basis of cereal grains with a 10 to 12 per cent of protein content which is nutritionally adequate for adults in essential amino-acids and carbohydrates. Currently cereals provide directly and indirectly about 75 per cent of the energy and protein needs of mankind.[1] It was not until the 50 s when the first grain food trend extrapolations to the year 2000 were made that people began to realize the serious long-term threats to world food production. Hence, during the past 25 years two approaches have been presented by food and nutrition experts to explain the world food crisis [2]:

(a) The aggregate supply and demand approach states that according to Malthusian demographic patterns food supplies must be planned both to eliminate existing food shortages and to cater for rising food demand. The latter is usually caused by population growth and changing food consumption patterns due to rising incomes. This approach makes two basic assumptions: one, economic demand is equal to human needs, and two, adequate food supply indicates adequate nutrition.

The qualification or rejection of either of these assumptions view the food problem in different fashions of which the better known is the "protein gap". In assumption two above, nutritional analyses led to diagnose protein

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[1] "Agricultural systems" by Robert S. Loomis, Scientific America, Sept.1976. "The requirements of Human Nutrition" by N. Scrimshaw and V. Young; "The plants and animals that nourish man" by J. Harlan, Scientific American, Sept. 1976.

[2] "Problems of World Food and Agriculture" by M.McLean and M.Hopkins, Futures, August 1974

deficiency in several countries whose cause was identified with a deficiency of the aggregate supply of protein-rich foods. Therefore during the 50's and 60's nutrition experts concerned themselves with the short- and long-term implications of the aggregate deficiency of suitable protein supply for the world poor. The rather recent rejection by nutrition and food experts of the protein gap concept stems from the progressively falling levels of the theoretically "safe" protein intake level recommended by nutritionists to a level at which aggregate protein supplies in poor countries have become theoretically adequate but malnutrition still exists.

From the facts that there is enough world food supply and that the nutrient composition of most foods is also satisfactory, nutritionists have concluded that the nature of the food problem is one of distribution. This shift of emphasis may be illustrated as follows: required food supply = population x statistically "safe" nutrient intake.
The statistically "safe" nutrient levels require a nutrition programme ensuring a balanced diet for the population. The "safe" quantity of nutrient may include at least two standard deviations from the protein distribution curve to provide 97 per cent adequacy of protein. Therefore agricultural planners, if they are unable to modify the food consumption patterns of the population, usually plan to produce food well in excess of theoretically "safe" needs in order to provide 97 per cent of the population with the statistically "safe" nutrient intake. This logic would create food overproduction and would enable the rich to consume even more since the poor will only be able to buy a part of this "allotted" food share.

(b) The distribution approach states that the nutrition problem is primarily that of poverty due to income inequalities, institutional barriers and misdirection of socio-political priorities. Thus malnutrition becomes a problem of ineffective food demand rather than insufficient food supply. This approach requires that supply adequacy be defined with reference to the number of underfed and from there on to country, region and world aggregates. It requires sophisticated analysis in determining nutritional needs while its implementation demands strategic plans and co-ordinated execution at all administrative levels.

The fact that even for the poor developing economies the overall rate of growth of food production has been higher than that of population with the possible exception of Africa, shows that malnutrition and hunger problems cannot be explained satisfactorily by the arithmetic of food divided by population. [3]

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[3] "The Statistical Chickens" by Amartya Sen, CERES, July-August 1977.

The fundamental question of how a person acquires food to eat points out that in an economy with exchange the basic feature is the system of entitlements that an exchange economy offers to its members, exchanging one commodity for another, and labour for commodities. This system of exchange entitlements is reflected partly by relative prices of goods and services, but also by other characteristics such as monopolistic restrictions, unemployment prospects, degree of welfare, institutional rules, traditions, technology etc., and it is this totality that is involved in precipitating or avoiding starvation for particular groups in a country or region. Therefore a person's ability to acquire food depends on this entire system, and malnutrition is a consequence of the characteristics of the entitlements and their shifts over time.

This approach touches upon thorny social and political problems whose solution would require long-term co-ordinated actions since it interacts practically with the whole economy.

All these efforts culminated in the convening of the United Nations World Food Conference held in Rome in November 1974 to provide a world form for debating the food problem. According to the World Food Conference Assessment report about 440 million people were underfed in 1970. Of these, 70 per cent were in the Far East, 15 per cent in Africa, 8 per cent in Latin America and 7 per cent in the Near East.4/ Moreover, before 1940 the developing countries were net grain exporters to the developed countries but around 1948 the grain net flow was reversed and it has grown larger ever since with grain exports being dominated by the U.S., Canada and Australia. Rather recent world food trade patterns show the worsening of the situation as follows:

- About 9/10 (nine tenths) of the exports of poor countries consist of food, feed and agricultural products.
- The U.S. ranks as the largest protein importer.
- The developing countries supply almost all the world trade with sugar, coffee, tea, cocoa, bananas etc.5/

4/ U.N. World Food Conference, "Assessment of the World Food Situation, Present and Future", Rome, 1974.

5/ "World Food Resources" by G. Borgstrom, Bucks, 1973

The Conference took note of these facts among others and recognized that the problems to be overcome were mainly political and economic rather than technical and that firmer political wills were required to achieve increased food poduction levels. Nevertheless, barring short-term modifications, four long-term factors are pressing on the world food supply as explained by Jean Mayer:[6]

(a) The explosive growth of human populations in the regions that are experiencing the greatest nutritional difficulties.
To better understand this process one should consider the phenomenon of demographic transition. It is a process whereby societies move from a level of high birth and death rates to one of low birth and death rates. Usually the decline in death rates precedes the decline in birth rates by from one to three generations. On both sides of the transition the result is a stable level of population. The developed countries have made the transition or are well on the way while the developing countries are now making the transition but have travelled varying distances through it.

(b) The changing patterns in food production and food counsumption. It points out that as societies become wealthier their consumption of animal products increases. The efficiency of converting plant food into animal food varies with the animal product but in no case is it higher than the 25 per cent conversion attained by milk and eggs. The net result is that rich countries consume far more food per capita than poor ones.

(c) The diminishing effectiveness of the fishing industry, an important source of protein for many poor countries, due to overfishing and water pollution.

(d) It has become apparent that the green revolution requires more time, work and capital than was thought of in the first flush of enthusiasm . The green revolution still has the potential of doubling or tripling grain yields in some areas, but requires large amounts of increasingly expensive inputs like improved seeds and fertilizers.

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[6] "The Dimensions of Human Hunger" by Jean Mayer, Scientific American, September 1976.

However, the battle to eradicate hunger and malnutrition is not lost. Complementing the socio-political alternatives there loom a number of technical possibilities among which are two quite promising for the future:

- The emergence of biological and agronomic technologies that may substantially increase agricultural productivity. [7]
- The second phase of the green revolution entails a socially and ecologically conscious approach to developing low-cost improved seeds and farming techniques to cater for the needs of the rural and urban low income groups. [8] This phase came about by realizing that in a number of countries root crops make up an important part of the diet and are a competitive source of calories with cereals, while pulses are a competitive source of proteins with cereals and animal products. [9] Root crops and pulses are the traditional products of the poor in many tropical zone developing countries whose agricultural yield has been very low for decades. The second phase of the green revolution sets out to redress this neglect.

1.2.2 Agricultural systems

Within the fairly complex agricultural systems, the sub-systems more closely related to nutrition and agriculture are the farming systems as providers of the world's food supply for fast growing populations.
In this context, farming systems are characterized by the dominant crops that have emerged in each area and region as result of ecological, biological, economic and social factors in the society that grows the crops. These systems are the survivors and results of a large amount of human experimentation. Notwithstanding the variations in farming systems, these can be identified by four basic approaches to cropping: [10]

(a) perennial tree or vine crops such as orchards, vineyards, rubber plantations;

(b) cultivated crops which are replanted in freshly tilled soil after harvest such as corn, wheat, etc.

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[7] "Impacts of emerging technologies on agricultural productivity projections" by Yao-chi Lu, Journal of the International Society for Technology Assessment, 1976.

[8] "Beyond the Green Revolution " by P. Harrison, New Scientist, 9 June 1977.

[9] "Meeting Food Needs in the Developing World", Research Report No.1, Feb.1976, International Food Policy Research Institute.

[10] op.cit. in [1]

(c) grazing of permanent grassland;

(d) alternation of cultivated crops with grass or other forage crop.

The interaction between ecological and biological factors determine whether it is feasible to introduce a certain crop in a given area, but the actual choice of crops and the manner and intensity of cultivation depend on the economic and social environment of the society that is doing the farming. It appears that the latter factors play as important a role as the first ones.

Over the centuries the interaction between biological and socio-economic factors has evolved an agriculture whereby cropping has been concentrated on plants that give a high return of product per unit of effort, whose biological performance is reasonably predictable and which satisfies basic nutritional needs.[11/] Through this process mankind now relies on 11 plant species for its nutrition. Most of the plant species represent large genetic complexes that are able to flourish in varied environments thus enabling a considerable substitution in cultivation and use.

Nevertheless, as a trade-off this process has created a risky crop vulnerability to epidemic deseases and pests through the genetic uniformity of modern high-yielding crops.[12/] The main contention of a number of plant scientists and pathologists is that in breeding high-yielding plant species for specific resistance capabilities dependent upon a single gene, the more general resistance capability characteristic of wild plants species is being lost.[13/] This problem is spurring, among several developments, bio-saline research to develop arid land agriculture as an alternative to temperate and tropical crops which depend on costly water supplies and energy-intensive technology developed for industrialized countries. A number of these arid land wild plants have formed the subsistance basis of native desert peoples for millennia.[14/]

[11/] "Farming Systems of the World", A.N.Duckham and G.B.Masefield, Chatto and Windus, 1971.

[12/] "Genetic vulnerability of major crops", U.S.Academy of Sciences,1972.

[13/] "Lasting immunity to Pests?", World Report, Ceres, Jan.-Feb.1978.

[14/] "Deceptive barrenness" by R.S.Felger and G.P.Nabhau, Ceres, March-April, 1976, and "How to help the Desert produce without Water", Research Report, Business Week, 28 Nov.1977.

The behaviour of farming systems as we know them today has at its core the farmer's assessment of risk and return and the government's agricultural policies, since most agricultural systems are very responsive to market conditions and social pressures.

Usually a modern farmer simplifies his problems by growing few crops with low risk of failure and high yield well adapted to local conditions. Frequently this task requires minimizing plant diversity and emphasizing a high transfer of nutrients and photosynthetic productivity to food crops and cash crops through weeding and pest control. This type of streamlined farms is possible only with machines or where labour is cheap.

However, in subsistence farms a greater diversity of low-yielding food crops is usual and customarily the farmer sells part of his food to cater for his remaining needs.

The most important single objective in farming is to increase crop yield and agricultural productivity. The wide range variations observed in different regions and years are basically due to two elements: [15]

(a) Differences in natural factors but whose ecological risk factors can be substantially modified by technology. The type and amount of technology employed are based on existing markets and social environment. Different resources are optimized in the various farming systems. However, the transfer of technology in agriculture is not a simple process because the biological components of agricultural technology need to be tailored for each location and developed in it. The lead times of this process take much longer than in industrial sectors.

(b) Differences in farm management and production intensity, for they are highly responsive to market and social conditions. Therefore management decisions are determinant in the amount of resources given to each crop and the level of farming effort required to achieve the desired output.

Nevertheless, the very success of modern farming mainly in the U.S. has depressed world food markets for several decades by offering low cost food and food aid to developing countries. Thus most developing countries

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[15] op.cit.[1]

stimulated the expansion of more profitable cash crops for export while domestic food production was discouraged by maintaining low cost food policies for their growing populations thereby ensuring a low return on investment for their own formers.

In general, two basic farming systems exist: 16/

(i) Traditional farming systems: comprise only man, a few tools, his animals, his seed and his land with little involvement of the government and industry or for co-operation with other farmers. These systems are usually labour intensive and quite diversified thereby distributing crops and labour requirements more evenly. On the other hand, the risk from natural factors is quite high even though it is averaged over several crops. This type of low intensity farming including subsistence farming, is very old and characterizes traditional agricultural practices in many of the developing countries. Many of these systems are quite finely tuned with the environment and demand very low external inputs such as fertilizers or machinery, in fact they have achieved a steady ecological state that might be maintained indefinitely.

Provided the population level is held within the food supply capability of these systems they are as safe as any that could be devised in spite of their crop yields being considered low by modern standards. The main characteristic of these systems is to optimize the natural supply of nutrients from a variety of sources.

(ii) Modern farming systems are based on science and technology and were generated mainly by consumer demand. This agricultural pattern has been fostered by research and educational institutions, industry and governmental bodies, and by the efforts of increasingly sophisticated and innovative farm populations. This type of intensive farming that created the green revolution and the agribusiness is the result of economic, social and political pressures made possible by a combination of three technological factors: 17/

16/ "The Agricultural Systems of the World: An Evolutionary Approach", D.B.Grigg, Cambridge Press, 1974, and "Food and Agriculture",Sterling Wortman, Scientific American, September 1976.

17/ "The Agricultura of Mexico", E.J.Wellhousen, Scientific American, September 1976.

- the genetic development of new, high-yielding plant varieties that are widely adaptable, responsive to fertilizer and resistant to disease;
- the development of an improved package of agricultural practices that enable the improved plant varieties to fully realize their high yielding potential;
- a favourable benefit/cost ratio for the farmer between the cost of fertilizer and other inputs and the price of crops.

In highly intensive farming such as in Japan, Holland and Israel, the main characteristic is to optimize the amount of sunlight by supplying nutrients for achieving a high yield per hectare in order to keep production levels close to the potential offer by biology and climate. In medium intensive farming such as in the U.S., the main characteristic of its machine-oriented system is to optimize labour in an environment where land, energy and capital are still relatively cheap.

Modern farming systems are relatively safe concerning a steady food supply provided they receive proper maintenance, inputs, research and high priorities for land and energy use.

The risks associated with the weather and other natural factors are usually countered by the farmer through two basic strategies: one, spatial diversification that involves raising the same crop in different places, and two, enterprise diversification that entails raising several crops in the same place.

During the present decade a third farming system is emerging that could be called ecological farming which aims at co-operating with nature rather than manipulating nature to make it perform in a specific way. Its operation in the developed countries is through ecologically conscious organic farming based on utilizing improved seeds, new cropping methods, partial mechanization, and composting for soil fertility. On the grounds of pollution and ecological damages it bans chemical inputs.[18/] This farming system is socially significant although its contribution to the economy is still marginal. Its main markets are health conscious consumers usually shopping in health stores although organic crop products are already being sold in supermarkets and food chains at premium prices. Its production is mainly by small farmers and a few medium-sized agribusinesses.

[18/] "The Closing Circle", B. Commoner, J.Cape, 1972.

In the developing countries this ecological farming concentrates on root crops and pulses carried out by poor small farmers to feed both the rural and urban poor. It is based on improved seeds being adapted to local conditions, new agricultural practices and very moderate amounts of other inputs like fertilizers (mainly composting and some chemical fertilizers) and simple tools and machinery. The basic biological research to produce the new high-yielding seeds able to adapt themselves to a variety of tropical and semitropical environments, and their ability to live and thrive off the environment without much man-given external inputs, are currently being developed by a growing network of national and international agricultural research and training centres throughout the developing world. The spur to develop this approach came after realizing that under the first phase of the green revolution the poor farmers became even poorer due to their lack of means to buy the expensive inputs demanded by modern farming systems. 19/

1.2.3 Fertilizers and agriculture

From time immemorial man settled for farming in easily arable fertile land rather than rely only upon food gathering from wild plants. He soon observed that some soils produced better crops than others and that the addition of organic residues to the soil resulted in substantially increased crop yields. Thus started the long-standing quest for ever-increasing agricultural yield that is currently agriculture's main objective.

The factors that determine agricultural yield are complex for the photosynthetic potential of the plants is usually limited by other elements such as nutrients, moisture and climate. From these, plant nutrition is the one that presents the more serious questions for the future of agriculture because at a certain stage the production rate of well-established farming systems will come to equilibrium with the supply rate of nutrients. 20/ The major source of plant nutrients is the mineral supply of the soil. This supply varies with the type of soil and ecological conditions in the area, and accounts for the large differences in fertility between temperate, tropical and arid soils.

19/ "Beyond the Green Revolution", op.cit.in 8/, "Waste not, Want not", N.W.Pirie, New Scientist, 28 July 1977, and "The Eight Myths of Hunger", F.Moore and J. Collins, Ceres, July-August 1977.

20/ op.cit. in 1/

At present the main limiting nutrient in agriculture is nitrogen for crop plants which have a high capacity for photosynthesis and can utilize far more nitrogen than they are likely to receive from natural sources. Native soil nitrogen occurs mainly in the organic fraction or top soil and its availability is chiefly due to micro-organisms which fix atmospheric nitrogen and decompose organic matter.

Following the introduction of farming on virgin soils, the organic matter content which was in a state of equilibrium starts declining and nitrogen plus other nutrients are released until eventually another equilibrium level is attained. Sooner or later the organic matter in the soil will reach a level at which as much nutrient must be added as removed by the crops, otherwise the organic matter level would continue to decrease until it reaches zero and the soil becomes barren.

The most significant discoveries concerning plant responses to mineral fertilizers have been known for over a hundred years. However, more than 50 years went by before this knowledge began to be significantly applied in practical farming in the world. At the beginning of this century commercial fertilizers were applied to less than 1 per cent of the world's farmland and mainly in developed countries. The world's supply of nitrogen was based on saltpetre and ammonium sulphate, that of phosphorous on superphosphates and Thomas slag, and potash was supplied by potassium saltsproduced by mining operations. Initially the commercial fertilizers were used for higher priced cash crops in Western Europe and the U.S. while food crops still relied on natural soil fertility which was exhausted to a considerable extent. The commercial availability of synthetic fertilizers by the mid-1910's enabled its application to food crops thus substantially contributing to a severalfold increase in crop yields. However, fertilizers alone cannot produce substantial crop yield increases without highly efficient seeds and improved agricultural practices. In spite of this fact, it has become common practice to directly correlate increases in fertilizer consumption with increases in crop yield per hectare on convenience grounds since the consumption of plant nutrients is that factor which can easily be dealt with statistically. 21/

21/ "Hundred Years of Increasing Crops thanks to the Use of Commercial Fertilizers", F.Baade, Study Week on the Use of Fertilizers and its Effect in Increasing Yield with Particular Attention to Quality and Economy, Pontificia Academia Scientiarum, 1973.

Nevertheless, after more than a hundred years after the proclamation of the doctrine on mineral plant nutrition by J.V.Liebig, two opposed attitudes concerning chemical fertilizing still persist: [22]

(i) the attitude of the agronomists who are concerned with unitary yields and see in the fertilizing of crops, no matter how it is applied, the basic means to obtain a higher crop yield;

(ii) the attitude of the hygienists who see in chemical fertilizing a forcing of the productive capacity of plants with disadvantages on the qualitative and health levels.

The truth might lie between these two positions, for food quality requirements should be balanced with a complete and equilibrated crop manuring. Nevertheless, in practical and economic oriented agriculture, fertilizers constitute one of the most effective technical factors to increase crop yield and farmers' incomes.

This situation is highlighted by the average yields of wheat and maize in various countries for two critical periods: (i) immediately after World War II where the availability of commercial fertilizers was limited, and (ii) just after the green revolution as illustrated in Table 1.

Table 1

	Average yield of wheat (Kg/ha)		Average yield of maize (Kg/ha)	
Country	1948-52	1965	1948-52	1965
USA	1,120	1,790	2,490	4,630
USSR	840	830	1,310	2,440
India	660	910	650	990
Mexico	880	2,470	750	1,140
Brazil	740	760	1,260	1,380
Chile	1,190	1,500	1,420	3,030
Turkey	1,000	1,070	1,250	1,530
Greece	1,020	1,770	920	2,003

Source: FAO Production Year book, 1966

During the period 1948-52 the average yields of the various countries were reasonably close despite the differences in continents, latitudes, climate, seed varieties and agricultural practices, thus reflecting the yields obtained in traditional farming systems. However, in the U.S. the use of chemical fertilizers was rapidly being adopted specially for maize.

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[22] "Soil Fertility and Fertilizing of Cultivated Plants", O.T.Rotini, Study Week on the Use of Fertilizers, Pontificia Academia Scientiarum,1973.

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SECOND WORLD-WIDE STUDY ON THE FERTILIZER INDUSTRY:
1975–2000

PREPARED BY THE

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Hence while the U.S. yield of wheat was similar to the other countries, the yield of maize was about double that of the other countries thanks to improved seeds and intensive fertilization. During 1965, immediately after the green revolution was successfully started in Mexico with the new dwarf and semi-dwarf wheat varieties, Mexico's wheat yield tripled the 1948-52 world average yield and far surpassed that of the other countries. In maize, the U.S. had about quadrupled the 1948-52 world average yield and some other countries like the USSR and Chile had doubled it. In the countries in which yields greatly increased,the use of chemical fertilizers was also markedly incremented.

An example of the interrelation between fertilizers, crops and ecology is provided by wheat production in Mexico. In the early 40's Dr.N. Borlaugh started the lengthy process of breeding new wheat varieties specific to Mexican conditions since the trials to raise the yields of local wheat varieties by fertilizing and good farm management were unsuccessful. Only when reliable sources of quality seed of the newly developed dwarf wheat varieties were available, did it become possible to apply larger amounts of fertilizers and to harvest more grain instead of more straw.

The enhanced profitability of wheat production, in turn, induced the Government of Mexico and other farm organizations to improve irrigation and drainage systems, to increase the supply of chemical fertilizers, and to strengthen agricultural institutions. Thus started the green revolution by solving the basic biological problems that were holding back wheat production in Mexico and rice in South East Asia, and are today still obstructing progress in many other areas of the world which have major crops and animals.[23]

From here on it has been proved that governments can take effective action if the will exists, and that many farmers will adopt new agricultural technologies if they see it demonstrated in their own area, as the examples of Algeria, Brazil, India, Malaysia, Mexico, Pakistan, Philippines and elsewhere have shown.

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[23] op.cit.17/

Nevertheless there is a need to devise agricultural and rural development systems for the large number of farmers and rural people who are intelligent but uneducated, and who are not yet in a position to undertake on their own the innovation required at the farm level as is customary in the developed countries. Based on the above the approximate chemical fertilizer use pattern that has evolved in the developed and developing countries is as follows:

(a) Fertilizer use pattern typical of several tropical and subtropical developing countries:

Cereal grains	50-70%
Other food crops	20-30%
Non-food crops	10-25%
Grassland	nil
Non-farm use	nil

(b) Fertilizer use pattern typical of some temperate zone developed countries:

Cereal grains	40-60%
Other food crops	15-25%
Non-food crops	5-20%
Grassland	0-20%
Non-farm use	0-10%

According to various estimates [24], in world agriculture as a whole chemical nitrogenous fertilizers represented about 30 per cent of the total nitrogen metabolized by crops in 1974. The world chemical nitrogenous fertilizer application was 42.4 million tons in 1974. The world annual biological nitrogen fixation amounts to about 89 million tons, i.e. 35 million in legumes, 9 million in non-legume food crops and 45 million in pastures. Probably another 45 million tons of atmospheric nitrogen are fixed annually by lightning, ozone and combustion, and part of this nutrient is deposited on the earth's farmlands.

The economics of fertilizer use, from the farmer's viewpoint, is reflected in his rational choice of a fertilizer policy adapted to the ecological conditions. This is usually decided upon by considering numerous criteria such as farming systems, crop sequences, expected yields, soil characteristics and reserves, desired quality of products, fertilizer/crop-cost/benefit, etc.

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[24] "The Resources available for agriculture", Roger Revelle, Scientific American, September 1976.

The objective of a fertilizer policy is to ensure, under the best economic conditions, the proper nutrition of crops for attaining their anticipated quality and yield while maintaining or improving soil fertility within the farming system practices. The principles on which a fertilization policy is based are two: [25]

(i) The selection of crops which can be raised and the size of their attainable yield are largely determined by the temperature, water supply, topography and the kind of soil; hence crop sequences and nutritional requirements are very dependent upon these ecological parameters.

(ii) The nature of the soil, its physico-chemical properties, its biological activity and its natural or acquired mineral reserves which entail different basic and annual manuring according to the situation, the expected yields and the rotations.

However, very often the advice given to farmers on fertilizers has frequently been established on the basis of one given, high-yield crop, not adapted to its ecological and socio-economic context. Yet this context is determinant for soil characteristics, crop selection and location in the crop rotation, yields attainable and farmers' effort and income. Since fertilizers are becoming expensive inputs wastefully applied (crops usually absorb about half of the fertilizer used in intensive farming systems), and this excess fertilizer may have injurious effects on soil fertility and crop economics, it is desirable that a rational fertilizer policy based on soil testing and ecological adaptation be devised for establishing an effective system for recommending fertilizers to the farmers. [26]

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[25] "Fertilizer use and Ecological factors", R.Blanchet, Study Week on the Use of Fertilizers, Pontificia Academia Scientiarum, 1973.

[26] "Adjusting Fertilizer Rates to Soil Fertility Levels on the Basis of Soil Testing", F.van der Paauw, Study Week on the Use of Fertilizers, Pontificia Academis Scientiarium, 1973.

II. GLOBAL ASSESSMENT OF THE FERTILIZER INDUSTRY: PAST AND PRESENT WORLD SITUATION

2.1 TYPOLOGY

The study adopts FAO's world classification by economic classes and regions to ensure its international comparability with other previous and on-going work in this field. However, taking into account the needs of the consultation meetings on the fertilizer industry, it was deemed useful to reduce the number of regions from FAO's eleven regions to the seven regions that have regional and economic significance for UNIDO's consultations and negotiations process. Table 2. below gives the classification used in the study and its correlation with FAO's classification.

Table 2.

Classification by economic classes and regions

- Developed countries
  - (a) Developed market economies correspond to FAO's Class I, Regions (a) to (d): Canada, U.S.A., Austria, Belgium, Denmark, Finland, France, Germany Federal Republic, Greece, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, Channel Islands, Isle of Man, Yugoslavia, Australia, New Zealand, Israel, Japan, South Africa.
  - (b) Developed centrally planned economies correspond to FAO's Class III, Region (b): Albania, Bulgaria, Czechoslovakia, German Democratic Republic, Hungary, Poland, Romania, USSR.
- Developing countries
  - (c) Developing market economies
    - (i) Africa corresponds to FAO's Class II, Region (a): Algeria, Angola, Benin, Botswana, Burundi, Cameroon, Cape Verde, Central African Kingdom, Chad, Congo, Equatorial Guinea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Ivory Coast, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Niger, Nigeria, Reunión, Rhodesia, Rwanda, Senegal, Seychelles, Sierra Leone, Somalia, Spanish Sahara, Swaziland, Tanzania, Togo, Tunisia, Uganda, Upper Volta, Zaire, Zambia.
    - (ii) Latin America corresponds to FAO's Class II, Region (b): Argentina, Barbados, Bolivia, Brazil, Belize, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Mexico, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, St.Kitts-Nevis-Anguilla, St.Lucia, St.Vincent, Surinam, Trinidad and Tobago, Uruguay, Venezuela, Virgin Islands (U.S.)

(iii) Near East corresponds to FAO's Class II, Region (c): Afghanistan, Bahrain, Cyprus, Egypt, Iran, Iraq, Jordan, Kuwait, Lebanon, Libyan Arab Jamahiriya, Oman, Qatar, Saudi Arabia, Sudan, Syrian Arab Republic, Turkey, United Arab Emirates, Yemen Arab Republic, The People's Democratic Rep.of Yemen.

(iv) Far East corresponds to FAO's Class II, Regions (d) and (e): Bangladesh, Bhutan, Burman,
nesia, Republic of Korea, Lao People's Democratic Republic, Malaysia (Sabah, Sarawak, West Malaysia), Nepal, Pakistan, Philippines, Singapore, Sri Lanka, Thailand, Christman Is. (Aust.), Fiji, French Polynesia, Gilbert Islands, Nauru, Papua New Guinea.

- Developing centrally planned economies

(d) Developing Asian centrally planned economies correspond to FAO's Class III, Region (a): China, Democratic People's Republic of Korea, Mongolia, Socialist Republic of Viet Nam.

2.2 GENERAL CHARACTERISTICS OF THE FERTILIZER INDUSTRY

The main characteristic of this industry is to produce standardized chemical fertilizers but to sell performance fertilizer compounds to farmers. Furthermore, the principal fertilizer intermediates such as ammonia, nitric acid and phosphoric acid have important industrial uses. Although production can be made by single-plant specialists or multi-plant operators, it usually has to supply a very extended multi-market distribution network with fertilizer formulations able to realize the yield potential of the farmer's crop in his own land.

The main characteristics of the fertilizer industry are widespread markets made up of very large numbers of small consumers, the technical complexity of its plants and processes, the large scale of operations in the production of its primary commodities, the large bulk and relatively low value of its products, and its low personnel requirements.

2.2.1 Markets

The fertilizer industry differs from other major industries in that it does not have a variety of markets for its products; it depends entirely upon agriculture. This dependence means that the growth and well-being of the industry depend upon the growth and well-being of agriculture, and that the nature of agriculture, its problems and hazards, has a major influence upon the industry.

(i) The growth of world population and the inadequate diet of many millions of people would appear to assure the industry of a growing market into the foreseeable future. One of the salient facts about the industry is indeed its rapid growth. Over the past 25 years it has grown at nearly 8 per cent p.a.

and has doubled in size every ten years. It is questionable whether growth can continue at this overall rate for much longer because of the limited scope for increased fertilizer application in many developed countries, but steady though less spectacular growth is possible.

However, the need for more food (and more fertilizers) does not automatically result in its production. Commercial factors enter; the farmer must have a reasonable prospect that the use of fertilizer will increase his income. This depends upon two basic factors, the increase in crop yield from a ton of fertilizer, and the ratio of crop prices to fertilizer prices. The farmer himself has some control over the first of these factors, but his efforts may be frustrated by the weather. The fertilizer manufacturer has some control over fertilizer prices but none over crop prices.

(ii) The market is composed of a multitude of small consumers. Their numbers may be reduced by the formation of co-operatives or purchasing organizations, but will always be large. The sales and distribution organizations therefore have to make contact with a very large number of small consumers, which leads to relatively high selling expenses. This does not apply to export markets, where sales are usually made to large importers or to government organizations and contracts cover large quantities.

(iii) In most countries fertilizer use is seasonal, often highly seasonal; and since production is continuous, the manufacturer or distributor has to provide large stocks, whose location is affected by the ability of the transport systems to cope with seasonal traffic.

(iv) The demand for fertilizers is not in general highly sensitive to price changes because the rate of use is in many areas well below the economic optimum. Sensitivity is greater in the developed countries where application rates, in some countries, are fairly high. The three-to-fourfold increase in export prices in 1974/75 did result in the first drop in world consumption (by just over 3 per cent in 1975) for over thirty years. The decrease occurred mainly in developed countries.

(v) A characteristic of the industry is that there is relatively little product competition. Urea from one manufacturer may have slightly better storage and handling properties than from another, but the basic thing about urea is that it contains 46 per cent nitrogen. A particular manufacturer may have the edge in a particular area because of his long connection with it. But in the main, the difference between similar products from one manufacturer and another is very small. Competition is basically in price, reliability of supply, and service to the farmer.

Though there is relatively little product competition there may be severe general competition in export, and indeed in domestic markets, caused by a surplus of production capacity. This phenomenon is not peculiar to fertilizers, it is common to many international commodities. In the late sixties and early seventies there was a slight excess of supply over demand and export prices, e.g. urea at $ 50-60 a ton, were in general below home market prices, but from 1972 to early 1975 fertilizer was in increasingly short supply and export prices soared to a peak of $ 350-400 a ton of urea in 1974/75. They have since settled down at about $ 125 a ton. The 1973 rise in oil prices an the large increases in phosphate rock prices contributed to the rise but by far the greater part of it was due to market forces.

(vi) Because the maintenance of stable and growing markets is essential for its prosperity the industry has a vested interest in seeing that the farmer gets the maximum benefit from the use of fertilizers and has traditionally devoted much effort to providing advisory and extension services whose function is to demonstrate the value of fertilizers, to advise the farmer on their use and to ensure that as far as practicable, agricultural practices and inputs are such as to secure the best results. However, it is not possible for the industry, particularly in developing countries, to provide adequate services of this nature for all the country's farmers, and the development of the industry's market must depend to a large extent upon government efforts in this field.

2.2.2 Technology

(i) Like the chemical industry, the fertilizer industry is technologically complex and sophisticated in its processes and in the equipment it uses. It depends for its progress on research and development. All large fertilizer companies have heavy research expenditure and their research departments assist in solving problems of plant operation, in improving processes, in devising new processes for existing products, and in discovering and marketing new and better products. The fertilizer industry is also involved in agricultural research, especially when new types or formulations of fertilizers are introduced to the market.

The dependence of the industry on research subjects it to continuous change, caused partly by the development of new products and processes and partly by developments in the engineering and plant construction industries. The changes may be gradual and relatively minor, affecting types of equipment, instrumentation and control systems, or particular stages in a complex process, but their effect is cumulative so that a plant gradually becomes out of date and uncompetitive. On the other hand changes may be major and far-reaching, rapidly making existing plants uncompetitive. In recent years the effect of these changes had been reduced by inflation, which prolongs the life of an otherwise uneconomic plant, because it would cost so much more to replace it.

(ii) Because of its technological complexity the industry requires numbers of highly trained and experienced technical staff, in its research activities, in the design, construction and operation of its plants, and in the sales force. Plant design is almost exclusively the province of graduate or equivalent staff most of whom have spent some years in plant construction and operation. Construction and operation employ many more skilled operators, and a variable number of unskilled people. In operation the number of unskilled people employed depends upon the extent to which the handling of solid raw materials and final products is mechanized.

Thorough training of all grades of employees, particularly maintenance craftsmen and plant operators, is essential for satisfactory plant operation and final results.

(iii) Fertilizer plants, particularly nitrogen fertilizer plants, are large consumers of energy and of water. This affects their siting and increases their demands upon the infrastructure of the area in which they are established. A reliable power supply is essential for successful operation and many plants are designed to produce their own power requirements.

(iv) The products of the industry, like its raw materials, are relatively low-value, high-bulk materials and are handled in very large quantities. A large plant produces half a million or more tons of solid fertilizer a year and may use up to a million tons of raw materials. In 1975 the industry produced about 200 million tons of fertilizers and used roughly 35 billion cubic metres of natural gas, 20 million tons of naphtha, fuel oil and coal, 90 million tons of phosphate rock, 20 million tons of sulphur and 40 million tons of potash salts. About 30 per cent of the 200 million tons was traded across national boundaries. Transport costs are an important component of the industry's costs and are often decisive in selecting a factory location. An adequate, efficient and reliable transport system is of prime importance to the industry.

(v) Because of the nature of the raw materials and intermediate products and of the processes used, fertilizer plants have potential environmental hazards. Many of the processes operate at high temperatures and pressures and deal with inflamable materials; the materials processed or produced may be harmful to animal and plant life or may adversely affect the quality of the environment. Damage may occur through gaseous, liquid or solid effluents which are continually discharged, through occasional accidental leakage or through major accidents.

The prevention of leakage or major accidents depends initially upon satisfactory design of plant and equipment, but it is primarily the responsibility of plant management who must be technically qualified and alert and give painstaking attention to regular and reliable maintenance, and to the provision and enforcement of safe operating and maintenance procedures.

Stringent environmental standards are mandatory in most developed countries; modern fertilizer plants are normally designed to meet these standards under the most unfavourable operation conditions. In normal operation, therefore, effluent quality is better than that legally enforced. These standards are not maintained without cost; the amount spent on equipment to control pollution varies widely according to the type of plant but on average amounts to 10-15 per cent of the cost of the plant.

2.2.3 Capital requirements

The fertilizer industry is capital intensive, i.e. the capital employed per worker is high, with the corollary that the cost of capital is a significant, sometimes a major part of the cost of the product. A large nitrogen fertilizer plant producing half a million tons of fertilizer a year costs between $ 200 and $ 300 million, depending on its location and the infrastructural development required. This corresponds to $ 0.3 to $ 0.5 million per man employed.

(i) It is therefore essential to use capital efficiently. This requires minimizing capital costs by careful decisions on what is and what is not essential, the selection of an experienced and reliable contractor, the avoidance of delays during construction and the maintenance of high "on line" time for the plant. Because of the high capital charges no factor has so drastic an effect upon production costs as loss of output caused by involuntary shut-downs of the plant. At total capital charges of about 20 per cent, the production costs on a large urea plant increase by about 20 per cent when output is 20 per cent below the design rate, and by about 50 per cent when output is 40 per cent down. Under these conditions profits disappear very quickly.

Because production costs are so sensitive to output it is important to maintain a stable and growing demand for fertilizers. A decrease in demand and a loss of markets which requires a restriction in output has a serious effect upon profitability. The industry therefore devotes much effort through technical and agronomic advice and other services to farmers, to maintaining and increasing its markets.

(ii) A further consequence of the high capital requirement is that production costs decrease markedly as plant size increases, because capital costs per unit of output are greatly reduced. The level of output at which this effect becomes small is today about 1700 tons a day for a urea plant. If we assume urea production cost, including 23 per cent capital charges, to be $ 150 a ton for a plant producing 1700 tons per day (t.p.d.) from natural gas, the cost for a 1000 t.p.d. plant would be over $ 170 a ton. The difference is large, and on a competitive market can make the difference between success and failure. Consequently, very large plants have become almost standard in the nitrogen fertilizer industry, and sizes have increased considerably in other branches of industry.

Because the units producing primary products are large, the number of primary producers in any one country is small and the typical industrial structure is one in which production is dominated by a few large organizations. Depending upon the way in which the industry has developed, there may be a number of much smaller secondary producers, taking primary products from the major firms and combining them to suit the needs and preferences of a local market.

(iii) Because the industry is capital intensive the policy adopted in fixing depreciation rates and the rate of return on investment has a major effect upon fertilizer prices. In the fertilizer industry depreciation rates are normally between 8 per cent and 10 per cent. In fixing a rate due regard should be paid to the effect of inflation upon replacement costs.

2.2..4 Summary

To summarize this discussion, the characteristics considered, and the major effects, are set out below in tabular form.

Characteristics	Major Effects
Technological complexity	- Rapid technical change - high obsolescence - High demand for technical knowledge and skills - Environmental hazards - Large energy and water consumption
High bulk/low value products	- High transport demands
Capital intensive	- High capital charges - importance of depreciation and R.O.I. - High plant utilization necessary - Major economies of scale - large plant units
Markets	
Only one market	- Growth depends on agricultural prosperity
Large number of small consumers	- High distribution and selling costs
Seasonal	- Large storage capacity needed-peak transport demands
Standardized products	- Little product competition
Close supply/demand balance	- Occasional severe price fluctuations in export markets

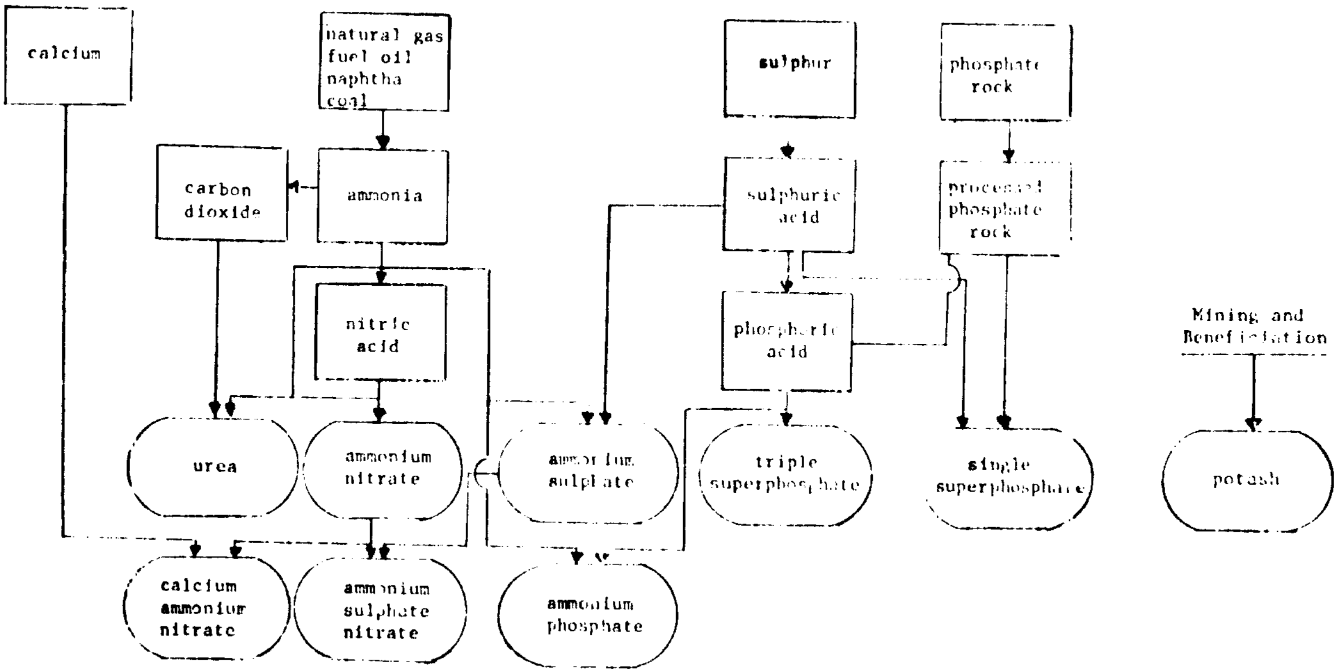
The main structure of the fertilizer industry is shown in the charts below:

FERTILIZER PRODUCTS

	Nitrogen			Phosphate		
	Product	Abbreviation	Nutrient Content	Product	Abbreviation	Nutrient Content
Intermediate	Ammonia	AM	82% N	Phosphoric Acid	PA	54% P_2O_5
End Products and Compounds	Ammonium Nitrate	AN	35.0% N	Single Superphosphate	SSP	21% P_2O_5
	Urea	U	46.0% N	Triple Superphosphate	TSP	46% P_2O_5
	Ammonium Sulphate	AS	20.5% N	Mono-Ammonium phosphate	MAP	11% N, 52% P_2O_5
	Ammonium Sulphate Nitrate	ASN	26.0% N	Di-Ammonium phosphate	DAP	18% N, 46% P_2O_5
	Calcium Ammonium Nitrate	CAN	26.0% N			

Potassium	
Product	Nutrient Content
Potash (Muriate)	60% K_2O
Sulphate of Potash	53% K_2O

FLOW CHART FOR THE FERTILIZER INDUSTRY



NOTE: Boxes with square edges contain raw materials and intermediates. Boxes with rounded edges contain fertilizers.

2.3 WORLD PRODUCTION OF FERTILIZERS

2.3.1 Factors affecting the production of fertilizers

There are a number of factors that affect the establishment of this industry arising from technical, economic, social, environmental and political areas. The analysis of the more important of them may enable us to gain a better insight into the structure, evolution and localization of the fertilizer industry in the world.

(a) Existence of a market

The existence of an effective and potential demand for fertilizers is the first precondition for setting up this industry, although there may be a large unfulfilled fertilizer need to boost food production that may not be realized due to the farmers' lack of purchasing power in developing countries. The rapid development of this industry in the last 30 years is due to its unique position as one of the most efficient means to increase crop yields, agricultural productivity and farmer incomes.

Its markets grew faster through heavier fertilizer application to food crops enabled by new quality seeds and improved farm management practices. Furthermore through modern farming methods that rely heavily on fertilizers, non-food farm produce is gaining cost competitiveness and improved characteristics by competing artificial and synthetic products, in order to counter the large market inroads. This is the case of cotton, wool, natural rubber.

(b) Availability of raw materials

This industry concentrates on producing fertilizers containing the three main plant nutrients: nitrogen, phosphorus and potash.

For establishing the nitrogen fertilizer industry ammonia or its main raw materials nitrogen and hydrogen should be available. The former is usually extracted from the air while the latter can be produced from fossil fuels, water or biomass through a variety of processes such as cracking, electrolytic dissociation and fermentation.

The concentration and development of this industry in the world took place in the developed countries due to the availability of favourably priced raw materials: natural gas and naphtha. With the fourfold oil price increase in 1973 naphtha became uncompetitive with other sources, while the rapidly expanding domestic and industrial uses of natural gas in the developed world is rapidly pricing out their basic fertilizer industry from the world markets. Currently the most important factor is the local availability of suitably priced natural gas which favours gas producing countries since a comparison of transport costs between liquified natural gas and ammonia gives a clear margin to the latter.

To set up a phosphorus fertilizer industry two basic raw materials are required: phosphate rock and sulphur. Although phosphate rock is easy to handle, its relatively low content of nutrient (30-34 % of P_2O_5) renders its transport cost incompetitive against that of phosphoric acid. There are 34 rock producing countries but the United States, USSR and Morocco account for over three fourths of current world rock production, while Morocco holds near 75 per cent of world rock reserves. Hence a significant shift is developing towards production of phosphoric acid by rock-producing countries and exporting the acid as the principal intermediate for this industry. Thus elementary sulphur demand for fertilizer purposes may tend to become concentrated in rock producing countries.

The potash fertilizer industry is usually established in those countries having potash deposits and creating an integrated mining/chemical operation. There are 18 countries with potash deposits but three of them: USSR, Canada and the Democratic Republic of Germany account for about two thirds of current world production and almost 90 per cent of world reserves.

(c) Existence of adequate infrastructure

The cost of the infrastructure required for setting up a fertilizer plant varies from place to place but it was tentatively estimated at 60 per cent of the battery limits costs for developing countries although in a grass-roots location it may well go up to 100 % thus doubling the direct plant investment costs. This factor will effectively penalize these producers against those established in a well developed site and may require important compensations for the plant to gain competitiveness. These compensations may include preferential raw material prices, grants, tax incentives, protected higher fertilizer prices, subsidies, etc.

The infrastructure usually required for production comprises the basic physical, transportation, utilities and materials handling infrastructures.

(d) Availability of manpower

The technological level of the fertilizer industry is quite sophisticated involving up-to-date technical developments in several disciplines such as chemistry, metallurgy, electronics, mechanics. The personnel needed to operate and maintain the modern fertilizer plants is relatively small and specialized.

Moreover, considering the large plant investments required and the need to operate at very high plant capacity rates to stay profitable, it is advisable that plant operation and maintenance be handled by experienced personnel. A generally supported view is that in developing countries the training and supply of operating staff are adequate but the skills likely to be scarce and critical are: engineering tradesman and maintenance staff, construction staff, management and marketing. The need to prepare and maintain efficiently trained personnel is a decisive factor and training involves considerable expenditure.

(e) Means for financing investment needs

The fertilizer industry is a capital intensive activity that requires considerable financial outlays. Access to means of financing these large investments is one of the major elements in deciding to establish this industry.

It has been estimated that for the period 1975-1980 the cost of new fertilizer plants may be broken down between foreign exchange costs (about 60 per cent) and domestic expenses (about 40 per cent). Currently a number of investment institutions require that the equity to loan ratio for fertilizer plants should vary between 1:1 to 1:2. Case studies on 10 plants recently built in developing countries show that the government or a government institution has provided a major part of the domestic financing and equity capital.

In countries where this industry is already established, the financing of new plants was facilitated by substantial retained earnings resulting from favourably priced raw materials. However, fertilizer prices may be controlled at a level that does not allow existing enterprises to accumulate enough funds from retained earnings. Furthermore, since construction and plant costs have risen sharply during this decade part of the earnings may be diverted to supplement depreciation provisions and cater for inflation. Therefore additional financing sources may be needed to build new plants.

(f) Technology aspects

The fast growth of the fertilizer industry was made possible through the continuous perfecting and improving of its technology thanks to the large sums devoted to research and development by leading chemical enterprises.

These steady innovative efforts account for the sophistication and relative complexity of fertilizer technologies and for the upheavals that ripple within the industry whenever a new technique is perfected and applied commercially.

The technologies involve not only improvements in production processes and product quality but also agricultural oriented research on crop responses to fertilizers under farm conditions. The feedback between the industrial and agricultural research efforts leads to lowering production costs and improved quality characteristics of fertilizers up to fertilizer formulations and its farm applications. The fertilizer technology market is highly competitive but the problems that occur in developing countries are not so much related to acquiring know-how as to its more effective utilization. The choice of technology should not be made without assessing the existing technological basis and know-how available in the country, to ensure a more effective technology absorption.

The partial mastery of the technology is usually reflected in five most widely experienced technical constraints on full capacity utilization: deficient plant design and quality of equipment, plant bottlenecks, lack of spare parts, unreliable power supply, and unsuitable sources of cooling water.

Furthermore, when choosing plant sizes and sites the most important factor is not to reduce production costs alone but to minimize production and distribution costs.

2.3.2 Development of the fertilizer industry

2.3.2.1 Evolution of the fertilizer industry

Although methods for conserving soil fertility were known from time immemorial they were restricted to the use of fallow, organic manuring and some mineral applications such as liming and coprolites. With the advent of the Industrial Revolution there was an upsurge in population coupled with rural migration to the growing urban industrial centres. These factors increased the pressure on agriculture to produce more with less people, thus speeding up the study of agriculture and the increasing use of natural fertilizers such as guano, bone meal and Chilean nitrate.

The announcement in 1840 of the later-called doctrine of mineral plant nutrition together with the new manufacturing methods brought about the chemical fertilizer industry. Superphosphate production began in 1843, potash fertilizer production started in 1861 and nitrogenous fertilizers were first manufactured in 1902.

(i) The first fertilizer industry, that of phosphate, initially began production using bones as raw material, later changed to ground coprolites which by 1885 were replaced by phosphate rock that due to its abundance truly enabled the rapid development of this industry. Since the beginning of this century the trend in the phosphate industry has been the removal of alkaline-earth metals, like calcium from the phosphatic fertilizers, in order to increase their nutrient content, reduce ballast and raise its water solubility. This trend reached its peak with the advent of multinutrients such as ammonium phosphate and potassium phosphate that contain no alkaline-earth metals at all. Apart from fertilizers like Thomas slag and direct phosphate rock applications, the production of phosphate fertilizers requires large amounts of phosphoric acid as its main intermediate product. During the 1960 s the acid was a captive commodity but in the 1970 s the acid accounts for more than half of the total rock demanded as raw material and a booming trade in acid was created.

(ii) The second to come, the potash fertilizer industry, was first known as a waste product of the rock-salt mining development that began in Germany in 1843. The initial disappointment of finding a large strata of potassium ores above the rock-salt that had to be heaped as waste gave way later on to acknowledge its value as a source for the supply of potash for plant nutrition. In 1861 the first factory for producing potassium chloride was founded in Stassfurt, Germany. From there the potash fertilizer industry grew to produce other soluble salts such as potassium sulphate. Nevertheless potassium chloride from sylvinite ores remain by far the largest potash fertilizer production in the world.

This industry has shown a remarkable stability on the types of potassium salts produced by very few countries for over a hundred years. It led to forming a cartel of Western European producers that was transformed into a marketing arrangement after World War II. The emergence in the 1950 s of three strong producers: Canada, USSR and the German Democratic Republic is rapidly changing this picture.

(iii) The last to come, the nitrogenous fertilizer industry, began early this century by producing synthesis ammonia using the flame-arc process thanks to Norway's inexpensive hydroelectric power.

The commercial application of the Haber-Bosch process for ammonia production during the 1910 s opened the way for the explosive growth of this industry that, notwithstanding the more than 50-year advantage of the phosphorus and potash industries, could catch up with them by 1960 to become the leading fertilizer industry.

At the beginning nitrogenous fertilizer production was based on coal as raw material shifting to petroleum cuts in the late 50 s. The advent of two major technical developments, new welding techniques for high pressure equipment and new high-temperature resistant materials for use in pressurized tube reformers, enabled the use of natural gas as feedstock since the 40 s.

A further technological breakthrough, the use of centrifugal compressors for the synthesis of ammonia, brought about the scaling up of large single-stream ammonia plants that very substantially reduced production costs during the second half of the 60 s. These changes dynamized this industry still further for it grew 130% between 1965 and 1976, far outdistancing the phosphorus and potassium industries.

The growth of production of the fertilizer industry is shown in table 3. below.

Table 3.

Growth in world fertilizer production

Year		N-P-K (millions of tons)	Growth rate a/ (percentage/yr)
1905/06		2.0	
1913/14		4.1	9.38
	World War I		
1919/21		3.7	- 1.72
1938/39		9.7	5.20
	World War II		
1945/46		7.9	- 2.97
1950/51		15.6	14.57
1960/61		30.3	6.96
1970/71		71.5	8.96
1976/77		98.4	5.46

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a/ The growth rate is the annual percentage change measured against the previous day.

Source: FAO, Annual Fertilizer Review

Since 1970 the production trend has slowed down markedly in the developed countries while developing countries are still busy expanding production capacities.

A number of events interacted in slowing down output such as slowing rate of consumption mainly of nitrogenous fertilizers, increased cost of raw materials and equipment, the impact on non-economic regulations, changing economies of scale leading to larger plants, some shifts in the location of manufacturers and a changing pattern of ownership.

This changing pattern of ownership affecting mainly the nitrogenous industry was largely a response by petroleum corporations who sought an outlet for their gas supplies through fertilizers. In most cases these companies built new substantial capacities that contributed to the surplus situation in the second half of the 60 s. At the beginning of the 70 s a number of these corporations pulled out from the fertilizer industry and went back to the more lucrative oil industry.

The growing number of modern large-scale single-stream plants producing mainly ammonia, urea and phosphoric acid made smaller plants of an earlier vintage relatively expensive to run and led many of them to their early retirement. However, after the energy crisis of 1973, the cost advantage is shifting to raw materials producing countries, with the result that a number of modern fertilizer plants in the developed countries less endowed with raw materials are now facing temporary or permanent closure.

The above developments are spurring a shift to high analysis fertilizers that minimize transportation, storage, handling and application costs.

2.3.2.2 Main fertilizer products

There are two types of fertilizers: one is straight fertilizers containing only one nutrient; the other is compound fertilizers containing two or more nutrients.

There are two main methods for producing artificial compound fertilizers: the complex fertilizers that are obtained by chemical processes, and the mixed fertilizers that are produced by mechanical mixing operations.

The main advantage of compounds is the supply of balanced nutrients to crops in one application instead of the two or three applications that would be required if straights were used. The cost of application is therefore reduced. Because of this advantage the use of compounds is steadily increasing in the world. In the US and Western Europe more than half the nutrients are applied as compounds, in the developing countries the proportion is about one third.

The proportions differ for the different nutrients. In the US and Western Europe about 27.5 per cent of the nitrogen, 80 per cent of the phosphate and 70 per cent of the potash are applied as compounds; in the developing countries the proportions are about 22.5 per cent, 55 per cent and 35 per cent respectively. The low proportion of nitrogen is partly due to agronomic reasons justifying separate and additional applications of this nutrient at specific times during the growing season.

(a) Nitrogen

The principal solid nitrogen fertilizers are ammonium sulphate, ammonium nitrate and urea, with nitrogen contents of 21, 34 and 46 per cent respectively. Ammonium sulphate is the easiest of the three to store and handle, and it has the advantage of containing sulphur which is also a plant nutrient, but its share of the market is restricted by its low concentration. Ammonium nitrate requires strict attention to safety precautions in its manufacture, handling and storage, because it supports combustion and there is therefore a fire risk associated with its storage, and it can, under extreme conditions, act as an explosive. Partly for these reasons it is often sold as a mixture with limestone at lower and therefore less hazardous concentrations; one product, "calcium ammonium nitrate", containing 26 per cent N, is widely used in Western Europe. Many million tons of ammonium nitrate are used annually as a fertilizer, but it does require more care in handling and its sea transport presents problems. Urea is free from these hazards; it has some tendency to cake in storage but this can be overcome by suitable treatment and by control of storage conditions.

TABLE OF CONTENTS

I. INTRODUCTION

II. GLOBAL ASSESSMENT OF THE FERTILIZER INDUSTRY: PAST AND PRESENT WORLD SITUATION

If all three fertilizers were equally efficient, the factor determining the share of the market obtained by each product would be the cost per ton of nitrogen applied to the soil. Since the production costs per ton of nitrogen do not differ very much the more concentrated fertilizers, which have lower bagging, handling and transport costs, would be preferred. This is broadly true in the warmer climates of most developing countries where urea has become the predominant nitrogen fertilizer. Because of its high bagging and transport costs ammonium sulphate is losing ground, but, because of its acid reaction in the soil and the nutrient value of the sulphur which it contains it is still preferred in some alkaline soils and for some crops, e.g. tea. Ammonium nitrate is the preferred form in the colder climates of Western Europe and parts of North America because nitrogen losses from urea can be high under these conditions, and where combine drilling of seed and fertilizer is practised urea can adversely affect seed germination.

From 1972 to 1976 capacity for urea production in the **market economy countries** rose from 13 to 22 million tons; ammonium nitrate capacity from 13 to 15.5 million tons and ammonium sulphate capacity from 5.5 to a little over 6 million tons.[27] This illustrates the very rapid increase in urea production.

The principal liquid fertilizer is ammonia, containg 82 per cent N. Fertilizer solutions containing urea, ammonium nitrate, ammonia and also ammonium phosphate and potash dissolved in water are also used, mainly in North America. When applied as a fertilizer, ammonia is handled as a liquid under pressure in special containers. Its transport, storage and

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[27] "Developments in Fertilizer Production Technology and Economies". Travis P. Higne. Latin American Seminar on Fertilizers, August 1975.

handling call for special techniques and equipment, as well as the stringent observance of safety precautions. It can be applied efficiently only in moist, non-stony soils. About 6 million tons of nitrogen, out of a world total of 40 million tons, are used as ammonia. In the USA it now accounts for more than half the usage of straight nitrogen fertilizers and nearly 40 per cent of all nitrogen fertilizers, but it has made little headway in Western Europe, where fertilizer application rates are high and its use could therefore be expected to increase appreciably. Its relative failure is probably related to a difference in average farm size and also to the scarcity of specialized fertilizer application organizations. However, although it requires a technically complex delivery and application system it is by far the cheapest form of nitrogen (in the USA in 1974 the cost per ton of N in the soil was only 65 per cent of the cost of urea and ammonium nitrate). It is of interest that ammonia constitutes about one third of fertilizer nitrogen consumption in Mexico. It is probable that in the long run the use of ammonia may increase significantly in developing countries. Initially the development will be slow and restricted to areas close to ammonia plants, but as transport facilities improve its use will steadily increase.

(b) Phosphate Nearly all phosphate fertilizers are produced as solids; the major forms are single superphosphate (SSP) with 16-18 per cent P_2O_5, triple superphosphate (TSP) with 45-50 per cent P_2O_5, and mon-ammonium phosphate (MAP) or di-ammonium phosphate (DAP) with 10-18 per cent N and 45-50 per cent P_2O_5. These account for 85-90 per cent of all phosphate fertilizers. Other forms are basic slag, a by-product of the steel industry, which is used mainly in Western Europe and which accounts for 2.5 per cent of current consumption, ground rock phosphate which accounts for about 5 per cent of consumption, and nitrophosphates chiefly in Eastern Europe.

Like ammonium sulphate in nitrogen fertilizers, SSP has the disadvantage of low nutrient concentration, but also the advantage of obtaining sulphur, which TSP and M/DAP do not. Because of its low concentration it cannot be economically transported over long distances in competition with TSP or M/DAP but it can compete over reasonably short distance, say 300 kilometers or so, and it does at present account for about 20 per cent of total phosphate fertilizer consumption. In 1935 it accounted for about 60 per cent of the total.

The agronomic differences between the different forms of phosphate fertilizer are slight and the choice between them is usually made on economic grounds.

(c) Potash The deposits which the potash fertilizer industry exploits consist o potassium chloride in association with other substances, and it is in the form of chloride that the overwhelming proportion of its output is produced. Most of the product sold contains 95 per cent potassium chloride (equivalent to 60 per cent K_2O) but a significant quantity is produced at lower concentrations. About 5 to 10 per cent of production is converted to potassium sulphate for use on crops, e.g. tobacco, which are adversely affected by chlorides. About 96 to 97 per cent of production is used in fertilizers and 3 to 4 per cent in other industrial uses. In the countries with market economies about 40 per cent is used as a straight fertilizer and about 60 per cent in compounds.

(d) Other Nutrients While the fertilizer industry is concerned primarily with the supply of nitrogen, phosphorus and potassium, other plant nutrients may assume considerable importance. Chief among these is sulphur, and of lesser importance calcium, magnesium and a wide range of "micro-nutrients", such as zinc, copper and molybdenum: elements required in very small concentrations, but whose absence or gradual removal from the soil may have serious effects upon plant growth. The symptoms of micro-nutrient deficiency are in general well known to agronomists and plant specialists. Where the deficiency of a particular element is established, it is usually practicable to incorporate it into fertilizers.

In recent years, much attention has been devoted to sulphur deficiency. Its growing importance is partly due to the gradual replacement of the original forms of nitrogen and phosphate fertilizers, ammonium sulphate and single superphosphate, which contain large quantities of sulphur, by more concentrated fertilizers such as urea and triple superphosphate or ammonium phosphates, which do not contain sulpur. In industrialized countries, significant quantities of sulphur are supplied to the soil when the sulphur diozide produced by burning coal or fuel oil is washed out of the air; however, this source of supply is generally insignificant in developing countries. As crop yields and the concomitant sulphur removal from the soil increase, sulphur deficiency may arise. In such circumstances, sulphur must be returned to the soil in the form of elementary sulphur or calcium sulphate (a by-product of phosphate fertilizer manufacture), or through the application of such fertilizers as ammonium sulphate and single sulperphosphate, or of mixtures in which significant quantities of sulphur are present either in elementary form or in various compounds.

2.3.3 Regional development of the fertilizer industry

The evolution of this industry presented in the preceding chapter led to the spread of new production facilities in all regions at the beginning of the 50 s. The FAO Annual Fertilizer Review for 1976 lists 86 countries as fertilizer producers, 76 producing nitrogen, 68 phosphate and 15 potash fertilizers. The division of these between developed and developing countries is 32/53, 32/44, 31/37 and 12/3 respectively. In order to present a comprehensive view of the characteristics of the various regions, annexes A-1 through A-10 were prepared. Annexes A-1 to A-3 present world and regional production figures for the three main nutrients for the period 1950/51 to 1976/77 based on FAO data 28/. They show in quantitative terms that fertilizer production is concentrated in the developed countries for all nutrients because this industry originated and developed in those countries. They possess the technology, skilled personnel, financial resources and the markets required for its development.

By contrast, the developing countries that started from a minimal fertilizer production base have grown much faster than the developed countries in all nutrients as shown in Annex A-5. This high growth rate was mainly brought about by their rapid population increase. The crop area is limited and expensive to expand thus the need to produce more food calls for an increased use of fertilizers. The developing countries' endowment with all fertilizer raw materials but potash and, to a lesser extent sulphur, have precluded their achieving in potash a production level comparable to that attained in nitrogen and phosphate. The fastest growth period was between 1960 and 1968 when substantial new capacities were built in anticipation to larger increases in demand due to impending grain shortages forecasted for the developing countries. Although

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28/ FAO Annual Fertilizer Review, 1975 and 1976, and FAO Bulletin of Agricultural Economics and Statistics, January and March 1978 the grain deficit did not occur, fertilizer demand did expand faster than the previous decade because the industry managed to lower production costs and prices due to favourable raw material prices and technological breakthroughs.

During this period major oil companies seeking opportunities to invest their large cash reserves built many fertilizer plants hoping for secure profits. At the same time the use of petroleum fractions as ammonia feedstock enabled the building of nitrogenous plants near major consuming areas making it unnecessary to locate the production plants near the feedstock sources. This newly gained mobility enabled a faster plant build-up in the developing countries mainly in the Far East and Near East where nitrogenous fertilizer production expanded 7.2 and 4.7 times respectively during 1960-68. They were closely followed by the developed centrally planned economies that grew 3.6 times during that period.

From 1960-68 the developed countries expanded production 2.42 times in nitrogen, 1.71 times in phosphate and 1.80 times in potash while their internal consumption expanded 2.32, 1.67 and 1.66 times respectively. At the same time the developing countries expanded production 3.25, 4.04 and 2.10 times respectively although they only supplied 48, 70 and 15.3 per cent respectively of their internal demand in 1968.

The plant overbuild by the oil companies did not reckon with the long time existing disequilibrium between the domestic requirement of the markets of developed countries and their production capacity whose surpluses have been exported all over the world. But the developing countries did not import fertilizers in volume parallel to their population growth or the expansion in world plant capacity. Moreover they became new producers thus creating an overcapacity situation in the developed market economies that led to a considerable price attrition which drastically reduced the fertilizer industry profitability in the world. This shock was buffeted by a rapid production cost reduction due to the large economies of scale gained by modern large-size single-train plant capacities.

In the following eight years, from 1968 to 1976, several events gave a thorough shake to this industry and created a trend toward important structural changes in the regions. In 1968 the production of developed countries in relation to that of developing countries was 7.73 times in nitrogen, 8.94 times in phosphates and 75 times in potash. In 1976 the relationship had reduced by about half to 3.66, 4.95 and 40.4 times respectively. The oversupply situation bottomed-out in 1970/71 when prices were less than half their 1964 level. This led to plant closures and the pulling out of most oil companies from the fertilizer industry.

During 1972-75 several events rocked the industry. The grain shortage developed due to droughts in parts of Africa, Asia and Europe; the quadrupling of prices for oil and phosphate rock, the increased production costs and environmental regulations, a first recorded drop in world demand all led to more apprehensive buying and stockpiling that sent prices sky-rocketing during mid-1974. By early 1975 prices fell rapidly because of weak demand. These fluctuations created an important structural shift so that variable costs became the dominant production cost factor. Therefore raw materials producing countries would become more competitive fertilizer producers if they can supply their infrastructural requirements without charging their investment costs to the new plants. During this period the developed countries expanded production 1.43 times in nitrogen, 1.36 times in phosphate and 1.57 times in potash, with nitrogen showing the more marked slow-down. Of these, the developed market economies suffered a production drop between 1973 to 1976 due to market conditions, while the developed centrally planned economies kept its past growth rate throughout.

The areas that have borne the brunt of the slow-down have been Japan and Western Europe due to their high raw materials import sensibility. Likewise the quantitative relationship between the developed market economies and the developed centrally planned economies is changing for nitrogen, phosphate and potash. In 1968 it was 2.69, 3.72 and 1.91 times respectively. In 1976 the relations dropped to 1.58, 2.20 and 1.15 respectively. By contrast, the developing countries expanded production by 3.03, 2.47 and 2.90 times respectively, for the period, with phosphates showing the more marked slow-down due, in part, to an upsurge in nitrogen plant investments. Annex A-9 shows the countries whose production weight determine the shape of the world fertilizer production structure:

- For nitrogen, in 1965, there was only one developing country, China, within the dominant eleven countries, with the USA and the USSR accounting for 39 per cent of world production. In 1975 there were four developing countries within the dominant 17 countries. The USSR, China and India had the larger production increases at the expense of the Federal Republic of Germany, Japan and USA. These shifts reflect the dominant position that the US, USSR, China and India have on food grain and nitrogen fertilizer product where on both counts they have more than half of total world production.

- For phosphates, in 1965 only China was within the dominant 13 countries, with the US accounting for almost 30 per cent of world production. In 1975 there were 3 developing countries within the dominating 16 countries. The USSR and China had the larger production increases at the expense of Australia, Federal Republic of Germany, USA and France, although the US still has almost 27 per cent of world production.
- For potash, in 1965 five developed countries held the dominant position about evenly distributed. In 1975, five developed countries were also dominant, but the USSR became the leader with almost 34 per cent of world production. The larger production increases were in the USSR and Canada at the expense of the US, France and the Federal Republic of Germany.

2.3.3.1 Regional growth patterns

The regional development described above generated a regional production structure and differing growth patterns as shown in Annexes A-4 (a) to (c) and A-5.

- The structure of the developed market economies shows a phosphate leadership during the 50 s that from 1960 onwards gave way to the lead of nitrogen. At the same time potash production was growing faster than phosphates but slower than nitrogen thus practically reversing the P-N-K structure of 1950 to a N-P-K in 1976 but along a trend towards an N-K-P structure. This situation reflects the difficult problems faced by Western Europe and Japan in relation to N and P that is forcing them to plant closures in order to achieve a better capacity utilization rate.
- The structure of the developed centrally planned economies shows a potash lead from 1950 to 1966 and from there on nitrogen leads. Although from 1950 to 1970 nitrogen and phosphates grew faster than potash, the situation was reversed during 1970-76, thus showing the USSR efforts to attain world potash production leadership. The K-N-P structure of the 50 s has changed to an N-K-P structure in 1976 that tends to remain, but changing the nutrients ratio, thus reflecting the USSR endeavour to achieve world leadership in nitrogen fertilizer production.
- Africa shows only phosphate production until 1967 when nitrogen production joined in, followed in 1969 by potash. Its structure shows a large phosphate leadership on a P-K-N structure, but since the flooding of its only potash mine in the Congo in 1977, remains with an unbalanced P-N structure. The trend shows a move towards a P-N-K structure.

- Latin America, that had the largest production capacity of the developing countries regions in 1950, shows a dynamic growth in phosphate and nitrogen but a stagnant position in potash. The N-P-K structure remains under nitrogen lead but phosphate is catching up fast, while potash keeps its steady output.

- Near East shows an unbalanced structure lacking potash production, but with nitrogen and phosphates showing the third fastest regional growth from 1950 to 1970, and the world's fastest regional growth from 1970 to 1976. The current unbalanced N-P structure shows a nutrient ratio of about 2:1, thus reflecting the weight of Turkey and the producing countries in nitrogen and the substantial phosphate rock production of Jordan and Egypt. The trend is toward a more balanced N-P-K structure due to Jordan's large reserves in phosphate rock and potassium from the Dead Sea.

- The Far East shows a structurally unbalanced N-P relationship due to the lack of potash ores although it is known that Thailand has an unproved deposit. The structure is heavily nitrogen-oriented showing the predominance of India, Indonesia and Republic of Korea and the requirements of rice-growing economies. Phosphate production is concentrated in India. The trend is to maintain the current N-P 4:1 nutrient ratio due to the stabilizing effect played by India's production structure.

- The Asian centrally planned economies show in the main, the production structure of China. It is an N-P-K structure with an 8:4:1 nutrient ratio. China's structure shows the heavy reliance on organic fertilizers to attain its agricultural produce output. The trend is towards producing more chemical fertilizers but maintaining about the same nutrient ratio.

2.3.3.2 Regional share in world fertilizer production

In Annexes A-6 to A-8 are given the regional share evolution from 1950/51 to 1976/77 by nutrient.

(a) Nitrogen. Concerning the regional share in nitrogenous production, the developing countries went from 7.2 per cent of world nitrogen production in 1950/51 to 21.49 per cent in 1976/77, almost a threefold increase in share but a hefty quantitative increase of 30.75 times during this 26-year period. The developing countries took 15 years between 1950/65 to increase their world share 1.47 times, but doubled it in the next 11 years between 1965 and 1976, with the period 1970/76 showing a large quantum jump of 1.6 times, by far the fastest growing period where its production grew 2.23 times in quantitative terms.

This situation contrasts with that of the developed countries where between 1970 and 1976 the developed market economies was the only loser for its share dropped 1.24 times while the developed centrally planned economies increased their share 1.13 times. All developing countries increased their share during 1970/76 lead by the Near East with 2.09, Asian centrally planned economies 1.82, Far East 1.45, Africa 1.44 and Latin America 1.26 times.

(b) Phosphate. Concerning the regional share in phosphate production, the developing countries went from 2.1 per cent of world phosphate production in 1950/51 to 16.82 per cent in 1976/77, an eightfold share increase but an increase of 35.3 times in quantitative terms. This growth is remarkable for the developing countries' phosphate production was about one third that of nitrogenous in 1950 and grew to become a bit below half of that of nitrogenous in 1976.

The developing countries increased their share 3.58 times between 1950 and 1965, but only 2.24 times between 1965 and 1976, with the period 1970/76 showing a 1.54 times share increase. These figures contrast with those of nitrogen, for they show that the fastest growth period was at the beginning while nitrogenous production has accelerated mainly in the last six years, overtook phosphate share growth rate, and continues to accelerate overtaking phosphate.

The developed countries show a similar situation of phosphate in relation to nitrogen production share.

During 1970/76 it is interesting to notice that the two largest market economies regions in rock reserves and rock production, those of the developed market economies and Africa, show a drop in share of 1.19 and 1.07 times respectively, while all the other regions show an increase. The regions are led, as in nitrogen, by the Near East with a 2.63 times share increase, Latin America 2.36, Far East 1.34 Asian centrally planned economies 1.33, and the developed centrally planned economies 1.10 times.

(c) Potash. Concerning the regional share in potash production, the developing countries went from 0.4 percent of world potash production in 1950/51 to 2.4 per cent in 1976/77, a six-times share increase but an increase of 30.5 times in quantitative terms.

Since there are only three potash producing developing countries with a handful of mining-industrial operations, the appearance or closing of a larger mine abruptly changes the quantitative production and production share.

The most dramatic of these cases was in Africa where the appearance in 1969 of its single mine in Congo made a quantum jump in production and share, while its closing down in 1977 because of flooding caused a large drop. Nevertheless, it is interesting to note that the two largest potash producing regions, those of the developed countries, are tending towards parity that reflects their relative positions in reserve ores and production facilities.

2.3.3.3 Regional production capacity

In Annex A-10 the regional installed capacity is given in terms of their basic fertilizer intermediates, those of ammonia, phosphoric acid and potash, for two years, for 1973/74 and 1977/78.

(a) Ammonia. The installed capacity of the developing countries has increased from 22.95 per cent of world ammonia capacity in 1973/74 to 26.96 per cent in 1977/78, thus reaching a size comparable to the developed centrally planned economies of 27.74 per cent. Only two regions diminished their relative world capacity share during 1973 to 1977: the developed market economies that dropped 1.12 times and Africa that dropped 1.30 times. The latter region had a larger share drop because its installed capacity remained stagnant while that of the other regions grew.

The region with leading capacity share growth is Latin America with a 1.4 times share growth followed by the Far East with 1.29, Near East 1.19, Asian centrally planned economies 1.07 and developed centrally planned economies 1.05 times.

(b) Phosphoric acid. The developing countries' installed capacity has grown from 13.8 per cent in 1973/74 to 17.2 per cent in 1977/78, thus becoming comparable with the developed centrally planned economies' capacity that had 17.43 per cent of world capacity in 1973/74 and 18.79 per cent in 1977/78, with a capacity share growth of 1.08 times during 1973-1977 while the developing countries' capacity share grew 1.25 times in that period. Two regions diminished their relative capacity share between 1973/77 although they grew in absolute terms. Latin America dropped 1.15 times and the developed market economies dropped 1.07 times. The regions leading in capacity share growth were the Far East 1.76 times, Africa 1.45, Asian centrally planned economies 1.32, developed centrally planned economies 1.08 and Near East 1.06 times.

III. THE MEDIUM-TERM OUTLOOK TO 1987

(c) Potash. The developing countries' installed capacity has decreased from 2.15 per cent of world potash capacity in 1973/74 to 1.15 per cent in 1977/78, a drop of 1.96 times of the capacity share during 1973/77. This was due to the closing of the Congo mine, the capacity stagnation of Latin America that dropped 1.15 times of its relative capacity share growth, and the small capacity added by the Asian centrally planned economies that produced a drop of 0.9 times of capacity share between 1973 and 1977. By contrast, the developed centrally planned economies grew 1.16 times their capacity share for 1973/77 while the developed market economies dropped 1.08 times for the period.

(d) Capacity utilization. Data on this count are not readily available and cannot be calculated with precision because much of the information is missing. It is not sufficient to take published data on nitrogen fertilizer production and divide by figures for installed nitrogen capacity. Much of the ammonia installed capacity is for non-fertilizer uses, and reliable information on this is not available. There are similar but less extensive problems in deducing utilization data for phosphates.

It is generally accepted that plant utilization in developing countries is appreciably lower than in developed countries. Lower utilization has a drastic effect upon profitability but the most serious effect is that a higher capital expenditure is needed to get a given output. For example, in 1975 the developing countries produced 8.8 million tons of nitrogen. If output could be improved by 5 per cent, a further 0.44 million would be produced; to secure this output by building more plants would cost more than 500 million dollars. A case study on capacity utilization in the Far East countries is given in Annex E.

2.3.4 Raw materials and energy requirements

The main raw materials of this industry are natural gas, naphtha, fuel oil and coal for nitrogenous fertilizers; phosphate rock and sulphur for phosphate fertilizers; and potash for potash fertilizers.

- Natural gas, naphtha, fuel oil, sulphur and potash ores are chemical substances or mixtures of chemical substances with defined specifications and which vary moderately from place to place.
- Phosphate rock and coal are mined products to which specifications can be applied only to a limited degree and which vary significantly from place to place. They contain constituents which can have important effects

upon the processes in which they are used to produce fertilizers. Therefore a change in the source of supply may adversely affect the process leading to lower efficiency and/or loss of output. It is therefore advisable to arrange long-term supply contracts which specify the source of supply. If a change in supply becomes necessary, careful and lengthy trials of alternative materials should be made before new supply contracts are signed.

Raw materials reserves

In given estimates of fertilizer raw materials reserves, only rough estimates are shown because of two inherent difficulties:

The first difficulty arises from lack of information. Large areas of the globe either have not been surveyed at all or have been surveyed inadequately. Reasonably complete data are available only for deposits being worked or for which concrete development plans exist, and even then the data may cover only the more easily worked and accessible parts of the deposit. The reason for this lack of data is that full exploration and evaluation of a deposit is expensive and is undertaken only when commercial exploitation is probable. It is customary in reserve estimation that in spite of high production rates reserves remain constant or may increase over long periods of time because new deposits are being discovered as fast as existing ones are being used up.

The second difficulty is that there is no agreed definition of reserves. Some estimators include the total quantity existing in the deposit whereas others include only that amount which can be extracted with present mining techniques. Others, again, include only the amount which can be economically extracted at one particular price range, for this depends upon the cost of mining and beneficiation in relation to the mineral market prices. Therefore the proportion of a deposit included in reserves varies from one deposit to another and would also be affected by changes in mineral market prices or in mining and extraction costs.

Considering the above, it is not surprising that estimates of reserves show very large differences while estimators often disagree on a given set of reserve figures. Furthermore, in comparing various reserves estimates the difficulties are compounded because the definition of reserves on which the compilation is based is often not always clearly stated. Of the various fertilizer raw materials the reserve estimates of phosphate rock, sulphur and coal have the greater margin of uncertainty.

2.3.4.1 Nitrogen fertilizers

Practically all nitrogen fertilizers are made from ammonia. Some ammonium sulphate is obtained as a by-product of caprolactam manufacture and some ammonia as a by-product of coke production, but the overwhelming proportion of nitrogen fertilizers is produced from synthetic ammonia. The manufacture of solid fertilizers therefore takes place in two stages, the manufacture of ammonia, and its conversion into a solid fertilizer. The first stage is common to all solid nitrogen fertilizers, the second differs according to the particular product. Ammonium sulphate is made by combining ammonia with sulphuric acid, which is usually made on site from sulphur. Ammonium nitrate is made by combining ammonia with nitric acid which is itself made from ammonia. Urea is made by combining ammonia with carbon dioxide which is a by-product of ammonia manufacture. The manufacture of ammonium nitrate and urea therefore requires no raw materials other than those needed for ammonia manufacture.

The two stages of manufacture can be separated and carried out on different sites. This possibility has led to the use of ammonia as a fertilizer intermediate, whereby it is made in an economically favourable location and shipped elsewhere for the manufacture of solid fertilizers.

The major change in nitrogen fertilizer production processes over the past twenty years has been the development of processes which have made available a much wider range of raw materials. Twenty years ago, nitrogen fertilizer plants were tied to locations close to their raw materials: natural gas and coal (as coke). The development of the naphtha reforming process, aided by the fuel oil-oxygen gasification process, brought a new flexibility into the location of plants, since it was now possible to bring the raw materials to the markets and build the plants there. Unfortunately for those countries which are short of natural gas, the increases in oil prices and changes in the demand pattern for various refinery products have raised naphtha prices to a level at which it is no longer, under normal circumstances, a competitive feedstock. Recently, however, plants using coal directly as a raw material for ammonia manufacture have been established, thus greatly increasing the possibility of using an indigenous raw material, since coal deposits are widely dispersed. The technology of coal gasification is complex and not, as yet, extensively used. Important process developments are likely to emerge from the research and development work now going on and from the large scale plants now being built.

The main raw materials used to make ammonia are therefore natural gas (or refinery gas), naphtha, fuel oil or coal. They are used as feedstocks, by means of which the necessary hydrogen and nitrogen are produced, and also as sources of fuel for the process. If the same material is used for both purposes the manufacture of one ton of ammonia requires about 800 m^3 of natural gas, one ton of naphtha or fuel oil and two and a half tons of coal. Approximately 65-70 per cent of ammonia is made from natural gas, 15-20 per cent from naphtha, 5-10 per cent from fuel oil and 5 per cent from coal. The physical and chemical complexity of these raw materials increases from natural gas, to naphtha, to fuel oil and to coal, and the technical complexity and cost of the processes increases correspondingly. A 1000-ton per day ammonia plant using coal costs nearly twice as much as a 10000-ton per day plant using natural gas.

About 3 per cent of current world production of natural gas is used in fertilizer production, about 0.5 per cent of petroleum products and 0.5 per cent of coal production. These materials are used principally as sources of energy, motor fuel or petrochemicals. Their relative prices are therefore determined by their competitive value for these purposes and not by their relative value as feedstocks for ammonia. At present price levels natural gas is the cheapest feedstock, hence its predominance in ammonia manufacture. Table 4 summarizes the regional distribution of reserves and production while Table 5 shows the countries accounting for 80 per cent of world reserves. All estimates of reserves are only approximate because many deposits have yet to be discovered and not all known deposits have been adequately surveyed.

Reserves of raw materials are widespread but are by no means uniformly distributed. Developing countries have 44 per cent of world reserves of natural gas, 28 per cent of which is in the Near East region. They have 79 per cent of world petroleum reserves, 58 per cent of which is in the Near East region. They have 14 per cent of world coal reserves. Among developing countries, apart from China, coal reserves are few, and the Far East region is relatively ill-supplied with all feedstocks. The developing countries' production covers 10 per cent of natural gas, 60 per cent of crude petroleum and 28 per cent of coal. In general, and particularly for natural gas, they are depleting their reserves more slowly than the developed countries.

Table 4. Regional reserves and production of ammonia feedstocks

Region	Natural gas				Crude petroleum				Coal			
	Reserves		Production		Reserves		Production		Reserves		Production	
	10^{12} m^3	% total	10^9 m^3	% total	10^9 MT	% total	10^9 MT	% total	10^9 MT	% total	10^6 MT	% total
Developed countries												
Market economies	13.2	22	776	62	9.0	11	0.54	20	2940	36	990	42
Centrally planned economies	20.6	34	353	28	8.4	10	0.51	19	4050	50	696	30
Total developed countries	33.8	56	1129	90	17.4	21	1.05	40	6990	86	1686	72
Developing countries												
Africa	5.7	9	14	1	7.7	10	0.23	9	13	-	5	-
Latin America	2.3	4	39	3	3.9	5	0.22	8	24	-	13	-
Near East	17.1	28	42	3	46.4	58	0.98	37	19	-	7	-
Far East	1.4	2	19	2	2.2	3	0.08	3	92	1	134	6
Asian centrally planned econom.	0.6	1	4	-	2.4	3	0.09	3	1010	12	509	22
Total developing countries	27.1	44	118	10	62.6	79	1.60	60	1160	14	668	28
Total world	60.9	100	1247	100	80.0	100	2.65	100	8150	100	2354	100

ource: Statistical Yearbook, 1976 (United Nations publication)

ote: Production figures are estimated values for 1975. Reserves for petroleum and gas are 1975 figures. Reserves for coal are for the most part 1974 figures.

Table 5. Countries accounting for 80 per cent or more of ammonia feedstock reserves

Natural gas		Crude petroleum		Coal	
Country	% of total world reserves	Country	% of total world reserves	Country	% of total world reserves
USSR	33.0	Saudi Arabia	19.1	USSR	49.1
Iran	17.4	Kuwait	12.8	USA	28.1
USA	10.6	Iran	11.5	China	12.4
Algeria	5.4	USSR	10.3		
Netherlands	3.0	United Arab Emirates	7.0		
Saudi Arabia	3.0	Iraq	5.9		
Canada	2.7	USA	5.6		
Nigeria	2.3	Libyan Arab Jamahiriya	4.8		
Romania	2.2	Venezuela	3.5		
Venezuela	2.0				

Source: Statistical Yearbook, 1976 (United Nations publication)

Unless there are major discoveries it seems probable that oil may be in short supply by the late 1980 s and gas some years after this. In this situation actual shortages, combined with steadily increasing prices, would cause a gradually increasing shift to coal as a raw material for ammonia production. This shift will be slow in getting under way, but once adequate design and operating experience of the next generation of processes has been obtained, there will be a marked increase in the use of coal for nitrogen fertilizer manufacture.

2.3.4.2 Phosphate fertilizers

Most manufacturing processes start by treating phosphate rock with sulphuric acid, which is normally made on site from elementary sulphur, though other sulphur-containing raw materials may be used. This process converts part of the calcium phosphate in the rock into calcium sulphate (in the form of gypsum) and part of it into more soluble phosphates. With SSP, the gypsum remains in the solid product, giving a relatively low phosphate concentration. In the manufacture of TSP or M/DAP the process is separated into two stages, in the first of which phosphoric acid is produced and the calcium sulphate removed. In the second stage the acid is reacted with more rock to make TSP or with ammonia to make M/DAP. As with nitrogen fertilizers, the two stages are separable; phosphoric acid can be made at an economically favourable site and shipped elsewhere for the manufacture of solid fertilizers,

There are processes which treat phosphate rock with nitric acid (made from ammonia) instead of sulphuric acid and product nitrophosphate fertilizers. They are technically complex but have the advantage of not requiring sulphur.

(a) Phosphate rock

Phosphate rock is, excepting coal, the more variable of the raw materials used by the fertilizer industry. The quality of the rock is defined in terms of its P_2O_5 content, the concentration normally lying between 28 and 34 per cent. All rocks contain a range of impurities which cause problems in the process and affect its efficienty. The quantities of these impurities, iron, aluminium, magnesium, silica, fluorides, chlorides, carbonates and organic matter contained in the rock are important. The production of phosphoric acid and hence TSP and M/DAP, is more sensitive to these impurities than the production of SSP. Iron, aluminium and magnesium can cause troublesome sludge formation in phosphoric acid and lower the P_2O_5 yield; fluorides lead to severe liquid and gaseous effluent problems; chlorides to serious corrosion, and carbonates to excessive sulphuric acid consumption and in conjunction with organic matter, to foaming problems. The disposal of by-product gypsum from phosphoric acid plants may also cause environmental problems. A phosphoric acid plant producing 600 tons of P_2O_5 a day will have to dispose of about 3000 tons of gypsum a day.

In addition to the rock's chemical compositon, its physical parameters: hardness, porosity, particle size and others, have a significant effect upon its suitability for phosphoric acid manufacture and upon the efficiency of the extraction of P_2O_5. Therefore, while a complete chemical and physical analysis of a sample rock is a useful guide to its suitability for fertilizer manufacture and corresponding plant design, it is only a guide. When in a new plant it is proposed to use a rock which is extensively used in fertilizer manufacture, the experience of other users is invaluable; but if there is little previous experience with the rock concerned, extensive trials should be made before the plant design is decided. Therefore it is often desirable when constructing a plant to build in sufficient flexibility to accept phosphate rock from a variety of sources in order to take advantage of competitive situations or to provide for the possibility that the contracted supply may be cut off.

As phosphate fertilizer production increases, the best quality rock deposits are gradually depleted and producers turn to lower grade deposits leading to a reduction in the average P_2O_5 content of the marketed product while increasing the impurities it contains. Plants can be designed to cope with the problems posed by lower rock grades but capital and operating costs and problems are increased. It seems probable that as time passes fertilizer producers may find it necessary to exercise greater care and sophistication in their rock selection. Likewise rock producers may become more specialized producing premium grades for existing plants that cannot satisfactorily handle rock with impurities above a certain level, and a range of "normal" grades for plants designed to handle rocks with higher content of impurities. Furthermore, as the fertilizer industry uses about 85 per cent of total rock production, there is a marked trend for major rock producers to move into the fertilizer industry, converting part of their production into fertilizers.

Table 6. Regional reserves, resources and production of phosphate rock

Region	Reserves [a]		Total identified resources [b]		Production [c]	
	(millions of MT)	(percentage of total)	(millions of MT)	(percentage of total)	(thousands of MT of P_2O_5)	(percentage of total)
Developed countries						
Market economies	6613	26	10961	15	17372	50
Centrally planned economies	726	3	3628	5	7260	21
Total developed countries	7339	29	14589	20	24632	71
Developing countries						
Africa	17215	69	55236	74	6578	19
Latin America	73	-	454	1	307	1
Near East	308	1	3756	5	1206	3
Far East	109	-	136	-	191	1
Asian centrally planned ec.	145	1	190	-	1830	5
Total developing countries	17777	71	59772	80	10112	29
Total world	25116	100	74361	100	34744	100

[a] Estimated recoverable reserves at 1975 prices.
Source: FAO Commission on Fertilizers, Rome 27-30 Sept. 1977

[b] Includes identified deposits and considered ultimately exploitable as well as reserves recoverable at 1975 prices. Source: FAO Commission on Fertilizers, Rome 27-30 Sept. 1977

[c] Figures for 1977. Assumes average content of 30% P_2O_5.
Source: FAO/UNIDO/World Bank Working Group on Fertilizers, June 1978

Table 6 summarizes the regional distribution of phosphate rock reserves and production while Table 7 below shows the countries accounting for 90 per cent of world rock reserves.

Table 7. Countries accounting for 90% or more of phosphate rock reserves

Reserves		Total identified resources	
Country	% of world total	Country	% of world total
Morocco	65	Morocco	71
USA	17	USA	6
South Africa	11	USSR	5
		South Africa	5
		Australia	4
		Jordan	3

Source: ISMA (International Phosphate Industry Association)

Reserves of phosphate rock are widespread, some 34 countries are producers, but are not evenly distributed. Western Europe and the Far East are short of indigenous resources while 3 countries: the US, the USSR and Morocco account for nearly 80 per cent of world production, while Morocco accounts for 71 per cent of total identified resources. The developing countries have 71 per cent of the reserves, 80 per cent of total identified reserves, and produced 29 per cent of world rock production in 1977. The estimate of reserves varies widely and the estimate used is at the lower end of the range, it makes no allowance for undiscovered deposits. About one third of the reserves can be economically mined at current rock prices. The estimated life of reserves at current production levels should last for about 600 years.

(b) Sulphur

Sulphur in various forms is widely distributed, it constitutes about 0.1 per cent of the earth's crust, but the forms in which it occurs differ greatly in their value as sources. It is found as elementary sulphur, as metal sulphides in coal and mineral ores, as sulphates, as hydrogen sulphide in natural gas, and as complex organic sulphur compounds in crude oil. All these are used as sulphur sources but the most important are elementary sulphur, hydrogen sulphide and iron pyrites. The uses of sulphur are varied but about 80-85 per cent is used in producing sulphuric acid. About half of

IV. THE LONG-TERM OUTLOOK TO THE YEAR 2000

V. THE ESTABLISHMENT OF THE FERTILIZER INDUSTRY IN DEVELOPING COUNTRIES

this acid is used in fertilizer production, so that fertilizers consume about 40 per cent of total sulphur production. But sulphur is also a major plant nutrient in its own right. An unusual but important feature of the sulphur industry is its relation to pollution control. Probably the most common industrial pollutant is sulphur dioxide which is produced when fossil fuels are burned and when sulphide ores are roasted for metal production. This gas is usually converted to sulphuric acid. However, the more important contribution to sulphur production from these sources comes from removing hydrogen sulphide from natural gas and its conversion to elementary sulphur. In 1974 this recovered sulphur amounted to 14 million tons, about half the world production of elementary sulphur and about 30 per cent of the production of all forms of sulphur.

The production of large quantities of sulphur as a by-product of other industrial operations, and therefore at a rate which does not respond to sulphur demand, requires sulphur production from elementary deposits and from pyrites to bear the load of all demand fluctuations.

It is difficult to give a significant estimate of total world resources of sulphur because of the wide variety of forms in which it occurs and because of large differences in the extent and efficiency of extraction from various sources. Total world reserves of sulphur are probably about 500 to 750 billion tons as compared with current world consumption of about 50 million tons of which 20 million were used by the fertilizer industry. However, this figure is not so relevant because 99 per cent of it is in coal, oil shales and gypsum which do not make a significant contribution to present production. An estimate of world sulphur reserves of the types of sulphur currently exploited is given in Table 8.

Table 8. World sulphur reserves
(millions of tons)

Source	Identified	Probable	Total
Elementary: Evaporites	580	100	680
Volcanic	130	100	230
Natural gas	155	885	1040
Petroleum	265	1330	1595
Pyrites	640	n.a.	>640
Metallic sulphides	260	>140	>400
Total	2030	2555	4585

Source: W.D.Bixby, "The role of phosphorus in industry", Muscle Shoals, Ala., Oct.1975

Table 9. gives sulphur production in 1976, by countries.

Table 9. Total sulphur production in 1976, by main countries
(millions of tons)

	Sulphur production	% of total
Developed countries		
USA	11.0	21.0
USSR	10.2	19.5
Canada	7.3	14.0
Poland	5.1	10.0
Japan	2.6	5.0
France	2.0	3.8
Others	7.4	14.2
Total developed countries	45.6	87.5
Developing countries		
Mexic	2.2	4.2
Iraq	0.7	1.3
Iran	0.4	0.8
Others	3.3	6.2
Total developing countries	6.6	12.5
Total world	52.2	100

Source: British Sulphur Corporation, Statistical Supplement No. 15, 1977

The comparatively low production in developing countries reflects the parcity of elementary sulphur deposits in these countries, with the exceptions of Mexico and Iraq and also the lack of demand. As the natural gas reserves of developing countries are exploited their production of sulphur will undoubtedly increase.

At the current rate of production the reserves would last for no more than 90 years. It is clear that during the latter part of the century, unless major new resources are discovered, we can expect a gradual exploitation of reserves of other forms of sulphur, with a consequent increase in costs for the consuming industries.

However, there are particular circumstances of the fertilizer industry which insulate it against the possibly serious effects of a long-term world-wide shortage of sulphur. The industry is not a net consumer of sulphur, it merely transforms sulphur into calcium sulphate. Except in the manufacture of single superphosphate, which will be a very small proportion of total output by the year 2000, the sulphur consumed by the phosphate fertilizer industry is discarded at phosphoric acid plants as calcium sulphate in the form of gypsum. This by-product gypsum is not under present conditions an economic source of sulphur. However, processes for sulphuric acid manufacture which use naturally occuring calcium sulphate (as gypsum or anhydrite) as a raw material, and which produce cement clinker as a by-product, have been operated for many years and are well established. Most of the plants have been shut down and no new ones are being built because their high capital and operating costs make them uneconomic in comparison with sulphur-burning sulphuric acid plants. These plants require about six times the investment needed for a plant using elementary sulphur. By-product gypsum is more difficult to use because it contains P_2O_5, but the difficulties can be overcome. In the unlikely event of a long-term world-wide shortage of sulphur, the fertilizer industry could resort to its gypsum dumps, though at considerable additional cost.

2.3.4.3 Potash fertilizers

The potash fertilizer industry is tied to its raw material deposits, as the other two branches in general, are not, and its operations, by and large, have more in common with those of the mineral extracting industries than those of the chemical industy. The industry extracts potassium chloride from natural deposits and purifies it to a level acceptable to the market, normally about 95 per cent, but with a significant quantity at 70 per cent purity or less.

Most commercial ores are either of the sylvinite type or the carnallite type. Sylvinite minerals consist mainly of potassium chloride (sylvine) and sodium chloride. Carnallite minerals contain as the main component the mineral carnallite ($KCl.MgCl_2.6H_2O$) intermixed with sodium chloride, sylvine and/or alkaline earth sulfates. On a world-wide basis sylvinite minerals are processed more widely, and products processed from carnallite now account for only a small portion of world potash production.

Sylvinite minerals are easy to process. In most cases, if the components are not too heavily aggregated, a flotation process can be applied for obtaining the potassium chloride; this gives a product with a 60 per cent K_2O content. Another process, the so-called dissolving-crystallizing process which is used for heavily aggregated minerals or for minerals with a high clay content yields 60-62 per cent of K_2O. This process needs only a simple technology based on the different solubility temperatures between potassium chloride and sodium chloride. Solid residual minerals are obtained which can be piled up and used for filling empty mines. No unnecessary solutions are left over. Due to the high yield of K_2O and the lower energy requirements as compared to the processing of carnallite, the production costs for potassium chloride made of sylvinite are lower than the production costs for potassium chloride made of other potassium minerals.

When processing carnallite minerals the magnesium chloride which is contained in the carnallite has to be diminished first. This is being done by dissolving the minerals by means of water or suitable salt solutions. Thus the magnesium chloride is separated; the potassium chloride contained in the carnallite crystallizes at the same time; but since the solution contains, besides magnesium chloride also potassium chloride, the content of potash in the decomposition only amounts to 80-85 per cent. The disposal of the magnesium chloride solution creates considerable environmental problems. The solution can only be partly discharged into rivers and lakes, eventually also into the sea. The evaporation of the solution is highly energy consuming. The crystals have to be processed further due to their low K_2O content. This is being done by a dissolving-crystallizing process, similar to the process used for sylvinite processing, but in the case of carnallite the magnasium chloride is the hindering factor.

Table 10. Regional reserves of potash

Region	Reserves a/ (millions of MT of K_2O)	Percentage of total	Life (years) at 1976/77 production b/
Developed countries			
Market economies	20,892	42	1580
Centrally planned economies	28,008	56	2440
Total developed countries	48,900	98	1980
Developing countries			
Africa	90	-	330
Latin America	5	-	250
Near East	250	1	indefinite
Far East	(3)	(3)	(3)
Asian centrally planned ec.	750	1	2340
Total developing countries	1,095	2	1800
Total world	49,995	100	1980

Source: Kali und Salz AG (figures for 1976)

a/ Production figures are given in Annex A-3

b/ Thailand is known to have large deposits which have not been fully investigated

Workable potash deposits are much more limited in their distribution than the sources of other fertilizer raw materials. Estimates of regional reserves of potash are given in Table 10. This estimate covers deposits with varying characteristics and takes a rather broad view of the technical possibilities of exploitation and extraction. Table 11 shows the countries accounting for 90 per cent of potash reserves.

Table 11. Countries accounting for 90 per cent or more of potash reserves

Country	% of total reserves
USSR	48
Canada	36
Germany, Democratic Rep.	8
Germany, Federal Rep.	4

Source: Kali and Salz AG

Only a few developing countries out of 18 potash producing countries have potash deposits. Deposits are being worked in China, Chile and until recently in the Congo. Plans for exploitation exist in Jordan and Brazil. Other deposits are known to exist in Thailand and Perú but they have not been fully determined yet. The reserves are located almost entirely in the developed countries and it will therefore be necessary for developing countries to import most of their potash needs. Only 4 developed countries account for 96 per cent of world potash reserves and 75 per cent of production, and their reserves have an estimated 2000 years of life at 1976/77 production levels.

2.3.4.4 Energy requirements

The energy requirements for fuel and electricity vary widely according to the different processes, but its major users are the nitrogenous fertilizers.

(a) Nitrogen

It is often remarked that an ammonia plant is really a power station making ammonia as a by-product[29/]. This is particularly true of steam reforming processes that use predominantly natural gas as source for feedstock and fuel, for they provide an integration between gas production and steam generation through a highly efficient heat recovery system into the process and a considerable reduction in the compression power requirements. Steam reforming processes based on natural gas and naphtha account today for over 80 per cent of world ammonia capacity.

The other main alternative processes, those of partial oxidation, use cheaper feedstocks such as heavy fuel oil and coal. These processes consume at least 20 per cent more energy than steam reforming, due to the need for oxygen and for its lower thermal efficiency. Heat production in ammonia plants is due to the formation of carbon dioxide by an exothermic reaction. In partial oxidation heat recovery proceeds in the CO to CO_2 shift conversion at lower temperature levels, whereas in steam reforming, carbon dioxide is mainly produced in the flue gas, thus allowing high temperature heat recovery.

Approximately 60 per cent of the raw material is feedstock and the balance is for fuel and electricity. Process improvements over the past 20 years have minimized electric power requirements. In a modern gas fed ammonia plant

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[29/] "Conservation of Energy in the Chemical Industry: Ammonia", ECE, CHEM/AC.6/R.2/Add.2, 6 June 1978 electric requirements are about 20 kWh per ton of ammonia, or about 0.5 per cent of total energy requirements. Table 12 gives the total energy requirements for ammonia production according to various feedstocks.

Table 12. Total energy consumption for a 1000 MT/D ammonia plant

Process	Total energy per ton (Gcal)
Water electrolysis	37.0
Coal gasification (25 atm)	14.1
Partial oxidation of heavy fuel oil	11.3
Naphtha steam reforming	10.9
Gas steam reforming	9.45

Source: ECE, CHEM/AC.6/R.2/Add.2, p.14, 6 June 1978

The energy consumption of solid nitrogen fertilizers such as urea and ammonium nitrate is very small in comparison to ammonia. For instance, urea requires 185 kWh and 0.77 Gcal of steam per ton of granulated urea.

(b) Phosphates

Its energy requirements are small in comparison to ammonia since the sulphuric acid production generates about 0.46 Gcal of steam per ton of acid after catering for all its needs. Therefore the energy required by a phosphoric acid plant is minimal because the sulphuric acid supplies practically all its steam needs and it uses about 150 kWh per ton of acid. The energy consumption of solid phosphate fertilizers such as TSP and M/DAP is minimal. When they are within the phosphate fertilizer complex they practically require only electric power. For example TSP needs 38 kWh per ton of product.

(c) Potash

Its energy requirements are moderate for both processes. The crystallization process consumes about 1.94 Gcal of steam and 77 kWh per ton of potash. The flotation process requires about 0.11 Gcal of steam and 95 kWh per ton of potash muriate.

(d) Water

The production of fertilizers, particularly nitrogen fertilizers, uses large quantities of water. In ammonia production, water is a raw material in the strict sense of the word for it is the source of more than half the hydrogen needed to make ammonia. This water is supplied to the process as steam and varies from 1.5 to 3 m^3 per ton of ammonia depending on the process used. However, most of the water needed in fertilizer manufacture is for cooling purposes, which is an integral part of efficient heat recovery systems.

2.3.5 Capital and production costs

The capital cost, and hence the production cost, of a fertilizer plant depend upon the product, the process used, the size of the plant, the year(s) in which it was built, and the place where it was built. The first three items are obvious and call for no comments, but the importance of the last two is not always realized. It is no longer possible as it was, say, ten years ago to compare plant costs solely on the basis of the first three items. Inflation, which has doubled plant costs in the last five years, and the erection of plants in remote and onerous locations with little supporting infrastructure, have made the attempt to produce generalized cost estimates a hazardous business and one in which it is essential to specify in detail the conditions and assumptions surrounding the estimate.

This section presents and discusses estimates of the capital and production costs of nitrogen, phosphate and potash fertilizers. The emphasis is on plants in developing countries but for nitrogen and phosphate, one developed country plant is included for comparison. Potash costs are for plants in developed countries.

There are some general conditions applying to all the estimates. They assume a "green field", i.e. an undeveloped site and in developing countries it is also assumed that the plants are built in an area where some supporting infrastructure is available. Additions are made to a basic fixed capital estimate to allow for inflation and for interest charges occurring during the construction of the plant. For developing countries 15 per cent is allowed for inflation and 12.5 per cent for interest charges. These are average figures based upon a survey of estimates for about a dozen major projects undertaken in the past three years. The 15 per cent inflation allowance corresponds to 9 per cent p.a. inflation rate over the three to three and half years of construction. Lower rates are used for developed countries because construction times are shorter and the financial gearing is lower.

Production costs are shown for profit rates of 10 per cent and 15 per cent of total fixed capital. The 10 per cent rate is often assumed in estimates for plants in developing countries but whilst this rate covers loan interest and dividends it may provide an inadequate cash flow for loan repayment. For a commercially viable plant in a developed country, 15 per cent would normally be the lowest acceptable rate.

The production cost tables are set out so that adjustments can easily be made for different raw material prices, depreciation and profit rates and plant outputs.

2.3.5.1 Nitrogen fertilizers

Estimates are presented in Table 13 of the capital costs of ammonia-urea plants for four different feedstocks, natural gas, naphtha, fuel oil and coal, and in Table 14 production cost estimates are given for the same plants. Figure 1 shows the effect of feedstock prices on urea costs.

It has been assumed that the solid fertilizer produced will be urea because this is by far the most popular in developing countries. As far as costs are concerned it makes little difference whether the final product costs per ton of nitrogen are practically the same. The ammonia and urea plants are matched in size, i.e. it is assumed that all the ammonia is converted to urea. With natural gas short of higher hydrocarbons this may not be possible without an additional supply of carbon dioxide or the use of some higher hydrocarbons, e.g. naphtha, as supplementary feedstock.

The feedstock prices used in Table 14 are those which could be obtained in developing countries with a surplus of natural gas, with no indigenous crude oil, but with indigenous coal resources. On a thermal basis the values of the feedstocks are:

	Natural gas	Naphtha	Fuel Oil	Coal
$/Mcal	1.98	13.3	8.33	2.27

It is obvious that the natural gas price is valid only as long as there is a surplus of natural gas. The price of $ 0.5/1000 s.c.f. is a reasonable one under the assumed conditions but these cannot last indefinitely. In the long run the natural gas price must approach the fuel oil equivalent, i.e. its long term price is $ 2.0/2.5 per 1000 s.c.f. Even at this price natural gas would still be the preferred feedstock.

Table 13. Capital costs of ammonia-urea plants

Feedstock	Developing Countries				Developed Countries
	Natural Gas	Naphtha	Fuel Oil	Coal	Natural Gas
Outputs					
Tons Ammonia/day	1000	1000	1000	1000	1000
Tons Urea/day	1725	1725	1725	1725	1725
Thousand Tons Urea/year	516	516	516	483	516
Capital Costs ($ m)					
Ammonia	110	175	150	210	85
Urea	70	70	70	70	55
Basic Fixed Capital	180	195	220	280	140
Inflation	15% 27	29	33	42	(10%) 14
Construction) Interest)	12.5% 23	24	28	35	(5%) 7
Total Fixed Capital	230	248	281	357	161
Working Capital	10	18	15	13	8
Total Investment	240	266	296	370	169
600 t.p.d. Ammonia/ 1300 t.p.d. Urea Plants					
Total Fixed Capital	163	173	194	243	
Working Capital	6	11	9	8	
Total Investment	169	184	206	252	

Notes:

a) Costs are based on December 1976 to June 1980 prices and assume a "greenfield" site.

b) The division between ammonia and urea is somewhat arbitrary since both plants use a common site and facilities.

c) Exclusions: All costs outside the site boundary i.e. road and rail connections to site; water supply and effluent disposal outside site boundary; port and harbour facilities; housing and amenities. Duties and taxes are also excluded.

d) The basic fixed capital includes 2.5% for pre-operational expenses and a 10% contingency.

e) A 10-15 MW power station is included to make the plants independent of outside power supplies.

f) The annual outputs assume 300 days/year at full output for natural gas, naphtha

ANNEXES

Production

Table 14. Production costs of ammonia-urea plants

	DEVELOPING COUNTRIES				DEVELOPED COUNTRIES
FEEDSTOCK	Natural Gas	Naphtha	Fuel Oil	Coal	Natural Gas
Feedstock Price ($)[a]	0.5/1000 s.c.f.	[illegible] ton	[illegible] ton	[illegible]/ton	[illegible]/1000 s.c.f.
Output: 1000 tons urea per year	[illegible]	[illegible]	[illegible]	463	[illegible]
Total Fixed Capital ($m)	230	[illegible]	[illegible]	[illegible]	[illegible]
Total Fixed Capital ($/ton urea/year)	115	[illegible]	[illegible]	[illegible]	[illegible]
PRODUCTION COSTS ($/ton urea)					
Feedstock[b]	[illegible]	[illegible]	10.0	13.0	[illegible]
Fuel for steam and power[c]	2.6	[illegible]	[illegible]	13.3	[illegible]
Other Variable Costs[d]	10.2	10.7	10.8	[illegible]	[illegible]
Total Variable Costs	24.7	[illegible]	63.8	37.4	[illegible]
Fixed Costs[e]	[illegible]	[illegible]	24.0	31.3	[illegible]
	44.4	[illegible]	87.8	68.7	[illegible]
Depreciation ([illegible] 1/3%)	[illegible]	40.0	[illegible]	[illegible]	[illegible]
	81.5	[illegible]	[illegible]	130.3	[illegible]
Profit (15% 10%)	66.8 11.5	[illegible]	81.8 54.5	[illegible]	[illegible]
TOTAL	148 [illegible]	[illegible]	[illegible] 186	[illegible] 204	151 [illegible]
600 t.p.d. Ammonia/ 1300 t.p.d. Urea					
Variable Costs	[illegible]	[illegible]	[illegible]	[illegible]	
Fixed Costs	24.3	[illegible]	[illegible]	37.5	
Capital Charges (15% 10%)	123 [illegible]	130 [illegible]	148 [illegible]	[illegible]	
TOTAL	172 145	241 [illegible]	241 [illegible]	270 [illegible]	

Notes:

a) The feedstock prices for developing countries assume that natural gas is in surplus, that naphtha and fuel oil are imported and that the coal-based plant is located near the coalfield. (For the effect of varying feedstock prices see Fig. [illegible])

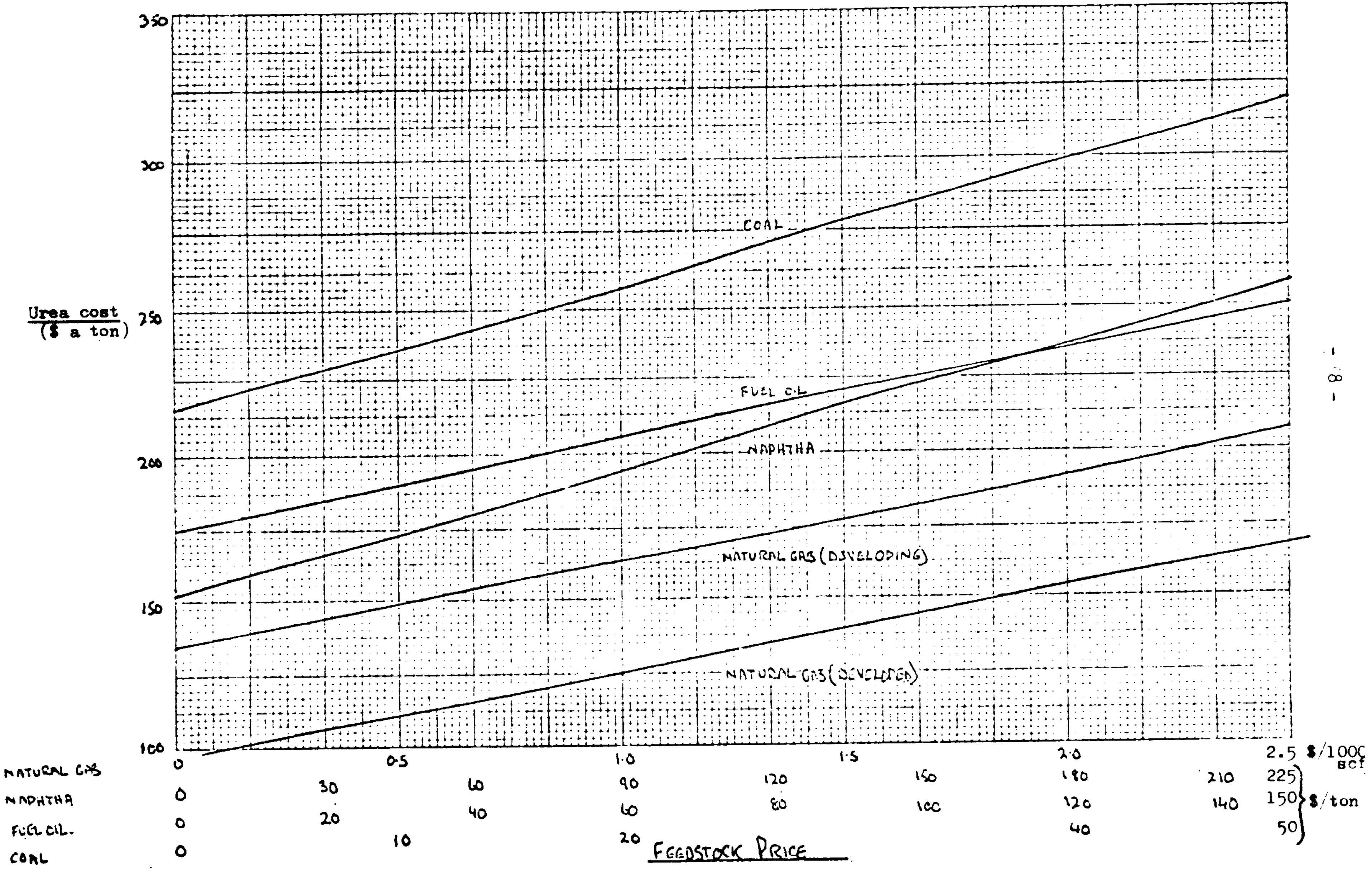
b) For natural gas and naphtha this covers both feedstock and reformer fuel. For the coal-based plant a low grade coal with a calorific value of 5500 cals per g. is assumed.

c) Natural gas is used on the natural gas plants. On the other plants coal of calorific value of 5500 cals. per g. is used but at a price of $ 17.5 a ton to allow for transport costs.

d) This includes bags at $ 7.5 a ton

e) This includes maintenance, taxes and insurance at 0.5% of total fixed capital, interest on working capital and selling expenses at $ 1.6/ton. Maintenance is taken as 2.5% of Basic Fixed Capital (see Table 1) for natural gas and naphtha ammonia plants, 2.75% for fuel oil ammonia and 3.0% for coal ammonia and 3.5% for urea plants. Administrative and operating labour costs are also included.

Figure 1 Urea cost versus feedstock price
(Table 14: 516,000 tons a year)
Profit: 15%



(a) Cost structure

It is interesting to separate the costs given in Table 14 into their major components. If these are grouped into feedstock, processing charges and capital charges (depreciation and profit) and expressed as a percentage of total costs we have, for the large plants, a 15% profit:

	Natural Gas	Naphtha	Fuel Oil	Coal	Natural Gas (Developed)
Feedstock	8	30	19	5	31
Processing Charges	22	19	22	23	21
Capital Charges	70	51	59	72	48

In all cases processing charges amount to about 20% of the total, and feedstock and capital charges together account for the remaining 80%. Natural gas and coal, at the feedstock prices assumed, have respectively low feedstock costs and very high capital charges; naphtha and fuel oil have significant feedstock costs and lower capital charges. The higher feedstock price assumed for the natural gas plant in a developed country puts it in the same category as the naphtha and fuel oil plants in a developing country. For all feedstocks capital charges account for at least half production costs and are of major importance. The significance of this emerges from a study of Table 15 which shows the effect of plant utilization on urea costs and plant profitability. A 30% drop in output increases costs for natural gas and coal by over 35% and for naphtha and fuel oil by 25-30% and reduces profit to 3%.

An alternative way of considering the effect of reduced output is to examine the marginal cost of production, i.e. the variable costs, in relation to total costs. When a plant is operating below its maximum output, the cost of producing an additional ton of urea is equal to the variable cost. The variable and total costs are set out below:

	Natural gas	Naphtha	Fuel Oil	Coal	Natural gas (developed)
Variable cost ($/ton)	25	84	64	37	65
Total cost ($/ton)	150	220	215	240	150

The standard profit per ton of urea for the natural gas plant in a developing country is $ 67; every ton of output lost reduces profits by $ 125. Because fixed costs form so high a part of production costs no factor has

TABLE 15. UREA COST VERSUS PLANT UTILIZATION

(Urea Costs in $ a ton)

Days output a year		DEVELOPING COUNTRIES				DEVELOPED COUNTRIES	RETURN ON INVESTMENT
NG.N.FO	COAL	NATURAL GAS	NAPHTHA	FUEL OIL	COAL	NATURAL GAS	%
300	280	148	218	215	241	154	15
270	252	162	233	232	264	164	12
240	224	179	251	253	292	177	8
210	196	201	275	280	329	193	3
180	168	230	307	316	377	213	-3.5

The return on investment assumes that the product is sold at the total price shown in Table 2, i.e. the price which gives 15% return at full operation.

(b) Urea costs: developed and developing countries

(i) Urea was available on world markets in January 1978 at about $ 120 a ton f.o.b. In most developed countries the equivalent domestic price is appreciably higher. At the very low natural gas price of $ 0.5/1000 s.c.f. assumed in Table 14.the estimated urea price is approximately $ 150 a ton; for naphtha and fuel oil the price is $ 220 a ton and for coal $ 240 a ton.

If $ 120 a ton was the stable long term world market price there would be little or no economic justification for additional urea plants in developing countries, or in developed countries for that matter, because it would be cheaper to import urea than to manufacture it. However, it is obvious that if no new plants were built urea would soon be in short supply and prices would rise to a level commensurate with current costs or higher. The price of $ 120 a ton is only possible because producers with established plants are including in their costs capital charges based on historic costs rather than on replacement capital values. The capital cost of a plant built in 1970 would be less than half current costs. This would enable urea from the developing country natural gas plant in Table 14. to be sold at about $ 85 a ton and still make 15 per cent profit; for the developed country plant the corresponding price would be about $ 110 a ton. As more new plants are built and as present producers realize that depreciation rates should be based on current and not historic capital costs, the world market price of urea should rise. There is a contributory factor of secondary importance which arises from the fact that because capital charges constitute so high a proportion of fertilizer production costs, marginal costs are very low. If the developed country producer in Table 14 had a plant which was operating at only 80 per cent of capacity, he could produce an additional 50,000 tons of urea a year at a marginal cost of only $ 65 a ton, and would be quite willing to sell it on world markets at $ 120 a ton.

In sum , world market prices and the import prices derived from them are an unreliable guide to project profitability. As long as the industry has surplus capacity, and especially in an inflationary situation, there are economic and market forces operating to keep prices at a level which is below that giving a reasonable return on investment. When there is no surplus capacity prices rise, sharply. In the long term the rapid inflation in capital costs and the consequent rise in production costs must be reflected in world market prices; projects in developing countries should not be deterred by the present low prices on world markets and the consequent low prices for imports.

(ii)The costs of producing urea from natural gas, at the feedstock prices assumed, are about equal in developed and developing countries. The developing country's advantage of cheap feedstock is, in this example, counterbalanced by the developed country's lower capital cost. It should be borne in mind that the developing country costs in Table 14 are for a plant in an area in which some supporting infrastructure is available. In a remote area with little or no infrastructure, capital costs would be greatly increased, by 20 - 30 per cent, and urea production costs would then be distinctly higher than in a developed country. Such a plant could then compete only if the delivery costs to its markets were much less than those of the competitive plant.

A further factor in the comparison is that the plant in a developed country is, because of its lower capital charges, less seriously affected by loss of output. Table 15 shows that the apparent slight advantage posessed by the developing country plant disappears if it has to run at 93 per cent of full output, and that at less than 90 per cent of the rated output the advantage passes to the plant in the developed country.

(c) Choice of feedstock

(i) Table 14 and Figure 1 show clearly why natural gas is always used as a feedstock when it is available in either developed or developing countries; capital costs are lower than for any other feedstock and production costs much lower. This conclusion is not specific to the very low natural gas price assumed in Table 14, even at $2.5/1000 s.c.f. natural gas would still be the cheapest feedstock.

(ii)If natural gas is not available the choice between imported naphtha and fuel oil or indigenous coal is a difficult one. At 15 per cent profit naphtha and fuel oil produce urea at $25 - 30 a ton cheaper than coal. This difference is significant. At 10 per cent profit the margin is reduced to $10 - 15 a ton, probably not a significant difference.

Other things being equal the indigenous feedstock , i.e. coal, would be preferred. But other things are not equal. For naphtha and, to a lesser extent, fuel oil the feedstock price, over which the fertilizer producer has no control, is an appreciable element in urea cost. **This is less true for coal. Coal prices, therefore, have less impact on urea production costs.** However, processes using coal are at present much less widespread and less technically developed than processes using naphtha or fuel oil. It is probable that during the next ten years better coal-based processes will become available and capital and operating costs will decrease. Countries with a market that will support several major nitrogen fertilizer plants and with their own coal would be well advised to consider seriously at least one coal-based plant. If the market will support only one or two major plants it would, at present, be safer to use naphtha or fuel oil.

(iii)For those countries which do not have indigenous feedstocks the choice between naphtha and fuel oil will depend mainly upon the view taken of probable future changes in their prices. Naphtha has important chemical uses for which it cannot be replaced by fuel oil, and as a potential component of gasoline its price is becoming increasingly tied to gasoline prices. Fuel oil prices, on the other hand, are more closely related to the prices of alternative fuels, such as natural gas and coal. The long term expectation therefore is that naphtha prices will rise relative to fuel oil prices. However, naphtha-based processes are technologically simpler and more widely established than processes based on fuel oil. The choice is not easy and **will depend to a considerable extent on local circumstances, which may significantly modify the general picture given above.**

2.3.5.2 Phosphate fertilizers

Capital and production costs for two sizes of phosphate fertilizer plants are given in Table 16A and 16 B. Each comprises a sulphuric acid plant, a phosphoric acid plant and a general purpose solid fertilizer plant capable of making triple superphosphate (TSP), mon-ammonium phosphate (MAP) and diammonium phosphate (DAP). The daily capacities of the plants are 1600/800 tons of sulphuric acid, 600/300 tons of phosphoric acid, and the corresponding quantity of TSP, MAP, or DAP. The solid fertilizer plant would make the different products in "campaigns", as required by the market.

The raw material prices chosen apply to countries without indigenous supplies of phosphate rock and sulphur. Where indigenous supplies are available and the fertilizer plant is close to the mine, prices of both rock and sulphur would be about $20 a ton lower. This has a considerable effect on production costs. Rock at this lower price would reduce production costs by about $30 a ton, and if sulphur was also locally available costs would be reduced by a further $9 a ton for DAP and $6 a ton for TSP.

(a) Cost structure

Separating the costs into raw materials, processing costs and capital charges.gives the following pertentage figures for the large plants, at 15 per cen profit.

	Developing		Developed	
	DAP	TSP	DAP	TSP
Raw Materials	47	45	54	51
Processing Charges	17	19	17	20
Capital Charges	36	36	29	29

As for nitrogen fertilizers, processing charges account for about 20 per cent of total costs and raw materials and capital charges for 80 per cent. However, the division between raw materials and capital charges is very different; raw materials account for a much higher proportion and capital charges a much lower one.

Two consequences follow from this. First, access to low-cost raw materials confers a much greater advantage than for nitrogen fertilizer production, and second, the reduction in production costs achieved by increasing plant size is less. Both these consequences can be illustrated from the recent history of the industry. The first by the growing investment in phosphoric acid and phosphate fertilizer production by countries with large deposits of phosphate rock, and the second by the persistence of a number of medium sized plants in new capacity. Some very large plants are being built, mainly by rock producers for whom the economies of scale are greater, but the medium sized plants have not, as in the case of nitrogen fertilizers, almost disappeared.

Table 16 A. CAPITAL AND PRODUCTION COSTS OF PHOSPHATE FERTILIZER PLANTS (600 tons phosphoric acid a day)

	DEVELOPING COUNTRIES		DEVELOPED COUNTRIES	
	DAP	TSP	DAP	TSP
OUTPUT	(18-46-0)	(0-46-0)	(18-46-0)	(0-46-0)
P_2O_5 (tons/day)	584	789	584	789
Product (tons/day)	1,275	1,715	1,275	1,715
Product (tons/yr)[d]	382,500	514,500	382,500	514,500
CAPITAL COSTS ($m)				
Basic Fixed Capital	115		90	
Inflation	(15%) 16.3		(10%) 9	
Construction Interest	(12.5%) 14.4		(5%) 4.5	
Total Fixed Capital	146		104	
Working Capital	19		16	
Total Investment	165		120	
PRODUCTION COSTS ($/ton product)				
Phosphate Rock[e]	62.8	62.8	62.8	62.8
Sulphur[f]	25.9	19.3	25.9	19.3
Ammonia[g]	29.9	-	29.9	-
Raw Materials	118.6	82.1	118.6	82.1
Other Variable Costs[h]	13.9	13.9	13.9	13.9
Total Variable Costs	132.5	96.0	132.5	96.0
Fixed Costs[j]	28.5	21.8	24.3	18.6
	161.0	117.8	156.8	114.6
Depreciation (8 1/3%)	31.8	23.6	22.7	16.8
	192.8	141.4	179.5	131.4
Profit (15%/10%)	57.3 38.2	42.6 28.4	40.8 27.2	30.3 20.2
Total	250 231	184 170	220 207	162 152
Total (per ton nutrient)	391 361	400 370	343 323	352 330

Table 16 B. CAPITAL AND PRODUCTION COSTS OF PHOSPHATE FERTILIZER PLANTS
(300 tons phosphoric acid a day)

	DEVELOPING COUNTRIES		DEVELOPED COUNTRIES	
OUTPUT	DAP (18-46-0)	TSP (0-46-0)	DAP (18-46-0)	TSP (0-46-0)
P_2O_5 (tons/day)	294	390	294	390
Product (tons/day)	638	858	638	858
Product (tons/yr) d/	191,250	257,250	191,250	257,250
CAPITAL COSTS ($m)				
Basic Fixed Capital	75		60	
Inflation	(15%) 11.3		(10%) 6	
Construction Interest	(12.5%) 9.4		(5%) 3	
Total Fixed Capital	96		69	
Working Capital	10		8	
Total Investment	106		77	
PRODUCTION COSTS ($/ton product)				
Phosphate Rock e/	62.8	62.8	62.8	62.8
Sulphur f/	29 5	19.3	25.9	19.3
Ammonia g/	29.9	-	29.9	-
Raw Materials	118.6	82.1	118.6	82.1
Other Variable Costs h/	13.9	13.9	13.9	13.9
Total Variable Costs	132.5	96.0	132.5	96.0
Fixed Costs j/	38.2	29.2	32.0	25.2
	170.7	125.2	164.5	121.2
Depreciation (8 1/3%)	41.8	31.1	30.1	22.3
	212.5	156.3	194.6	143.5
Profit (15%/10%)	75.3 50.2	56.0 37.3	54.2 36.1	40.2 26.8
Total	288 263	212 194	249 231	184 170
Total (per ton nutrient)	450 411	461 422	389 361	400 370

Consumption

Notes to Tables 16 A. and 16 B.

a) Notes a, c, d, to Table 13 apply to these tables.

b) The plants have their own power station.

c) No special costs have been allowed for gypsum disposal.

d) Annual outputs assume 300 days a year at full output.

e) 1.57 tons rock (31.6% P_2O_5) at $40 a ton.

f) $60 a ton. For DAP 0.432 tons and for TSP 0.322 tons.

g) 0.23 tons at $130 a ton.

h) Includes bags at $7.5 a ton.

j) Includes maintenance at 4.5% of basic fixed capital, taxes and insurance at 0.5% of total fixed capital, labour and management, interest on working capital, and sales expenses at $1.6 a ton for the large plant and $2.0 a ton for the smaller plant.

k) A change of $1.0 a ton in phosphate rock price alters the cost of the final product by $1.54 a ton. A change of $1.0 a ton in sulphur price alters the cost of DAP by $0.43 a ton, and of TSP by $0.32 a ton. A change of $1.0 a ton in ammonia price alters the cost of DAP by $0.23 a ton.

(b) Developed and developing countries

The lower capital cost of plants in developed countries is of much less advantage than in nitrogen fertilizer production. A developing country producer with indigenous rock supplies is in a strong position, as long as his capital costs are not seriously inflated by lack of infrastructure.

Because of the reduced incidence of capital charges in production costs the benefits of very large manufacturing units are less marked and phosphate fertilizer production can therefore be justified at a lower level of demand than would be required for nitrogen fertilizer production. In regional or intra-regional planning the desire for some degree of national self-sufficiency can be met with less economic disadvantage than in nitrogen fertilizer production. As with nitrogen fertilizers, world market prices which are much lower than production costs in new plants (and for similar reasons) are an inadequate criterion for assessing the economic viability of a new plant. A better guide is the project's ability to meet competition in its market area from large new plants close to phosphate rock deposits.

2.3.5.3 Potash fertilizers

Information on potash investment and production costs is difficult to obtain and is usually considered confidential. However, it is generally accepted that Canadian production costs are about the lowest in the world on account of their rich potash seams and the world's largest and modern concentration of potash production capacity. Capital and production costs for two potash production facilities are given for a mine in Canada and a mine in New Mexico, USA. Each facility comprises underground dry mining with continuous mining equipment and conventional flotation process with crystallizer scavenger circuits for beneficiation. The chosen size of mines was determined by the nature and size of the assumed deposits and the mine shaft capacity. The following plant criteria and investment and operating costs for the new potash plants illustrated were taken from a recent World Bank study on the subject[30], and are given in Table 17.

(a) Cost structure

Based on updated published information an attempt was made to relate capital and operating costs for a new mine in Canada to size of operation[31]. These calculations are summarized below:

Capacity (60% K_2O)	500,000 stpy	1,000,000 stpy	1,500,000 stpy
Investment[a] ($/Annual short ton)	210	160	130
Operating cost[b] ($/short ton)	40	32	28

[a] Includes direct operating costs, maintenance and depreciation

[b] Excludes working capital and infrastructure other than that associated with direct plant operation

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[30] "World Potash Survey", W. Sheldrick and H.Stier, Fertilizer Unit, Industrial Project Department, World Bank, June 1978.

[31] op.cit. in 30.

Table 17. Capital and production costs for potash fertilizer plants

	Canada	New Mexico
Capacity stpy a/ b/	1,500,000	850,000
Plant investment c/	211,825,000	97,325,000
Start-up fees	4,950,000	4,500,000
Subtotal	216,775,000	101,825,000
Contingency (10%)	21,677,000	10,182,000
Total plant investment	238,452,000	112,007,000
Working capital	9,540,000	6,540,000
Total investment	247,992,000	118,547,000
Operating cost - Mine	6.36	12.11
$/short ton - Refinery	6.83	8.83
Subtotal	13.19	20.94
Depreciation (8 1/3%, 12 yrs)	13.24	10.98
Insurance and local taxes(1%)	1.59	1.32
Subtotal	14.83	12.30
Total production costs d/	28.02	33.24
Return on investment (15%)	24.80	20.92
Estimated realization price ex-works, $/short ton at 15% ROI	52.82	54.16
Return on investment (10%)	16.53	13.95
Estimated realization price ex-works, $/short ton at 10% ROI	44.55	47.19

Source: "World Potash Survey", W. Sheldrick and H. Stier, World Bank, June 1978.

a/ Production costs in the USA and Canada are usually expressed as short tons (2,000 lbs or 907 kg)

b/ The plant design characteristics are as follows:

Design item	Canada plant	New Mexico plant
Plant production stpy	1,500,000	850,000
Shafts, 16 ft diameter	2 of 3,000 ft	2 of 2,000 ft
Product grade, %KCl	95	95
Feed: % K_2O	26	15
% Insoluble	5	5
Feed, stpy	4,000,000	4,352,000
Ratio of concentration	2.67	5.12
Recovery	90%	83%

c/ The capital costs of each plant reflect the complete facilities to produce fertilizer grade material. The mine costs include continuous miners and haulage equipment, underground crushing, storage, etc., ore and service shafts and hoisting facilities. The surface plant also includes offices, laboratories, maintenance and product storage buildings. Special allowances for costs to cover special environmental requirements have also been included. The main increase in cost between the surface plant in Canada and New Mexico is explained by the more difficult climatic conditions in Canada.

Item	Canada plant (US$)	New Mexico plant (US$)
Mine: Shafts with hoisting equipment	53,128,000	10,992,000
Equipment	29,484,000	34,808,000
Subtotal mine	82,612,000	45,800,000
Surface plant	129,213,000	51,525,000
Total estimated cost(US$)	211,825,000	97,325,000

d/ Estimates of total production costs and realization prices do not include allowance for tax reserves. In Canada, provincial and federal taxes on a 1.5 million stpy mine can be as high as $ 20/ton.

2.4 WORLD CONSUMPTION OF FERTILIZERS

2.4.1 Factors affecting the demand of fertilizers

Among the various factors responsible for variations in the consumption of chemical fertilizers in the world the more significative are the following:

(a) Existence of a market

Since the middle of the last century the important role mineral fertilizers play in plant nutrition was known; this is reflected in higher crop yields and increased food availability. However only when biological research produced new plant varieties of much higher yield potential coupled with improved farm management practices was the main fertilizer market established, that of grain fertilization around the time of the Second World War.

The developed countries that pioneered the application of science and technology to agriculture developed the modern farming methods for production and the agribusiness concepts for marketing and further processing of the agriculturel produce. Within this context at present there is no commercially viable substitute for chemical fertilizers.

In the developing countries the main fertilizer markets are concentrated on three major grain crops: wheat, rice and maize in those countries applying green revolution methods and on agricultural exports be it non-food and/or food crops. The major part of arable land is still under traditional farming methods that require little external inputs which anyway most farmers cannot acquire for lack of purchasing power. The experiences of many green revolution countries show that governments and farmers are willing to change to modern farming systems but are often restricted by constraints such as foreign exchange difficulties, lack of adequate infrastructure, credit restrictions, etc.

(b) Existence of a marketing and agronomic infrastructure

Chemical fertilizers can best provide its benefits to farmers when there exists an adequate supply of quality seeds locally adapted and an assured supply of water through irrigation/drainage systems.

Since fertilizers are relatively low-value high-bulk products that need to be moved over long distances to reach farmers widely scattered throughout the country, it is important to minimize transport and distribution costs in order to keep fertilizer prices within farmers' reach. This entails the setting up of an efficient physical distribution and storage network,suitable fertilizer marketing systems, and advice to farmers on the fertilizer policy more appropriate to their farm conditions. Furthermore, without efficient farm produce marketing, technical advice, and credit facilities, farmers would be unable to fully realize the economic benefits of crop fertilization.

In developing countries the cost of setting up a fertilizer marketing system can be very substantial if small villages are to have an assured supply and timely availability of chemical fertilizers. But often the fertilizers physical distribution network only reaches sizable towns and concentrate on those few areas under modern farming systems usually producing export crops and/or green revolution cereals.

(c) Government support

A country willing to have a productive and efficient agriculture should provide it with adequate technical, economic and logistic support. No individual enterprise is in a position to provide on a country-wide scale all the support agriculture requires considering the sheer magnitude of the efforts and resources involved. Hence government participation has proven to be the only viable alternative to back up agriculture. Government support usually covers agricultural policies, subsidies, agricultural extension services, agronomic research and development and training, rural credits, social services, and major physical infrastructure. Without this backing chemical fertilizer demand would only concentrate on modern farming areas operated by innovative farm management that sooner or later will stagnate when farmers reach a marginal rate of return for their crops at high fertilizer application rates.

(d) Price

The most important economic relationship for farmers is that of cost/benefit. This relates the amount a farmer is willing to pay for relatively expensive inputs such as seeds, fertilizers, machinery with the income the farmer expects by selling his produce. This factor was high-lighted when fertilizer export prices that have been steadily diminishing during the 60's through manufacturing improvements, suddenly shot up during 1974 fueled by the oil crises and fears of difficulties in supply. The farmers' response was swift: they reduced the purchase of fertilizers until prices came down in 1975 to a little over the 1973 levels and have been kept there ever since. However this situation cannot remain for long in view of soaring fertilizer production costs. Nevertheless it should be noted that the real cost of fertilizers to the farmer is much more than its market price due to risk and uncertainty over a cycle of years and associated cost of fertilizer use such as cost of credit, labour, plant protection measures, etc.

(e) Population growth and standards of living

The two most important factors responsible for agricultural consumption are growing populations and rising income per capita. The first needs more of everything and creates an incremental quantitative demand. The latter, when coupled with sensible income distribution policies, creates a qualitative and quantitative incremental demand that results in changing food consumption patterns and increased nutritional levels. Both factors may combine in different ways each of which will produce its own resulting demand of agricultural produce. Thus there are important stakes in the steering of favourable alternatives, for the higher the resulting agricultural demand, the greater the fertilizer consumption.

(f) Existence of local fertilizer production

The existence of local fertilizer production usually leads to an acceleration of the indigenous demand if the new producer can sell fertilizers to farmers at prices providing him with attractive cost/benefit ratios. Farmers with traditional farming systems usually apply empirical barter relationships such as one kilo of fertilizers should cost about the same as one kilo of rice. Therefore farmers customarily weigh the advantages brought by local production versus the increased cost of local fertilizers. The result of this weighing is reflected in either government support to satisfy the expectations of the parties concerned, or the farmers' buying less fertilizer than expected.

2.4.2 Evolution of fertilizer consumption

The idea of feeding the soil so that it, in turn, may feed mankind, is known and practiced from time immemorial. Traditional methods such as fallow, crop rotation, burning stalks, burying fish, wood ashes, etc., were practiced by peoples in different cultures and continents. Indeed, up to the end of the nineteenth century, agriculture was mainly practiced with organic manure. Fertilizer consumption by farmers grew by the interaction of highly increased food demand for the fast sprawling industrial-urban centres and the pressing need to increase food production with shrinking rural labour. Apart from the basic agro-related developments such as plant breeding, infrastructure, farming methods etc., fertilizer consumption is linked to soil fertility as a technical means to increase crop yield. The use of chemical fertilizers was brought about by the doctrine of mineral plant nutrition and the promise of substantial economic returns to the farmers.

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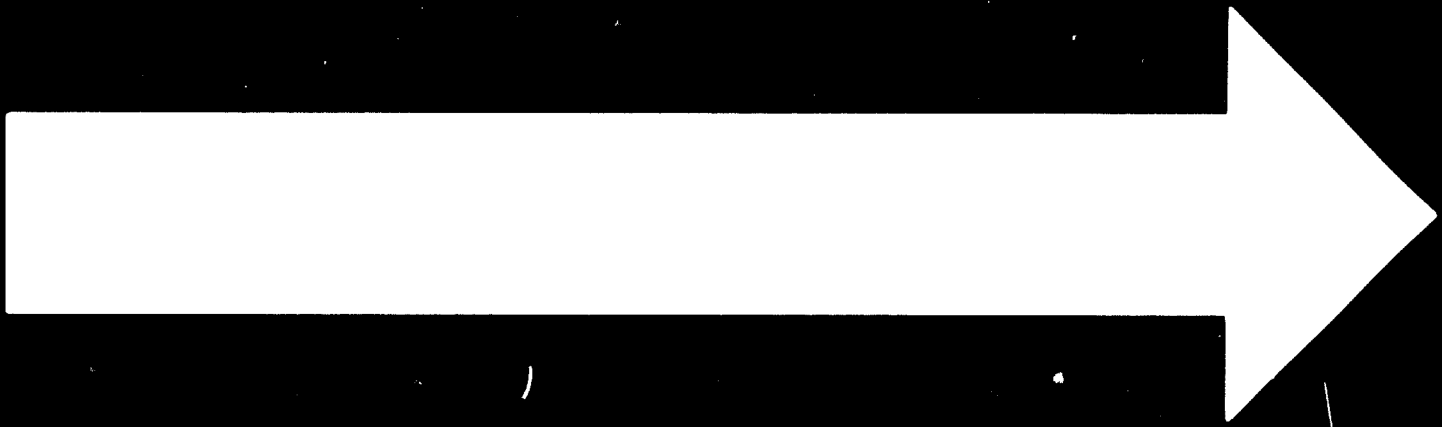

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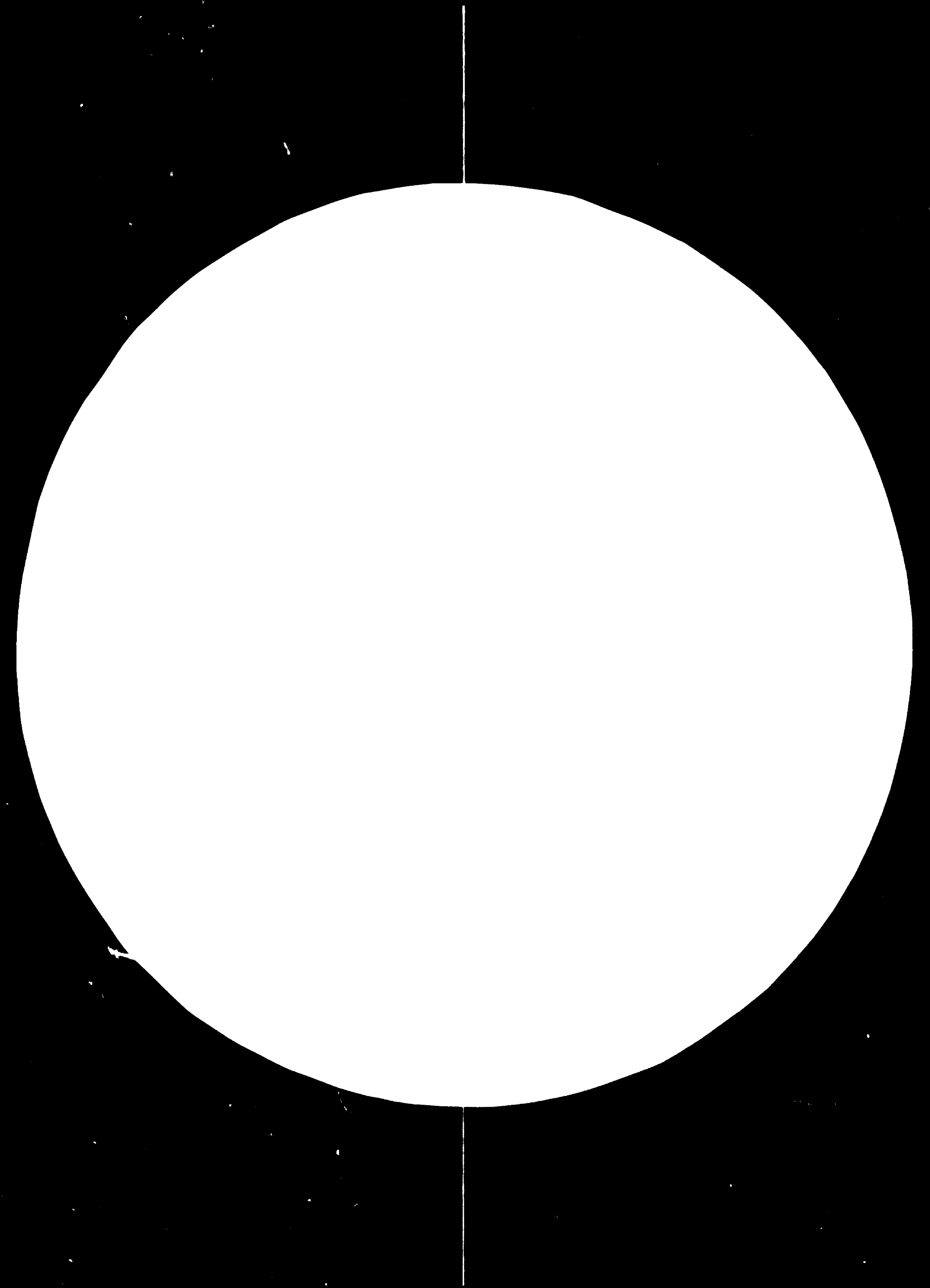

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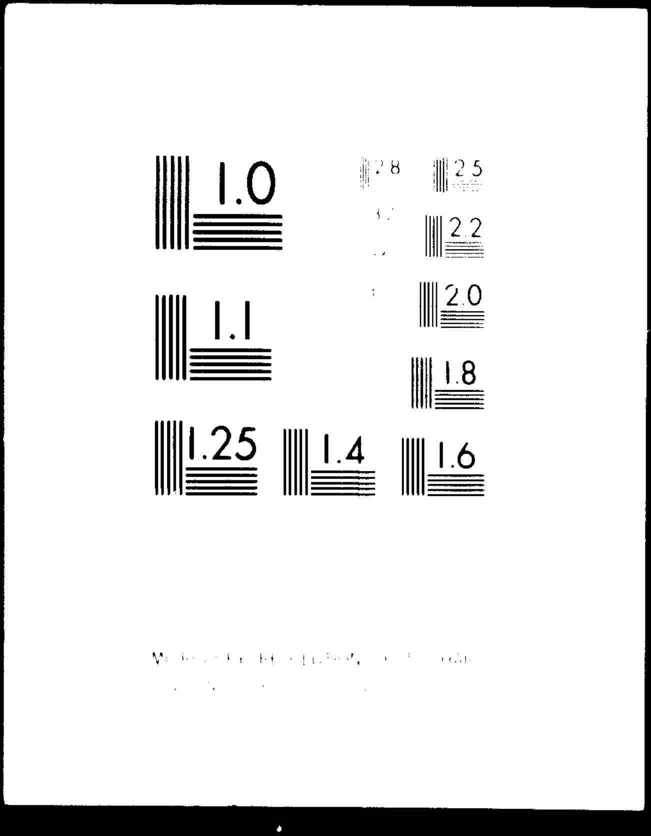

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Table 19. Regional fertilizer consumption per hectare and per capita, 1965-1975

Region	(Kgs per hectare arable land plus land under permanent crops) N			P_2O_5			K_2O			Total			Total (% p.a.increase)		Total (kgs p.capita)		
	1965	1970	1975	1965	1970	1975	1965	1970	1975	1965	1970	1975	1965/70	1970/75	1965	1970	1975
Developed countries																	
Market economies	28	39	46	27	31	29	21	25	25	77	95	100	4.3	1.0	44	52	55
Centrally planned economies	14	27	41	10	15	24	13	18	31	37	60	96	10.2	9.9	30	48	74
Total developed countries	22	34	44	20	24	27	17	22	27	59	80	98	6.3	4.1	38	51	61
Developing countries																	
Africa	0.8	1.5	2.4	0.6	1.3	2.0	0.5	0.8	1.1	1.9	3.6	5.6	13.6	9.3	1.4	2.3	3.2
Latin America	6	10	14	4	7	11	2.4	5	7	12	22	32	12.9	7.8	6.2	10	14
Near East	6	10	16	2	4	8	0.2	0.3	0.4	8	14	25	11.8	12.3	4.2	6.5	10
Far East	4.4	11	14	1.4	3.1	4.2	1	1.9	2.6	6.7	16	21	19.0	5.6	1.9	4.1	5.1
Total market economies	3.9	7.9	11.3	1.7	3.5	5.5	1.0	2.0	2.8	6.5	13.3	19.6	15.4	8.1	3.0	5.1	6.8
Asian centrally planned ec.	13	26	36	5	7	11	1.6	2.8	3.4	19	36	50	13.6	6.8	2.7	5.7	7.6
Total developing countries	5.4	11	15	2.3	4.7	6.4	1.1	2.2	2.9	8.8	18	24	13.4	5.9	2.9	5.3	7.1
Total world	13.3	21.6	28.7	10.5	13.5	16.0	8.4	11.3	14.2	32.4	46.3	58.9	7.4	4.9	13.9	18.8	22.3

Source: FAO

Table 20 FERTILIZER CONSUMPTION PER HECTARE 1965 - 75: COUNTRIES

(Kgs. per ha. arable land plus land under permanent crops)

	N			P_2O_5			K_2O			TOTAL			TOTAL:KGS. PER CAPITA
	1965	1970	1975	1965	1970	1975	1965	1970	1975	1965	1970	1975	1975
U.S.A.	27	38	45	20	23	23	16	20	23	63	81	90	88
Netherlands	321	467	537	119	126	94	141	156	120	581	749	751	46
Germany F.R.	106	140	152	99	113	97	144	147	136	349	400	386	50
U.S.S.R.	10	20	32	7	10	17	8	11	22	25	40	70	64
Algeria	2	4	9	2	8	11	2	4	3	6	16	23	9.7
Kenya	8	13	12	6	14	12	1	2	2	14	29	25	3.4
Nigeria	0.1	0.1	1.3	0.1	0.1	0.7	–	0.1	0.3	0.2	0.3	2.3	0.8
Argentina	1	1.2	0.8	0.3	1.2	0.6	0.2	0.2	0.1	1.4	2.6	1.6	2.2
Brazil	2	8	11	3	11	25	3	9	16	8	28	52	17
Mexico	10	16	30	3	5	8	–	0.9	1.7	13	22	39	19
Egypt	107	116	145	20	14	29	–	0.7	1.1	127	131	175	13
Lebanon	34	59	20	12	55	14	4	22	3	50	135	37	4.5
Sudan	4	5	13	–	–	–	–	–	–	4	5	13	5.2
Burma	0.5	1.4	3.4	0.1	0.5	0.6	0.3	0.1	0.1	0.9	2.1	4.1	1.4
India	3.3	9	12	0.8	2.8	2.7	0.6	1.4	[illegible]	4.7	13	17	4.5
Indonesia	5	11	18	1	1.6	6	–	0.4	1.3	6	13	25	3.6
Philippines	7	13	17	3	5	5	4	4	6	14	22	28	5.0
China	12	25	35	4	6	10	[illegible]	2.4	3.1	16	34	48	7.3

Source: FAO Annual Fertilizer Review and Production Year Book.

- For phosphates, in 1965 only China was within the dominant 16 consuming countries. In 1975 there were 4 developing countries out of 20 dominant consuming countries accounting for 12.1 per cent of world consumption. The USSR, China and Brazil had the larger consumption increases at the expense of Australia, the US, France and the Federal Republic of Germany.

- For potash, in 1965 no developing country was within the dominant 14 consuming countries. In 1975 two developing countries, Brazil and China, were among the dominant 13 consuming countries, and account for 4 per cent of world consumption. The USSR, Poland and Brazil had the larger consumption increases at the expense of the Fed. Rep. of Germany, the UK and Japan. The USSR is becoming the dominant consuming country with 24.2 per cent of world consumption.

Annexes B-10 to B-12 show the basic relationships between fertilizers and two fundamental macroeconomic variables: gross domestic product and population. Annex B-12 indicates that in the developing countries of market economies, phosphates and nitrogenous fertilizer consumption have still the highest growth potential while potash consumption has distinctly slowed down in the Far East and Latin America, and the Near East has relatively stagnated its potash growth between 1971 and 1975. The Asian centrally planned economies show a marked drop in elasticity for the period 1970/75 in all nutrients but phosphates; this points out the very dynamic growth this nutrient has achieved, for being the last phosphate-consuming region in 1950 it has become second only to Latin America in 1976, whereby consumption grew 82.5 between 1950 and 1976 in quantitative terms. By contrast, the developed market economies' countries reflect the market saturation achieved in phosphates and potash where growth during 1970/75 was below that of the economy in general while nitrogen still retains some attractive growth potential. The developed centrally planned economies show attractive growth potential in all three nutrients that reflect their relatively lower application rates than those of the developed market economies in nitrogen and phosphates.

2.4.3.1 Regional consumption growth patterns

The regional development described above created differing regional consumption patterns that reflected the reality of fertilizer supply and government fertilizer policies. They are shown in Annexes B-4(a) to (c) and B-5.

- The countries of the developed market economies show a predominance of phosphate consumption until 1962 when nitrogen took up the lead and continued to outgrow the consumption of the other two nutrients. During the period 1950/76 potash consumption grew faster than phosphates and by 1976 it is 16 per cent away from phosphates in quantitative terms, down from a 54 per cent quantitative difference in 1950. The P-K-N consumption structure of 1950 became an even P-N-K in 1960, and then shifted to a N-P-K structure. This situation reflects the relative saturation of phosphate consumption in relation to the other two nutrients.

- The consumption structure of the developed centrally planned economies shows a potash lead from 1950 to 1963 and from there on, nitrogen leads. Although on the average nitrogen consumption grew faster than the other nutrients, there is a tendency to maintain an even nutrient ratio for all three nutrients. The K-P-N structure of 1950 became N-K-P from 1960 onwards with phosphate growth lagging behind the other two nutrients throughout 1950-76.

- Africa shows a lead in phosphate consumption from 1950 to 1962 when nitrogen took over and kept the lead. On the average, nitrogen and phosphate consumption grew faster than potash and the region shows a marked nutrient ratio imbalance against potash, while nitrogen and phosphates keep a 1.3 : 1 nutrient ratio. Its P-N-K structure of 1950 became N-P-K from 1962 onwards.

- Latin America has a nitrogen lead consumption structure that has remained as N-P-K throughout the period with a tendency to keep a 2.1 : 1.6 : 1 nutrient ratio, that represents the less marked nutrient ratio imbalance against potash from the developing countries.

- Near East shows a strongly led nitrogen consumption structure that has remained as N-P-K throughout the period 1950/76. The nutrient ratio is heavily imbalanced against potash and less markedly against phosphates, although the period 1970/76 shows a tendency towards a 2 : 1 ratio between nitrogen and phosphates, but potash is in such a low ratio that it is improbable it remains there much longer as soon as the new potash production from Jordan becomes available.

- Far East shows a strongly led nitrogen consumption structure that has remained as N-P-K throughout the period 1950/76. The nutrient ratio is heavily disbalanced against phosphorus and potash, and shows a tendency towards a 5.5 : 1.6 : 1 nutrient ratio. This situation reflects the high nitrogen demand of the dominant rice crop in the region.

- The Asian centrally planned economies show a strongly led nitrogen consumption structure that has remained N-P-K throughout the period 1950/76. The nutrient ratio shows a strong disbalance against phosphates and potash with a tendency towards a 10 : 3 : 1 nutrient ratio. This situation reflects the heavy nitrogen requirements of the dominant rice crop, and holds an N : P ratio similar to the Far East region, another rice economy region.

2.4.3.2 Regional share in world fertilizer consumption

Annexes B-6 to B-8 give the regional share evolution in consumption between 1950 and 1976, by nutrient.

(a) Nitrogen

Concerning the regional share in nitrogenous fertilizer consumption, the developing countries went from 9.3 per cent of world nitrogen consumption in 1950 to 30.5 per cent in 1976, a 3.3 times increase in share but a 34.5 times increase in quantitative terms during this period. These countries took 10 years, between 1950 and 1960, to increase their world consumption share 2.33 times, but in the next 16 years, from 1960 to 1976, their share increased only 1.4 times although their consumption grew 5.8 times in quantitative terms. By contrast, the developed market economies dropped their share in world nitrogen consumption from 75.3 per cent in 1950 to 44.4 per cent in 1976, while the share of the developed centrally planned economies grew from 15.4 per cent in 1950 to 25.1 per cent in 1976. This situation shows that the markets of the developing countries are growing even faster than the fast growing developed countries, hence the relatively poor share growth in 1960/76. It is interesting to notice that the share of the developing countries in world nitrogen consumption in 1950 was 60 per cent that of the developed centrally planned economies, but in 1976 the proportion reversed to become 22 per cent more than that of the developed centrally planned economies. This market situation contrasts with that of their production, for in 1976 the developing countries supplied only 71 per cent of their regional demand while the developed centrally planned economies exported 24 per cent of their production after satisfying their own demand.

(b) Phosphate

In relation to the regional share in phosphate fertilizer consumption, the developing countries went from 3.51 per cent of world phosphate consumption in 1950 to 23.14 per cent in 1976, a 6.6 times increase in share but a 35.3 times increase in quantitative terms between 1950 and 1976. They took 10 years between 1950 and 1960, to about double their world consumption share but in the next 16 years, from 1960 to 1976, their share trebled. The developed market economies diminished their share in world phosphate consumption from 84.85 per cent in 1950 to 50.43 per cent in 1976, while the share of the developed centrally planned economies grew from 11.64 per cent in 1950 to 26.43 per cent in 1976. This situation shows that the markets of the developing countries are growing faster than those of the slow growing dominant region, the developed market economies. In comparing the share of the developing countries in phosphate consumption with the immediately larger region, that of the developed centrally planned economies, one finds that it was 30 per cent of the latter in 1950 and 88 per cent in 1976. Their production in 1976 supplied 75 per cent of the demand of the developing countries, while the developed centrally planned economies exported 1 per cent of production after satisfying their own needs.

(c) Potash

Concerning the regional share in potash fertilizer consumption, the developing countries went from 2.17 per cent of world potash consumption in 1950 to 11.35 per cent in 1976, a 5.23 times increase in share and 30.5 times increase in quantitative terms during 1950 to 1976. These countries took 10 years, from 1950 to 1960, to increase their potash market share 2.55 times, but in the following 16 years, from 1960 to 1976, their share doubled. The developed market economies diminished their share in potash consumption from 74.46 per cent in 1950 to 50.03 per cent in 1976, while the share of the developed centrally planned economies grew from 23.37 per cent in 1950 to 38.62 per cent in 1976. This situation shows that although the market share of the developing countries has been growing quite in tune with nitrogen and phosphate, their absolute amount has been lagging far behind that of the other nutrients as indicated in the preceding sub-chapter. This may be explained by the fact that farmers in developing countries are not as aware of the benefits of potash application as they are of those of nitrogen and phosphates, and especially nitrogen that produces immediate and visible effects. Moreover, government support to potash within their fertilizer policies and subsidy schemes has been much less than that to the other two nutrients.

2.4.4 Organic fertilizers

Organic fertilizers are those obtained by processing organic waste materials such as crop residues, animal and human manures, sewage sludge, wastes from industries such as food-processing, lumber mills etc., and domestic garbage.

In addition to the principal nutrients (nitrogen, phosphorus and potash), organic fertilizers contain trace elements (micro-nutrients) essential for optimum plant growth and resistance to plant diseases and parasites. Furthermore, organic fertilizers provide the soil with humus, which enhances the efficiency of mineral fertilizers, improves soil structure, increases water retention and reduces soil erosion. The provision of humus is especially important for intensively cultivated soils, soils in tropical areas, heavy clay soils, loose sandy soils, and saline and alkaline soils.

Organic fertilizers and mineral fertilizers are therefore complementary products. The organic fertilizer makes a significant addition to the soil of the major nutrients, but its major contribution lies in its effect upon the structure and texture of the soil, an effect which is lacking in the use of mineral fertilizers. In recent years emphasis has been placed on the use of mineral fertilizers because they produce quick and positive results and because of their relative ease of handling and application. Yet organic fertilizers have traditionally played, and continue to play, a vital role in the maintenance and improvement of soil fertility. Properly used, they possess a potential for increasing soil fertility, which is at present very inadequately exploited.

The growing awareness that the world's raw materials and energy resources, which are used up in the manufacture of mineral fertilizers, are not unlimited, has led to a revival of interest in the use in agriculture of organic fertilizers, which are based upon renewable resources. The shortage and high prices of mineral fertilizers in 1974/75 has emphasized the potential contribution of organic fertilizers which are more readily and universally available and do not require the large, concentrated capital investment needed for mineral fertilizers. The production of organic fertilizers also has a significant contribution to make to the ever-growing problem of the disposal of organic waste materials from increasing and increasingly urbanized populations. In developing countries in particular there is a strong case for a vigorous campaign for the reclamation of organic wastes for use in agriculture.

FAO Soils Bulletin No. 27[37/] gives an estimate for the quantity of nutrients in organic wastes of all types in developing countries of about 100 million tons a year, a very large quantity indeed. The relevance of this figure is, however, doubtful, because: (a) the amount of organic wastes available in practice is considerably less than the amount potentially

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[37/] FAO Soils Bulletin No. 27, "The Use of Organic Materials as Fertilizers", 1975.

available owing to the high cost of collection and transport and to the use of crop residues and other organic wastes as fuel, and (b) there are very real constraints to the use of organic fertilizers because of their excessive bulk, which gives rise to high costs of handling, processing and application. Organic fertilizer, in its untreated form, has a low content of nutrients. When compared with the most common compound fertilizer of 15 per cent N, 15 per cent P_2O_5, and 15 per cent K_2O content, i.e. a total content of 45 per cent of the three nutrients, or urea with a 46 per cent content of nitrogen, the total content of the three nutrients in organic fertilizers is below 10 per cent, in some cases as low as 3 per cent. Nevertheless, FAO estimates that organic wastes at present supply about 10 per cent of the fertilizer nutrients added to the soil, and that there is probably the potential to raise this to about 25 per cent.

Traditionally, China and India have been the world leaders in the use of organic fertilizers. Along with the rapid expansion of its inorganic fertilizer production, China is increasing the use of organic fertilizers. An increasing emphasis is being laid on the utilization of human and animal wastes, which remained at the top of the list of organic fertilizers in China's Agricultural Development Programme. It has been reported that some half a million bio-gas plants were installed in 1975 and that the economy of these plants depends upon the successful reclamation of the spent slurry for use as an organic fertilizer. A particularly interesting development has been the programme for the production of "humatic" fertilizer, a compound organic fertilizer made from peat, brown coal, lignite and similar materials together with other organic substances and which can be mixed with ammonium or potash salts. The equipment needed appears to be relatively simple and the processing cost reasonably low. The process uses raw materials that are locally available in significant quantities in most provinces of China. The information at present available suggests a planned annual production of several million tons[38].

In India, a programme of compost production from both rural and urban wastes was launched as early as 1945 and has been making good progress. More and more villages have pits for cattle manure, night soil and domestic refuse, and many farms practice composting of farmyard manure and crop residues. The programme also covers utilization of sewage through sewage

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[38] FAO Soils Bulletin No. 40, "China: recycling of organic wastes in in Agriculture", 1977

irrigation and sludge fertilization. It is estimated that about 40-50 per cent of animal wastes and other farm residues are currently utilized as organic fertilizers. Some urban refuse is being composted but a considerably smaller fraction (about 5 per cent) of the night soil is being used to produce organic fertilizers. It is estimated that the use of sewage irrigation has led to increases in crop yields ranging from 30-50 per cent, as compared with irrigation by ordinary water.

Many developing countries are finding an economic solution to their rapidly increasing urban refuse problems through the establishment of compost plants. With careful planning and organization, and the use of simple processing techniques and equipment, municipal refuse can be transformed into a source of valuable fertilizer to market gardeners in the vicinity. As an example of what can be done in this respect,the capital and operating costs of a plant to produce 45,000 tons of compost a year from 80,000 tons of city refuse are given in Table 21. Although urban refuse composting can meet only a fraction of a country's fertilizer needs, in many cases it may provide the only fertilizer readily available. It may also provide the most economic method of urban waste disposal, because labour costs are low in developing countries and their urban refuse contains a far higher percentage of organic matter than that from cities in industrialized countries. Urban compost programmes are being planned and implemented in a number of developing countries.

There is undoubtedly room and need for a much greater use of organic fertilizers but there are at present many constraints to rapid expansion. The labour requirements are high and in rural areas may conflict with farm labour needs. Because the materials used are bulky, transport is difficult and costly. The use of certain organic wastes may raise serious sociological problems in some countries. Finally, the greatest handicap is probably a lack of specific experimental work under controlled conditions, adapted to the possibilities in different rural environments, to establish cost/benefit ratios for different uses of organic materials and to provide a sound basis for the transfer to the farmer of an appropriate technology.

Table 21. Estimated cost of a city refuse compost plant

Input: 80,000 tons of city refuse a year, delivered free of charge

Output: 45,000 tons of compost a year: N, P_2O_5, K_2O contents 1.0, 1.0 and 0.8 per cent.

Capital costs, 1977	(thousands of US$)
Machinery and equipment erected	600
Civil work	500
Total	1,100

Production costs	(dollars per ton)
Maintenance	2.55
Salaries and wages	2.45
Capital charges (17.5%)	4.30
Fixed costs	8.30
Fuel and power	2.50
Total	10.80

2.5 INTERNATIONAL TRADE AND DISTRIBUTION

2.5.1 Evolution of fertilizer trade

The differing regional evolution of fertilizer consumption and production shown in the preceding chapters generated specific regional surplus or deficit balance situations which in turn were the originators of trade flows and fertilizer exchange patterns. Annexes C-1 to C-3 give data on the regional surplus/deficit balance by nutrient at mid point of three decades, the 50 s, 60 s and 70 s[39]. This balance represents the tonnages exchanged, net variations in stocks, losses over formulations, products in transit, etc. Fertilizer products and their raw materials form an important share of international trade. In 1976/77 the developed market economies,which is by far the largest exporting region, exported about 600 million dollars in nitrogen, 300 million in phosphates and 500 million in potash fertilizer products without accounting for the fertilizer raw materials. The developed centrally planned economies in 1976 exported about 200 million, 15 million and 250 million dollars respectively.

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[39] Sources: op.cit.28

Now we shall review the concept of soil fertility and the development of the doctrine of mineral plant nutrition in order to gain perspective and insight into agriculture, the only market of the chemical fertilizer industry. [32]

(a) Concept of soil fertility is a complex function of many variables that experts maintain is not susceptible tc a precise and absolute definition but constitutes an experimental ascertion on the propensity of the soil to favour more or less high yields. Therefore fertility is a polyvalent concept of many factors that tend to modify soil productiveness through specific effects that are temporary and efficient within certain limits, thus creating situations capable of rapid changes. Not all of these factors can be modified through man's intervention. These factors can be grouped into three categories:

(i) Fertility of position or general soil fertility comprises two groups of factors:

- positional factors such as location, altitude, climate, are parameters where farmers can by no practical means interfere;
- farm management factors such as the lie of the land, the depth of the cultivated stratum, land clearing, surface levelling, slope correction, the hydric state of the soil, etc., are parameters essential for soil fertility that the farmer can modify in proportion to his means.

(ii) Physical soil fertility concerns soil texture and structure. The texture is a function of particle size. The structure is the way the particles are grouped among themselves and is extremely important for fertility because it influences the capacity for accumulating water and air and plays a role in top soil resistance to erosion.

(iii) Chemical soil fertility concerns the existence of catalytic and enzymatic activities capable of transformations in numerous metabolites for plant and microbiological nutrition. Chemical fertilizer applications are only linked with this component of the complete soil fertility that in its entirety is responsible for increased crop yields.

32/ "Soil fertility and fertilizing of cultivated plants", O.T.Rotini, Pontificia Academis Scientiarum, 1973

During 1950/76 the developing countries continued to depend on developed countries for a substantial share of their fertilizer supplies as represented by the balance figures in relation to consumption. In 1955 they imported 61% of nitrogen, 46% of phosphates and 93% of potash of their total demand. In 1976 the corresponding figures were 29%, 25% and 77% respectively. However, total net imports of the developing countries in relation to the production of developed countries in 1955 was about 10% for nitrogen, 20.3% for phosphates and 3% for potash. In 1976 the corresponding figures were 11%, 6.8% and 8.2% respectively. In 1955 this net trade was 64% in nitrogen, 16% in phosphate and 20% in potash fertilizers. In 1976 the corresponding figures became 53%, 20% and 27% respectively.

Considering the rather modest impact the developing countries represent in the overall fertilizer trade, it is not surprising that the supply of fertilizers and their prices in the international market have fluctuated according to developments in the overall production/consumption balances in the developed countries. Furthermore, the periodic foreign exchange scarcities in the developing countries, uncertainties about the size of aid-financed programmes, bilateral trade and credit arrangements, fluctuation in domestic consumption of the developed market economies and periodic plant capacity fluctuations, have created severe cyclical fluctuations in fertilizer supply and prices.

2.5.2 Patterns of fertilizer trade exchange

Annexes C-4 to C-6 show the overall interregional trade exchange by nutrient between 1965 and 1975[40]. For all nutrients, the export-import balance of the developing countries was deficient, showing net trade flows from the regions of the developed countries; the only exception is phosphate where developing countries are net exporters of phosphate rock.

The weight of international trade in fertilizers over world production is given in Annex C-7. In 1965, 20.4 per cent of world nitrogen production, 11.5 per cent of phosphates and 42.8 per cent of potash entered international trade. In 1975, the corresponding figures were 18.8%, 17.5% and 58.6% respectively. These figures point out a slightly diminished trade for nitrogen due to increased regional supply in developing countries. Phosphate trade has greatly increased, reflecting the remarkable interdependence of developed and developing countries in the production, trade and use of phosphates.

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[40] Source: op.cit.28

These include a trend towards the point of diminishing returns for farmers in phosphate applications in the developed market economies and an accelerated shift to produce phosphate intermediates for trade in phosphate rock producing countries. Potash trade increase shows the growing dependence of developing countries on imports from developed countries. Annex C-8 shows the countries that accounted for 80 per cent of world export and import by nutrient in 1975/76.

- Concerning nitrogen, 12 developed countries were the dominant exporters, 22 countries were the main importers out of which 10 were developed countries, although there is no single dominant country in either export or import. In 1975 the total exports of developing countries was 8.2 per cent of total world exports of which 12 out of 25 exporting developing countries were net exporters of nitrogen fertilizers, with Kuwait accounting for about 45 per cent of the total.

- Concerning phosphates, 9 developed countries were the major exporters, 19 countries were the main importers out of which 10 were developed countries. In phosphate trade the US holds the dominant export position with 48.5 per cent of total world phosphate exports. There is no dominant importer. In 1975 the total exports of developing countries was 7.3 per cent of total world exports, of which 10 out of 17 exporting developing countries had a net export in phosphate fertilizers, with Morocco and Tunisia accounting for about 50 per cent of the total.

- Regarding potash, 4 developed countries are the major exporters, 16 countries are the main importers out of which 13 are developed countries. In potash trade, Canada is the dominant exporter with about 36 per cent of world export and the US is the dominant importer with about 30 per cent of world imports. In 1975 there were 3 potash producing developing countries whose export amount was insignificant in world terms.

2.5.2.1 Inter- and intra-regional trade

The international trade classifications (SITC and BTN) attempt to show fertilizers trade according to their chemical composition but irrespective of nutrient content and degree of processing, hence ordinary trade statistics cannot show fertilizer trade separately by nutrient. The FAO trade statistics show total exports and imports of individual countries in terms of nutrients but without indication of either origin of raw materials and intermediates, or destination of exported fertilizers. Two recent studies[41] give useful inter- and intra-regional trade data for potash and phosphate rock. For nitrogenous and phosphate fertilizers UNCTAD prepared a broad geographical world trade pattern using FAO import-export data and available trade statistics expressed in value[42].

(a) Trade pattern of nitrogenous fertilizers

The traditional major suppliers of developing countries for the past 25 years have been the developed market economies: Western Europe, the US and Japan, but Western Europe accounted for about half these exports in the last 10 years. The largest importing developing countries have been China, India, Turkey, Brazil, Mexico and Egypt. Table 22 gives a broad view of nitrogen and phosphate fertilizers trade patterns for 1973, based on UNCTAD preliminary tabulations. The table estimates indicate that in all major regions, intra-trade held the dominant proportion of the region's exports. It is interesting to note that for the dominant exporting region, the developed market economies, its exports to developing market economies is about equal to that of its intra-trade. This explaines the higher responsiveness the developing market economies show to supply and price fluctuations in the developed market region, and conversely the influence which the constraints in the developing market region (such as foreign exchange difficulties, increasing regional self-supply etc.) exert on the developed market region and international trade.

In relation to imports, intra-trade accounted for 89.8 per cent in the developed market economies and 63.4 per cent in the developed centrally planned economies, while in the developing market economies it only accounted for 14.2 per cent and 7.5 per cent in the Asian centrally planned economies. Both regions of the developing countries depend on the developed market economies for the major part of their imports: on the developing market economies for about 83 per cent and on the Asian centrally planned economies for about 68 per cent. Nevertheless, a fairly large proportion of nitrogen fertilizer exports to developing countries occurred under various aid schemes. Recently shifts in trade patterns are starting to take place in the regions, spurred by the barter deals of the developed centrally planned economies with the US, North Africa and Middle East countries, including all three nutrients but involving chiefly nitrogenous fertilizers (ammonia, urea) for phosphate fertilizers (phosphoric acid, phosphate rock).

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[41] "World Potash Survey", op.cit.30 and "Consideration of International Measures on Phosphates", UNCTAD, TD/B/IPC/Phosphates/2/Add.1, 31 Oct.1977

[42] "Draft World-wide Study of the Fertilizer Industry: 1975-2000", UNIDO/ICIS/22/Rev.1, 28 Dec.1976

Table 22. Broad regional world trade pattern in nitrogenous and phosphate fertilizers, 1973
(percentage)

Export to / from	Developed countries: Market economies		Developed countries: Centrally planned economies		Developing countries: Market economies		Developing countries: Centrally planned economies		Total World Exports
	Import	Export	Import	Export	Import	Export	Import	Export	
Developed countries									
Market economies	89.8	44.95	8.5	0.75	83.6	44.5	68.7	9.8	100
Centrally planned economies	4.5	21.2	63.4	52.5	1.2	6.1	14.9	20.2	100
Developing countries									
Market economies	5.7	20.3	28.1	17.3	14.2	53.4	8.9	9.0	100
Asian centrally planned ec.					1.0	33.3	7.5	66.7	100
Total world imports	100		100		100		100		

Source: Calculations based on "Draft World-wide Study of the Fertilizer Industry, 1975-2000", Annex Table 2, p.153, UNIDO/ICIS.22/Rev.1, 22 December 1976

(b) Trade pattern of phosphate fertilizers

The traditional major suppliers of the developing countries have been the US and Western Europe but the main producers of phosphate rock are the US, the USSR and North Africa (Morocco, Tunisia). The largest importing developing countries are Brazil, India, Bangladesh, Rep. of Korea and Indonesia with the notable exclusion of China. One of the main features of this industry is its high interdependence between developed and developing countries. A large part of the developed market economies industry is dependent on rock supplies from a few developing countries located in the Near East and North Africa, and it is likely to become more dependent because of the rock reserves concentration in those countries. At the same time, many other developing countries are dependent on phosphate fertilizer imports from developed market economies and this situation is likely to remain for some time to come.

Table 22 gives the broad regional trade pattern for nitrogenous and phosphate fertilizers whose main characteristics have been analyzed in the preceding heading. Nevertheless the relationship between phosphate rock and phosphate fertilizers is becoming stronger since the main rock producing developing countries are also becoming major world fertilizer producers.

Table 23 gives the international trade pattern of phosphate rock production for 1972 and 1976, by country. The developing countries accounted for 55 per cent of world rock exports in 1972 and 60.5 per cent in 1976, and for 11.4 per cent and 13.3 per cent of world imports respectively. Their intra-trade accounted for 57 per cent of imports in 1976.

The market structure of production and sale of phosphate rock appears to have features similar to those of markets for other minerals rather than for chemical commodities. Apart from a few developed market economies, rock production and sale is in the hands of state enterprises and companies owned or controlled by governments. Contracts of at least one year duration predominate but spot transactions account for only a small fraction of total rock trade. There are no dealings in phosphate rock on any commodity exchange and spot prices are not published.

Important changes are now taking place in this industry due to diminishing rock grades, a shift to high analysis fertilizers, more expensive transport costs and very high infrastructural investments for new mines. The most important is a shift toward greater processing of the rock in producing countries. In 1973, rock deliveries to their domestic markets amounted to 52 per cent of world rock consumption, whereas in 1977 they amounted to to 59 per cent, despite the recovery of demand in importing countries[43].

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[43] "Further examination and analysis of the situation and problems of the World Phosphate Market". UNCTAD, TD/B/Phosphates/6, 16 June 1978

Table 23

International trade in phosphate rock, by origin and destination 1972 and 1976
([illegible] weight) in percentage of total [illegible]

Exports from / Destination		World	Developed market economy countries			Developing countries									Socialist countries of Eastern Europe	Socialist countries of Asia
			USA	Others a/	All	Jordan	Morocco	Senegal	Togo	Tunisia	Christmas, Nauru and Ocean Islands b/	[illegible] c/	Other Africa and Asia d/	All	USSR	Viet Nam
World	1972	100.0	[illegible]	[illegible]	[illegible]	[illegible]	31.2	3.6	4.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.7
	1976	100.0	[illegible]	[illegible]	23.7	3.9	[illegible]	3.7	4.3	4.1	5.3	[illegible]	[illegible]	[illegible]	[illegible]	2.6
Developed market-economy countries	1972	[illegible]	26.3	1.2	[illegible]	0.5	24.1	3.3	4.2	2.1	6.4	0.2	[illegible]	41.4	4.9	-
	1976	[illegible]	[illegible]	1.3	16.6	0.9	[illegible]	3.1	4.0	2.2	4.8	[illegible]	1.3	[illegible]	3.2	-
EEC e/	1972	36.0	8.6	0.7	9.3	-	19.4	2.0	4.0	1.6	-	-	0.2	23.8	2.9	-
	1976	31.9	6.4	0.5	6.9	0.5	14.9	2.3	3.5	1.4	-	-	0.6	23.3	1.7	-
Other Western Europe	1972	12.7	1.3	0.4	1.7	0.1	7.5	0.5	-	0.8	-	-	0.1	9.0	2.0	-
	1976	11.6	0.5	0.4	0.9	-	7.0	0.5	0.4	0.8	-	0.1	0.4	[illegible]	1.5	-
Canada	1972	6.2	6.2	-	6.2	-	-	-	-	-	-	-	-	-	-	-
	1976	5.2	5.2	-	5.2	-	-	-	-	-	-	-	-	-	-	-
USA	1972	0.2	-	-	-	-	-	-	-	-	-	0.2	-	0.2	-	-
	1976	0.1	-	-	-	-	-	-	-	-	-	0.1	-	0.1	-	-
Australia and New Zealand	1972	6.2	-	-	-	-	-	-	-	-	6.2	-	-	6.2	-	-
	1976	4.9	-	-	-	-	0.1	0.1	-	-	4.7	-	-	4.9	-	-
Japan	1972	6.9	4.8	-	4.8	0.4	1.0	0.2	0.2	-	0.2	-	-	2.1	-	
	1976	5.7	3.2	0.4	3.6	0.4	1.2	0.1	0.1	-	-	-	0.3	2.1	-	
Developing countries	1972	11.4	6.9	0.2	7.1	1.4	1.3	0.2	0.1	0.2	0.3	-	0.1	4.3	-	-
	1976	13.3	5.2	0.5	5.7	1.1	4.5	0.3	0.1	1.1	0.4	-	-	7.6	-	-
Brazil	1972	2.0	1.7	-	1.7	-	0.2	-	-	0.1	-	-	-	0.4	-	-
	1976	3.6	1.7	0.1	1.8	-	1.5	0.1	-	0.2	-	-	-	1.8	-	-
Mexico	1972	2.6	1.9	-	1.9	-	0.8	-	-	-	-	-	-	0.8	-	-
	1976	2.5	0.6	-	0.6	-	1.8	0.1	-	-	-	-	-	1.9	-	-
Other America	1972	0.5	0.3	-	0.3	-	0.1	-	-	0.2	-	-	-	0.3	-	-
	1976	0.3	0.1	-	0.1	-	0.1	-	-	0.1	-	-	-	0.2	-	-
India	1972	2.0	0.9	-	0.9	0.9	0.1	0.1	-	-	-	-	-	1.1	-	-
	1976	1.2	0.5	-	0.5	0.3	0.3	0.1	-	-	-	-	-	0.7	-	-
Korea, Republic of	1972	1.2	1.2	-	1.2	-	-	-	-	-	-	-	-	-	-	-
	1976	1.8	1.6	0.1	1.7	-	-	-	-	-	0.1	-	-	0.1	-	-
Other Asia	1972	2.9	1.1	0.2	1.2	0.4	0.1	0.1	-	0.5	0.3	-	0.1	1.7	-	-
	1976	3.8	0.8	0.3	1.1	0.7	0.8	-	-	0.8	0.3	-	-	2.7	-	-
Africa	1972	0.1	-	-	-	0.1	-	-	-	-	-	-	-	0.1	-	-
	1976	0.2	-	-	-	0.1	-	-	0.1	-	-	-	-	0.2	-	-
Socialist countries of Eastern Europe	1972	17.0	0.8	0.1	0.9	0.1	4.0	-	-	1.8	-	-	0.6	6.5	2.6	-
	1976	23.6	1.1	0.2	1.3	1.5	7.0	0.3	0.7	1.2	-	-	1.6	12.3	10.0	-
Socialist countries of Asia	1972	3.4	0.2	-	0.2	0.1	1.8	-	-	0.2	-	-	0.4	2.5	-	0.7
	1976	3.8	0.1	0.1	0.2	0.4	0.2	-	-	-	0.1	-	0.5	1.0	-	2.6
China	1972	3.3	0.2	-	0.2	0.1	1.8	-	-	0.2	-	-	0.4	2.5	-	0.6
	1976	3.6	0.1	0.1	0.2	0.4	0.2	-	-	-	0.1	-	0.3	0.9	-	2.6
Korea, Democratic Republic of	1972	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1
	1976	0.2	-	-	-	-	-	-	-	-	-	-	0.2	0.2	-	-

Source: ISMA.

a/ Australia, Israel, South Africa, Sweden.

b/ Christmas, Nauru and Ocean Islands.

c/ Curacao and Mexico.

d/ Algeria, Egypt, Syria and Western Sahara.

e/ Enlarged community of nine members.

Source: UNCTAD, TD/B/IPC/PHOSPHATES/2/Add.1, page 12, 31 Oct.1977

In quantitative terms, the largest increases in rock processing were in the US, USSR and in developing countries, but in percentual terms the order of increases was reversed. Increased domestic processing has been reflected in a sales expansion of processed phosphates in competition with domestic products in rock importing countries. A slowing down of rock production growth rate has been noticed in the USSR in recent years. Although the USSR continued exporting rock to Western Europe in 1977, the developed centrally planned region had to import about 20 per cent of its consumption in 1977, up from 7 per cent imports in 1973. This situation may explain the move of these countries towards very long-term supply agreements with the US, North Africa and Near East countries based on barter.

In 1977, Morocco overtook Mexico and Tunisia to become the leading developing country exporter of phosphoric acid, a chemical commodity more standard than rock. The acid has also become the principal form of processed phosphates exported by Morocco, replacing triple superphosphate. Tunisia exports both acid and TSP. At the same time many developing countries are interested in producing their own phosphate fertilizers. Nevertheless some of the larger phosphate importing developing countries like Brazil and India are increasing their imports of phosphoric acid.

(c) Trade pattern of potash fertilizers

The main exporting countries have traditionally been Canada, the US, Federal Rep.of Germany and Democratic Rep. of Germany and USSR. The major importing developing countries have been Brazil, India and the Rep. of Korea.

Table 24 gives the potash trade pattern for 1976, by country. World potash exports grew 8.7 per cent annually between 1965 and 1975, more than 3 per cent faster than world production that grew 5.3 per cent in the same period. Trade in straight potash is carried out by developed countries endowed with potash ore, 8 of which account for 99 per cent of these straight exports. The trade in compound fertilizers that represented 7 per cent of total world potash exports in 1973, is dominated by Western Europe with 70 per cent of total compound exports, whereby 3 countries: Belgium, Holland and Federal Rep. of Germany account for over 40 per cent of it[44]. In 1976 the developing countries accounted for 16.4 per cent of world potash imports with no significant intra-trade between them.

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[44] op. cit. 30

Table 24. POTASH TRADE IN 1976
('000 metric tons K_2O)

IMPORTERS:	FRANCE	FED.REP. GERMANY	ITALY	SPAIN	DEM.REP. GERMANY	USSR	CANADA	UNITED STATES	ISRAEL	1976	1975
WORLD TOTAL[1/]	476	779	54	239	2,303	2,304	4,923	848	341	12,268	11,721
DEVELOPED MARKET ECONOMIES	371	566	16	179	639	597	4,412	323	273	7,377	6,781
North America	-	20	5	15	-	-	4,030	14	43	4,132	3,286
West Europe [2/]	283	453	11	150	618	462	25	38	172	2,213	2,237
Oceania	-	2	-	-	-	14	54	175	-	245	210
Others [3/]	88	91	-	14	21	121	303	96	53	787	1,048
DEVELOPING MARKET ECONOMIES	100	190	38	60	349	104	420	524	68	1,854	1,677
Africa	47	5	1	-	-	-	-	3	8	64	42
Latin America	30	78	4	36	201	101	147	471	19	1,088	821
Near East											
- Africa-	4	-	25	24	3	-	-	-	-	56	85
- Asia-	-	-	5	-	10	-	-	-	-	15	8
Far East											
-South Asia-	-	91	-	-	131	3	110	-	-	335	245
-East Asia-	19	16	3	-	4	-	163	50	41	296	476
CENTRALLY PLANNED ECONOMIES	5	23	-	-	-	1,315	1,603	91	1	3,038	3,263
Asia	-	-	-	-	-	38	33	91	1	163	292
E. Europe [2/]	5	23	-	-	-	1,277	1,570	-	-	2,875	2,971

1/ Totals Rounded, not always comparable.
2/ Yugoslavia included in W. Europe
3/ Includes Japan, South Africa & Israel

SOURCE: International Superphosphates & Phosphate Manufacturers Association
Source: "World Potash Survey", W. Sheldrick and H. Stier, World Bank, June 1978.

The international trade pattern in potash is the result of three main factors:

- As production costs are relatively cheap but the product is bulky, transportation costs constitute a major factor affecting the producer's competitive range;

- for many developing countries, potash imports are determined by amounts of aid financing or through barter deals. This factor illustrates the sales of the Democratic Rep. of Germany to India despite its disadvantageous position for freight;

- the relative few numbers of producers has led to an oligopolistic structure which allows orderly market supply arrangements that effectively preclude wild price and supply fluctuations.

However, recent developments may point to a possible disruption of the orderly international potash marketing system within the developed countries themselves.

2.5.3 Fertilizer prices

The market situation for most fertilizer products was tight during the early 60 s. Growing demand in developed and developing countries plus lagging supplies induced higher fertilizer prices which peaked around 1966. International prices plummeted in the second half of the 60 s and touched rock bottom in the 1970/71 agricultural year.for nitrogen and phosphates, while potash bottomed out in 1969. During this period spot prices were frequently lower than contracted prices. Starting late in 1971, shortages and rising prices once again began to emerge for nitrogen and phosphates, by 1973 leading to non-delivery on contracts and forcing most international trade into the spot market for immediate sale and delivery.

Table 25 gives the evolution of international prices for representative fertilizer products from 1960 to 1977.

Table 25. International prices for representative fertilizer products, 1960-77
(Price range in US dollars per metric ton FOB)

Year	North West Europe	U.S. Gulf Coast		Vancouver, Canada
	Urea (bagged)	DAP ← (bulk)	→ TSP	Kcl (bulk)
1960	79-83	n.a	n.a	27-30
1962	60-81	92-97	48-50	28-32
1966	90-100 a/	96-104 a/	59	25-30
1968	60-65 b/	54-57 b/	34-38 b/	23-25
1970	48-52 a/	50-55 a/	42-46 a/	31-32
1971	42-46 a/	55-60 a/	37-43 a/	32-33
1972	65-70 b/	94-104 b/	70-80 b/	32-35
1973	95-120 b/	105-160 b/	100-130 b/	35-50
1974	335-390 b/	320-430 b/	310-380 b/	45-55
1975	115-185 b/	137-207 b/	107-196 b/	60-93 b/
1976	105-124 a/	96-140 a/	76-114 a/	46-75 a/
1977	110-140 a/	122-138 a/	88-102 a/	46-56 a/

Source: World Bank and British Sulphur Corporation

a/ Refers to the first half of the year
b/ Refers to the second half of the year

The quadrupling of petroleum posted prices in October and December 1973 and the quadrupling of Moroccan phosphate rock in January and July 1974, directly affected the production costs of nitrogen and phosphate fertilizers. The apprehensive buying of some regions in 1974 to buffer themselves against forecasted supply deficits and greatly increased prices, did lead to the large price increases recorded in Table 25. Nevertheless, farmers found that those levels of fertilizer prices were much too high giving a disfavourable cost-benefit ratio for them. Thus they greatly reduced their buying and brought down the fertilizer prices. The big losers were the dealers and distributors engaged in apprehensive buying. Prices peaked off in the second half of 1974 and slumped through until mid-1976, regained some momentum in September'76 and then about evened out during the first half of 1977.

Only potash followed a different price pattern since this industry was not directly affected by sudden price increases in their raw material. Potash prices peaked off by mid-1975 and evened out during 1976/77.

Concerning the developing countries, they have continued their steady increased import of fertilizers from the international markets, and do not appear to have reached a cost-benefit ceiling in relation to the international agricultural prices for their exporting agricultural commodities. The main constraints on fertilizer imports seems to be the growing fertilizer production capacities and foreign exchange restrictions. At present, trade in fertilizers is not significantly affected by tariffs or other trade barriers, thus reflecting their character as essential inputs for agriculture.

2.5.4 Distribution of fertilizer commodities

All final and intermediate fertilizers can be defined as commodity chemicals, that is, products sold solely on the basis of their specifications. They should be distinguished from their formulations or other application-ready products that are sold to farmers on the basis of their performance in agriculture. Figure 2 shows the patterns of commodity chemical distribution applicable to fertilizer trade and distribution. It shows the types of commercial channels through which fertilizers move and the manner in which they change hands along a distribution line. This figure illustrates the fact that the market actually available to a new exporter is usually but a fraction of the actual overall demand.

The truly merchant market is further broken down into contract sales and spot sales. Although nowadays prices are seldom fixed for more than three months, longer-term contracts are usually established for periods covering several years but containing price escalation clauses. Therefore new exporters will have to wait until on-going contracts expire before they are able to compete for the business. Spot sales include both regular transactions of a speculative nature and non-recurring sales. Usually a large buyer of a given fertilizer meets between 60 and 80 per cent of his requirements by contracts, the rest will be acquired on the spot market, in the hope that by agile purchasing the weighted average fertilizer cost can be somewhat reduced, without incurring in too great a risk. The spot market is handled mainly by brokers and traders. The new exporter thus initially faces markets where rather little is left to chance and where real structural shortages are uncommon. The speculative apprehensive buying of 1974 left a vivid mark in this respect. The new market entrant must then carve out his share from a market that is basically in balance. The extent of his success will depend, among other things, on the number and aggressiveness of current suppliers.

(b) *The doctrine of mineral plant nutrition* was first declared by Justus von Liebig in 1840; it showed the experimental results of the soil as a source of inorganic salts for plants, and when the soil is lacking some of the major organogenic elements the plants showdefects and are unable to fully complete their vegetative cycle. These organogenic or macroelements were the basis for the doctrine of mineral plant nutrition and chemical soil fertility although at that time Liebig considered there was no need to supply nitrogen as fertilizer because the nitrogenous forms existing in the air were enough for the plants' needs. About a century later the important role played by trace inorganic elements in plant growth was realized. These oligodynamic elements or micronutrients promote catalytic functions indispensable for a sound plant growth. The degree to which micronutrients are available in the soil depends on the pH of the soil, hydric erosion, level of the clay humus complex and microbial activity in the soil. In modern farming systems the water soluble salts of the microelements are usually applied in the amount required by soil conditions and crop needs, but they must always be carefully kept below toxicity levels, especially concerning the salts in heavy metals.

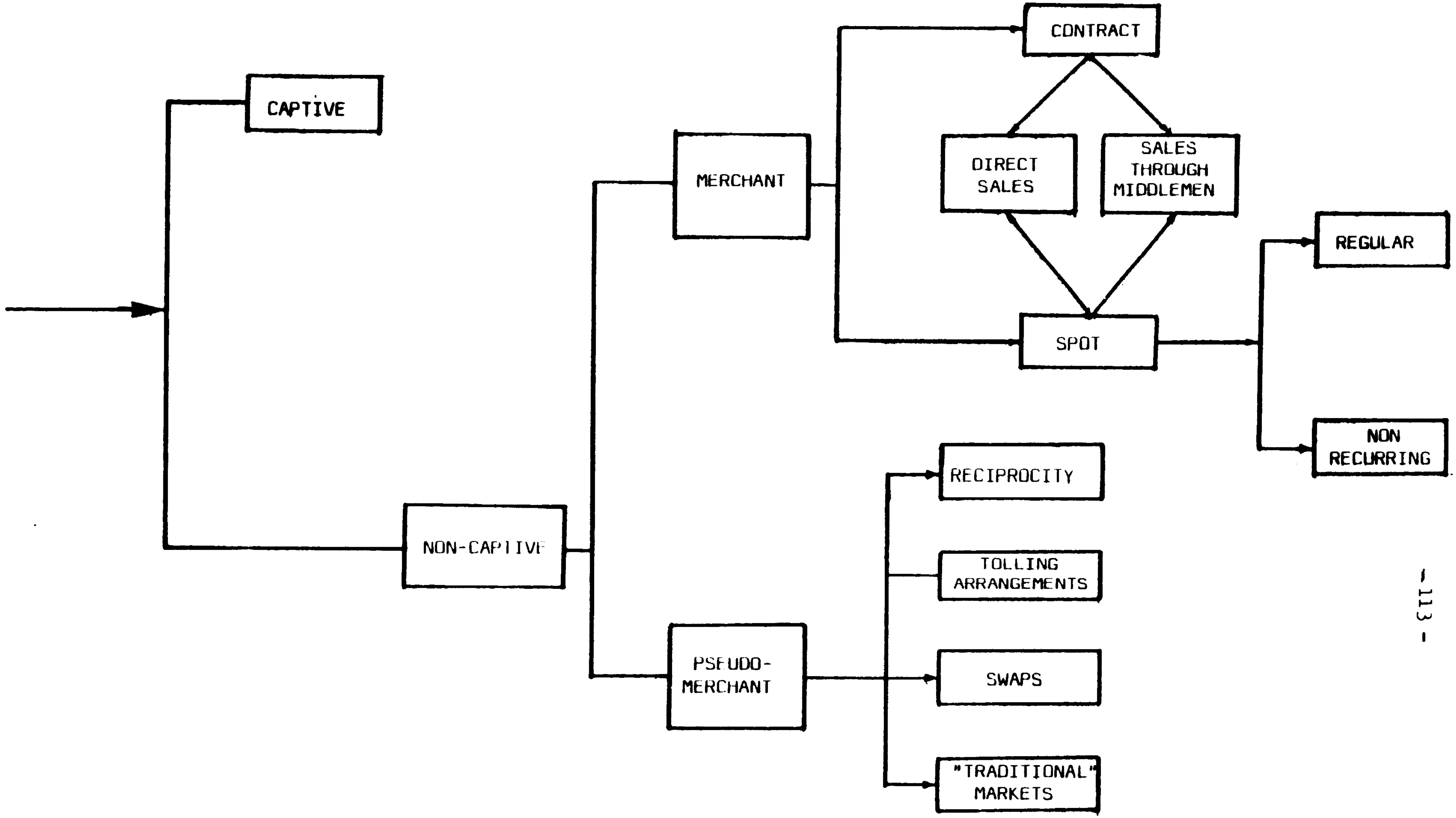
During the 60 s the doctrine of mineral plant nutrition underwent a third stage of development,that of the simple and complex alimentary interactions, the knowledge of which has already suggested profound modification in the fertilizer management of crops. This approach demands that manuring must be complete and equilibrated for properly responding to crop needs and soil structure. Thus the role of any particular fertility element does not depend on the direct effects of its concentration, but also on the repercussions it exerts on all the other factors of the system.

In agricultural practice soluble fertilizers constitute the most efficient factor to increase soil productivity but they should be applied under well-balanced formulations custom made for the land.

On the physiological level, plants can feed even if the fertility elements are applied in small concentrations, but for obtaining adequate economic returns soil concentrations of macro and microelements should not diminish below defined levels. However, there is no strict correlation between the quantity of fertilizer used and crop production, since the other factors of a complete soil fertility, the plant varieties and seeds, and farming practices, constitute important elements in crop productiveness. Furthermore, when additional fertilization does not bring about a correlated increase in agricultural production as happens in many modern farming systems, the reason may be found in the way and frequency of application and the limits of soil fertilization beyond which fertilizers become economically marginal and may endanger the ecological equilibrium.

FIG. 2

PATTERNS OF COMMODITY CHEMICAL DISTRIBUTION



2.6 TRANSFER OF TECHNOLOGY

2.6.1 Development of technology transfer in the fertilizer industry

In the early part of the 1950's a trend towards more ownership and control of the basic raw materials and intermediates was appearing, as a consequence of which the sale of technology in the fertilizer industry started to grow.[45] Previously, apart from superphosphate production, other important intermediates such as ammonia and liquors and ammonium sulphate were purchased as by-products from other industries. As engineering companies expanded their experiences and developed their simple design concepts in fertilizer manufacturing, they marked a new era which led to the development of proprietary machinery and process equipment, rather than proprietary processes. This period also marked an expansion in the use of phosphoric acid and its derivatives as a route to higher analysis straight and complete fertilizers. Door Oliver, Inc. was a pioneer in production of wet process phosphoric acid, and the company became the leading engineering enterprise with "in-house" phosphate technology. The reason for encouraging manufacturers of fertilizer in Europe to develop their know-how was mainly the availability of new phosphate rock sources, each with its unique characteristics in such aspects as phosphate rock dissolution rate, free sulphate level, gypsum filter ability, and system corrosion properties. In the U.S.A., however, with its indigenous phosphate rock of more uniformity, there has been considerably less scope for activity in the licensing field by fertilizer manufacturers.

Engineering companies with "in-house" processes have maintained a leading position in nitrogenous fertilizer technology. The relatively pure and limited range of feedstocks for these processes allows the operating company to assume that process design concepts, equipment specifications, and operating procedures have long since been standardized.

During recent years the process engineering industry has been a mixture of both national and international interests as a means of maintaining and developing business. There can be an expectation that the progressive nationalization of this industry in such manner will continue. In such circumstances there may well be an incentive for a similar nationalization of process technology, particularly where the various sources of know-how are owned by the engineering company. It can also be expected that engineering companies will be

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[45] For more detailed information see "Transfer of Technology in the Fertilizer Industry" by J.D.C. Hemsley, ID/WG.21915.

increasingly selective in their sub-license arrangements with operating companies having sellable processes.

2.6.2 Selection of process technology

There are two well-designed stages in the selection of the most attractive technology for a production unit or complex. The first stage is concerned with the evaluation of the various process routes that are available, and the requirements of the proposed production route with respect to feedstocks, by-product disposal, product quality, etc. The second stage is essentially concerned with the in-depth evaluation of the various processes which are available and commercially proven for the process route already selected.

Process routes used in the modern fertilizer industry are few and well established so that the first stage - process route selection - is simple. For example, the vast bulk of the world's nitric acid capacity is based on the oxidation of ammonia. Similarly, phosphoric acid for the use in fertilizer production is largely based on a route which depends upon the dissolution of phosphate rock with sulphuric acid. Even the integration of individual process routes and processes into a total factory complex offers only a limited opportunity for unique or novel solutions.

The second stage - process selection - is not simple. Although there are only a few commercial processes available for the production of fertilizer intermediates and products, careful evaluation is needed if the proper identification and measurement of individual process benefits is to be achieved.

Selection of process technology in the phosphatic fertilizer sector is often arduous and has a high risk factor, this stemming from the nature and source of the principal feedstock - phosphate rock.

The usual approach to process selection is concerned with the assignment of monetary values to feedstocks, products,utilities, chemicals and catalysts etc. Estimates or prices for the total plant are obtained together with those for labour requirements, maintenance, taxes, finance charges, loan repayments etc. Individual processes are compared, and the one that shows the highest return on investment becomes the logical choice. Care must be taken, however, to ensure that individual process selection will be compatible with the requirements of the overall fertilizer complex. In a phosphatic fertilizer complex, the selection of process technology is within the context of an overall optimization exercise. The "new generation" phosphoric acid processes can produce a concentrated phosphoric acid without the need for steam evaporation unit. The benefit of a "new generation" process must therefore be weighed against the economic contribution that can be obtained with the surplus steam from the sulphuric acid plant, this is not always an easy task.

There are at least six active and successful licensors - all operating companies - presently offering wet process phosphoric acid technology. The essential differences between several of the processes appear to be minor to the lay person.

Indeed, processor licensor selection should properly take account of the more important peripheral factors such as proven commercial exploitation on a range of phosphate rocks, adequate demonstration of plant utilization, knowledge and ability to deal with the unique and complex corrosion aspects, availability of licensor's expert staff. All these factors can combine to outweigh intrinsic process attraction.

Process selection in the fertilizer industry can be a difficult task and there is no orderly and straightforward procedure. As the centre of interest moves towards the emergent countries, such features as the provision of hard currency financing, equity participation, expatriate management, and joint marketing ventures also become important considerations.

2.6.3 Legal and commercial aspects of technology transfer

Know-how and patents are abstract forms of industrial property, the sale of which demands a different approach to that for the marketing of merchandise. An important prerequisite to the successful selling of know-how is the adequate protection by law against misuse of the transferred information and rights. The transfer of know-how is not merely in exercise in law, the license contract exists to define the obligations and rights of the participants. These are commercial and technical matters involving business people, technologists and engineers for the successful implementation and servicing of the terms of the contract. Corporate management is now aware that licensing is a business function in its own right, and that it is no longer merely a legal or patent by-product. The modern trend in licensing, as in other business activities, is toward the development of scientific management through the formulation of a well defined licensing policy, and the assignation of the licensing function to a senior executive or department whose measure of success is measured by profitable marketing of licence rights which can be fully supported by the legal function.

It is worthwhile at this stage to consider the status of technology as industrial property. The material negotiated in a license agreement exists largely as intellectual property which can usually be characterized into three main forms. These forms are historically evolved concepts in the transaction of intellectual property which require formal expression in the license agreement.

(a) Patents

A patent is an exclusive right of monopoly granted by the State to an inventor for a specified period of time in recognition of a novel and useful invention or development. During the life of the patent, the patentee has the right to:

- Use the patented invention or not at his own discretion
- Exclude all others from the use of the invention
- Grant a license under the patent to another

The State enjoys the reciprocal right of publishing the patent, and the public is able to use the invention on expiry of the patent. The patent system therefore encourages the publication and dissemination of inventions whilst granting the inventor the opportunity of obtaining financial reward should he choose to exploit his invention.

The patentee can enforce his rights by suing infringers, and the successful plaintiff can secure an injunction calling for discontinuance of use and damages for infringement. The legal right to sue for infringement often confers a decisive marketing advantage.

The value of the patent as a marketing aid or as a licensable commodity varies from industry to industry. In the fertilizer industry, patenting is of less significance than in the pharmaceutical or agrochemical industries. The possibilities for a radically new fertilizer material or a completely novel process are relatively few. The majority of fertilizer patents are concerned with small changes or variations on well established fertilizer process concepts which offer limited advantage. Successful patent litigation is not usual based on the presentation of a complete anticipation of the patented invention, but rather argument that the patent is an obvious variant of what has gone before. On the other hand, the high cost involved in testing the validity of a patent is such that even a weak patent can prove an effective deterrent when it is strongly defended.

The function of patents in the fertilizer industry is not, therefore, as clear cut and of decisive importance as in the pharmaceutical and other industries. However, they can serve as valuable "keep off the grass" notices to preserve a narrow area of technology for the patentee.

(b) Know-how

Whilst a patent describes an invention which is recognized by a "person skilled in the art" as novel, the working and commercial implementation of the patent requires a wide range of knowledge and expertise in matters associated with the invention and the disciplines involved. Much of this material is unpatentable but nevertheless evident to the skilled engineer and marketing executive. It is this background of information - trade secrets - which constitutes "know-how".

Know-how is an essential and valuable commodity which frequently surpasses the value of a patent. It appears to be of particular importance to the fertilizer industry where the modern tendency is to spend many months in putting process plant into successful operation, and especially in maintaining successful operation once it has been achieved. Know-how is the property of the developer until such time as it is disclosed. Disclosed know-how can be freely used by other parties unless prior agreement is reached. Identical know-how can be independently developed without infringement of right. These features effectively distinguish the characteristics of the patent and know-how concepts. Clearly, the most valuable package is one in which know-how is supported by patents.

(c) Data

Data is the interpretation of pilot plant operation, the preparation of heat and mass balances, equipment specifications, plant arrangement drawings, operating and analytical methods manuals, and so on. Such data need not be prepared by the licensor - an experienced engineering organization can effectively deal with such data preparation. It can therefore fall outside the scope of a licence agreement and is bargained for on a separate basis. It is know-how - the intellectual property existing in the form of skilled people - which effectively relates data into a homogenous and commercially valuable package.

Most countries recognize and protect the right of a person or a company to invest and commercially exploit technology. In the case of patents, the rights are protected by legal statutes. Unpatented know-how, however, is difficult to define, with a varying interpretation from country to country.

Simply, know-how is understood to be intellectual property whose content and ownership is created in the licence agreement, the practical reality of which is tested by the willingness of the licensee to pay a royalty. In the event of dispute, the laws pertaining to commercial contracts apply.

(d) The license agreement

The licence agreement formalizes the commercial understanding between the licensor and the licensee. It is the legal mechanism through which the licensor confers a "right to use". For a patent licence, the "right to use" pertains to published information. The know-how licence embodies the "right to use" based on secret information. In return for the rights, the licensee undertakes the payment of a royalty or fee.

Process licence agreements should be written in easily understood language, preferably by a senior licensing executive with assistance from the legal and patent functions. Precedent of documents must be defined in the agreement. Letters of intent are generally undesirable, and the execution of the agreement should be completed quickly in order to avoid misunderstandings.

Many countries have regulations concerning the import of licensed technology and technical aid. Knowledge of these regulations is vital to the successful negotiation of a contract acceptable to the State, the State Bank, and other organizations. Some countries levy an import duty, it is important to ensure that this is settled by the licensee. In developing countries hard currency export is carefully controlled. Payment for peripheral services such as plant start-up assistance, detail design work, etc., may be more conveniently included in the licence fee, so that additional ad hoc payments are avoided.

A typical process licence agreement will certainly be made up from the following "standard" clauses:

- Definition of the parties involved
- Definition of the subject process
- Grant of the right to build and use the process
- Services to be provided by the licensor
- Royalty and/or fee
- Interchange of process developments
- Secrecy provisions
- Patent indemnification
- Process guarantees

- General legal safeguards - "boiler plate" clauses - law of country under which the agreement is legally binding, arbitration, force majeure, assignability, etc.

The clauses covering the definition of the subject process and the services to be provided are perhaps the most important, and both licensor and licensee should ensure that the content is adequate and clearly understood. It is vital to the licensee that he is aware of the performance of the process with regard to such aspects as the nature and quality of any process effluents, down-time for routine maintenance and cleaning. It will be necessary to state the properties and quantities of the feedstocks, utilities, and additives, such appearing as a formal attachment to the legal document. For example, a specification for the nitric acid feedstock in terms of concentration, temperature, nitrogen oxides content and level of iron contamination is essential if satisfactory and safe working of an ammonium nitrate process is to be assured. Again, the quality of phosphate rock in terms of rock grind, level of impurities, and chloride content is important for the proper design of a phosphoric acid plant.

2.6.4 The cost of technology transfer

The determination of process licence fees and royalties is not simple, depending much more on collective "feel" for the process, the likely value to the licensee, and the status of competing processes. It is a topic of discussion at most meetings and conferences on licensing which provokes much interest but leaves the licensor with little tangible benefit. It is a complex subject and corporate secrecy requirements do not assist in the free interchange of experience. The frequent comment "charge as much as you can get" does the licensing business a disservice. Clearly, an essential prerequisite is the need for the licensing function to operate on a sound commercial basis with its budgeting, internal and external costs, revenues, targets, etc., fully defined. A licensing department operating under the umbrella of a manufacturing company should pay a realistic contribution for the services rendered to it by the mainstream production, engineering and marketing functions. On the other hand, an equally realistic contribution for the know-how brought into the company by the licensing department as a result of its international activity should be also acknowledged. It will also be necessary to take quantitative account of the losses of a commodity market which might stem from the sale of process know-how.

Payment for licensed processes can be made in several ways. The running royalty and lump sum fee bases are the most common. The running royalty basis requires the licensee to pay a monthly or annual fee related to a specified percentage of the value of volume of sales for a fixed period of time. In practice, a fixed fee payable on contract signature to cover the initial servicing costs plus a guaranteed minimum running royalty fee are worthwhile adjuncts to the running royalty concept. Where this sytem is used, the running royalty rate will generally be in the range 1-5 per cent of the sale value, although the higher rate can only be negotiated for unique processes and highly profitable products. Another basis for fixing a running royalty rate is the increase in value-per-pound as the feedstocks are converted to product. In this case, a rate of around 5 per cent is typical.

The lump sum method is becoming much more prevalent in the heavy chemical industry. It is preferable where the cost of preparing the know-how package is substantial and where effective marketing of the product at a high and profitable level may be difficult. The lump sum concept with only minor variants is almost universally used in the fertilizer industry. In this industry, process licensing is extremely competitive. There are several internationally based licensors for all the important processes. Licence fees are therefore sensitive to the prevailing level of business - which has been low during the past four years or so - and the need for licensors with new technology wishing to establish an adequate reference plant list. Lump sum fees for fertilizer processes generally lie in the range 5 - 10 per cent of the battery limit plant capital investment, with only the unique processes offering considerable advantages able to command the higher fee levels.

A lump sum licence fee is normally payable in three or four instalments tied to the major stages in the development of the project from contract signature to completion of the plant or factory commissioning. Where a project requires long term credit financing backed by credit guarantees from the appropriate state or bank authorities - and this is typical of fertilizer projects in Eastern Europe - the licensee may request that the process license fee is paid in instalments over the loan period which is frequently five to eight years. In these cases, the appropriate allowances for interest and inflation rates should be made in determining the value of the instalments.

There is now a trend for the licensee to ask for and often insist that a considerable part of the licensor's reward should be taken up in equity participation. Several developing countries make this stipulation for their fertilizer projects. Indeed, the stipulation often extends to the managing contractor and the other engineering companies which may be involved. It is felt that such participation will assure a maximum response from the licensor and his associates. There are difficulties in effecting this type of involvement and the inherent risk of subsequent nationalization and other implications where the licensor participant has no control should be carefully evaluated.

Import duty and tax regulations can often determine the most favourable method of licence payments. A technical aid contract may be preferable to a licence agreement in certain situations.

Finally, the licensor should always be aware of the financial implications of currency devaluation.

2.6.5 Responsibility in licensing

The licensee can reasonably expect to seek assurances for the process and services he is to invest in. He can also expect to receive compensation for any faults which prevent the process from operating satisfactorily - provided always that such faults stem from the licensor or the services provided by other companies. It is natural for the licensee to ask for formal process guarantees with respect to plant capacity, raw material efficiencies, utilities consumption and product quality. Indeed, any reputable process licensor is willing and able to give such guarantees. On the other hand, over-emphasis on guarantees usually results in the process licensor providing higher factors of safety, thus increasing the licensee's investment without any real commercial benefit. Licensor selection on the basis of his guarantee policy alone is a poor business decision. One aspect of plant performance which sometimes appears to be over-emphasized is the efficiency of phosphoric acid processes. Many licensees will attach importance to a process which offers a small fraction of one per cent higher efficiency than other compatible processes. In reality, the capability of the licensor and his associates in building a plant which can operate continuously with the minimum of lost time for planned and unplanned shut-downs is far more important.

Usually a process licensor will commit a considerable proportion of the licence fee to the correction of a plant and the payment of penalties. On the other hand, the licensee stands to gain a much higher financial benefit than either the licensor or contractor. This being so, the licensee must be prepared to accept cost of the financial liability, including the costs of

Few additions may be made to the list of mineral nutrients known to be required for plant growth but substitutions among them are very unlikely since each performs specific functions. Thus the essence of fertilizers remains but their form, concentration and combinations are changing.

The analysis of the above mentioned factors in the case of the developing countries concerned mainly with tropical and subtropical agriculture, may help explain why their crop yields are in most cases lower than that of temperate climate agriculture. Without accounting for microbiological and other soil fertility factors but chemical soil fertility, knowledge of soil chemistry and best fertilizer applications alone become ever more insufficient after some years of initial success until they give antieconomic crop responses because the soil deterioration provoked by the destruction of soil structure renders it infertile within a few years of use and incorrect treatment of tropical and subtropical soil.

Research and experience have shown that while in temperate climate regions the soils may be badly treated for years before its structure declines, this happens rather quickly in the tropics and subtropics where practical agriculture is more difficult and complicated than in temperate regions.[33] Furthermore, there are two practical factors that are usually overlooked in tropical and subtropical agriculture:

(i) the rapid changes of the different fertilizers available to farmers demand careful consideration for the pedological and physiological coherence of the various types of fertilizers and the different ways of fertilizer application;

(ii) the need to manure the soil in a balanced way to ensure the optimal concentration of each nutritional element in the soil and to preserve soil structure. This often requires the joint application of chemical and organic fertilizers and careful soil testing.

Evolution of fertilizer use by farmers

The use of fertilizers has grown because they can be substituted for land, labour and other capital inputs in the production of crops, and often crop production and yields can be expanded more efficiently by adding fertilizers than by adding any other production factor.

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[33] A. Primavesi, "The study week on the use of fertilizers and its effect in increasing yield with particular attention to quality and economy, pag. 728 to 730, Pontificia Academis Scientiarum, 1973.

initial losses in raw materials and production. Whilst the reputable licensor realizes his obligations and even exceeds them in his effort to ensure a satisfied licensee it is important that the latter has the ability and knowledge to carry out the necessary evaluation procedures for satisfactory licensor selection and to ensure adequate transfer of all the relevant process information. The latter aspect is discussed in the next section.

2.6.6 The transfer of information

Until recently, the transfer of process technology took place by the simple means of transferring the specifications schedules and drawings of an existing plant with a proven commercial performance. Process guarantees were not called for since essentially a duplication took place.

With the advent of a rapidly changing technological environment and the growing transfer of technology on an international scale, such practice is no longer acceptable. Plants based on licensed processes are rarely identical to those operated by the licensor. It is necessary therefore, that the transfer of technology should take place in an organized manner. The process licensor is required to assess the information and data and create a process design package based on the optimum criteria for each new plant. It is not really good practice or indeed effective for a process licensor to merely provide a collection of information, data, typical drawings, patents etc., to the process engineering company or the licensee for resolution into a physical reality.

There are two well established routes to the transfer of a process licence and the associated technology from the licensor to a licensee. The first route, often used for the lower capital investment projects, is based on a direct link between licensor and the licensee, leaving the latter to make independent arrangements with his own organization or a process engineering firm of his own choice for the detailed engineering, procurement and erection services. The second and more important route, frequently used for major projects, is based on the transfer of the licence and technology through the process engineering company responsible for the overall engineering services. In this way the licensee is dealing essentially with only one party, so that risk of misunderstanding and inadequate collaboration which is likely with the tripartite concept of the first route is minimized. Although the second route implies that the process engineering company carried the legal responsibility for process guarantees which are properly the onus of the licensor, it is well suited to the modern concept of a licensor having formal and long term general collaboration arrangements with a few international engineering contractors who are therefore well experienced in the technology and with whom worthwhile working relationships can be developed.

To organize and prepare a process package in a set period of time, the process licensor has to be able to call upon the services of an experienced project manager who in turn has the authority to claim the services of specialist engineers on a priority basis. It is of considerable importance that the process engineering company or the licensee can be in a position to identify by means of curriculae vitae and personal contact the key personnel in the process licensor's organization. Although know-how is spread through an organization, it does reside in people; the loss of key staff through promotion and transfer to other sectors can have serious consequences to the capability of a process licensor to discharge his responsibilities in an effective manner.

2.6.7 Strategies for transfer of technology

There are two main stages of "transfer of technology", of which the first is prerequisite to the second. The first stage includes the transfer of technical and technological knowledge and know-how in general.[46] Its aim is to update and to upgrade human resources in developing countries, especially those which are responsible for industrial planning, for the selection of industrial sectors to be given priority for the choice of technologies and the purchase of equipment. The second stage of transfer of technology is the stage of market transactions and of decisions which are irretrievable for some period of time and which are of deep influence on the development of local industries. In addition to the two main stages of transfer of technology, one may consider the third stage where local capacities are developed to such an extent that imported technologies may be adopted to local conditions and national technologies may be developed.

It has been observed that these commercial transactions in purchasing "technologies" are problematic, mostly regarding the developing countries which are the buyers of technology. One may consider that the following major problems under conditions prevailing still were existing in most developing countries:

- Most developing countries still have no opportunities or facilities to get full information on technologies (hardware and software) offered to them. Even more important is the lack of information on technological

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[46] For more details see "Transfer and Adaptation of Technology, CMI.2/INR/TP/10

alternatives, their technical specifications and data, performance and prices.

- They have very limited opportunities to evaluate different technologies and their appropriateness for specific purposes, local conditions etc.

- They have also a very limited capacity to adapt imported technologies to local needs; and finally

- In spite of advice and assistance, directives and instructions, major difficulties may arise in the utilization of imported technologies and their optimal exploitation. Maintenance and repair are additional sources of failures.

In considering these problems it is recognized that the "transfer of technology" is not limited to the transfer from industrialized to developing countries, but it occurs between industrialized countries as well. Although these problems to some extent exist in purchasing foreign technology, these are solved easier as a result of their long-year experience, a tight network of industrial information and a continuing process of updating and upgrading professional skills.

Knowing the above problems, the important question comes up on the choice of appropriate technologies. This question mainly involves how to evaluate technologies to be purchased against the background of local needs and conditions and the background of national planning policies including their socio-economic aspects.

Criteria of appropriateness will normally differ from country to country, from industrial sector to industrial sector and from enterprise to enterprise. Each time, however, at least three aspects have to be considered carefully and balanced against each other:

- the technical and economic aspects of the technology to be imported, specifications and parameters, possible performance, handling, costs, other requirements (maintenance, spare parts, repair, raw materials, etc.);

- local conditions, availability of labour (skilled, unskilled), industrial infrastructure (power, water, transport), market conditions, consumer habits and purchasing power, eventual export-orientation, profitability;

- policy, industrial planning, socio-economic targets, employment problems (labour-intensive versus capital-intensive technologies), political priorities, the element of prestige (not to be under-estimated), regional versus national planning, priorities for import-substitution and others.

The fourth element is environmental aspects, which is the most modern one that should be examined in view of the adoption of technologies to be selected.

Taking into consideration the stages of problems and criteria of appropriateness of transfer of technology, various have been developed recently reflecting a wide range of theories. Still in most cases the development of industries in developing countries practically followed the traditional technological pattern developed in industrialized countries. The supporters of this method normally believe that the transfer of technology and technological experience from developed countries and the confrontation of modern technology with local conditions will gradually work in favour of adapting local societies to modern technologies. There is a second theory which advocates and recommends strongly that modern technology has to be adapted to local conditions and societies before being introduced, while revolutionary strategies even believe that the development of local technologies independent from the achievement industrialized countries, even if starting from a very low level, may be the only way leading towards industrialization appropriate to developing countries and towards economic independence. Very probably, however, the development of industries in the third world under present conditions will not follow the pattern of one or the other strategy but will look for ways and means to arrive at an optimal solution which may in many cases be a compromise of different strategies and theories.

It is recognized that selecting and carrying out any strategies is influenced by the skills and sound judgement of those in charge. Although the strategies of developing countries in selection of technologies in fertilizer are different from each other, still, there are certain criteria which are considered as common factors. They are as follows:

- Whenever possible, the technology selected should be appropriate to the conditions in the developing country. When the fertilizer industry is begun at an early stage of fertilizer use this is possible, but the need rapidly to build up indigenous manufacturing capacity may call for the use of an advanced technology,modified where practicable, that can only be thoroughly acquired over a period of years. In this situation the contractual arrangements governing the transfer of technology must provide for continuing technical assistance after the start-up of the plant, possibly for some years. The agreement should be flexible covering, say, annual reviews of progress and fixing of the requirements for the ensuing year.

- The technology which is purchased should be one which is well-proven on a commercial scale. A developing country, with an urgent need for maximum fertilizer output and with limited indigenous technical resources, is not the place in which to try out on a commercial scale novel processes or equipment. In many cases processes are so well established that no detailed investigation is necessary, but care is required to ensure that the process version offered is a standard one and that modifications or innovations are not included.

- A contract should be precise and, whenever possible and appropriate it should be quantitative in nature, e.g. if specialist personnel are to be provided, the numbers of people involved, their functions, and the duration of their secondment should be stated.

- The technological area involved should be defined and the agreement should indicate whether it covers all the licensor's knowledge in the defined area or only specific parts or versions of it. It should say whether it covers only currently available knowledge or applies to subsequent improvements and additions in the defined area.

- The extent to which local industrial and personnel resources are to be used in construction should be defined. Vague clauses calling for the maximum possible use of local resources consistent with contractual obligations are often ineffective. A serious attempt should be made to specify the types of equipment and services to be obtained locally.

- The participation or presence of local personnel in the process of design and construction management should be required, when qualified local people are available.

- The provision of documentary information, e.g. operating and maintenance manuals, drawings etc., in a form suitable to local conditions should be covered, together with the dates on which the various documents are to be available.

- One of the most important aspects of any agreement on the transfer of technology is the provision for training of local personnel. This should cover the training of key personnel on existing plants, preferably in countries in a similar state of industrial development, the organization of formal and informal training programmes in the developing country, and the participation of selected personnel in the design, erection and start-up of the plant. The numbers of trainers and trainees, the technological areas to be covered, and length and starting dates of training programmes should be specified.

- A forum should be established in which the progress of the transfer of technology is reviewed and problems discussed at regular intervals.

III. THE MEDIUM-TERM OUTLOOK TO 1987

3.1 CHARACTERISTICS OF THE MEDIUM-TERM FORECASTS

In 1971 the UNIDO/FAO/IBRD Working Group on Fertilizers was created in order to review the world fertilizer situation and outlook for the following five years. This Group is formed by representatives from the fertilizer industry associations, as well as by the three above-mentioned international organizations and by the FAO-FIAC advisory group. It pays particular attention to forecasts of world fertilizer supply/demand balances and developments in the industry. These 5-year supply and demand forecasts represent the harmonized result of commercial, lending and international technical assistance points of view, and are given with minimal data manipulation to preserve the integrity of the data and trends but are cross-checked by the information supplied by each group member. This integrity has, in a very short time, placed the Group's forecasts as the more reliable and credible world forecasts available.

It is for this reason that the information presented in this chapter will mainly be that of the Working Group with practically no attempt at estimation in variables such as trade, manpower or investment. For those who wish these estimates, they can obtain them by using the methodology and assumptions given in chapter 4. However, as the three international organizations need a longer-term outlook of at least 10 years ahead, since June 1978 the Group has started to make these forecasts only in relation to demand. The supply figures remain within the 5-year period for they represent either operating plants or firm commitments.

3.2 MEDIUM-TERM DEMAND FORECASTS

3.2.1 Methodology

The methodology used is a delphi type panel of experts meeting representing all institutional group members. It is a direct contact panel that reviews prospective demand figures, governmental plans and policies, and recent and future consumption-related events, for each country and for each nutrient. There is an initial presentation of demand figures, followed by a detailed discussion by nutrient and country with the most recent and specific information available to group members to cross-check and explain the presented figures. The discussion continues for as long as needed to reach convergence of opinions, that may or may not modify the figures presented initially. In case of doubt or impasse, field cross-checkings are carried out to furnish any last minute development that may help dispel it. The roughly harmonized demand figures that emerge from the meeting are then re-checked back at each institution's headquarters and any further comments are forwarded to the co-ordinating institution during the final clearance round.

The above methodology applies to the 5-year forecast. As 1978 was the first time the Group did look 10 years ahead, for the second 5-year period statistical trend extrapolation methods were applied based on the panel's concensus. The way this extrapolated demand affected the past long-term trends is discussed in chapter 4.

3.2.2 Outlook on the evolution of fertilizer demand to 1987

In Annex D-1 the demand forecast figures for 1978, 1982 and 1987 by region and nutrient are presented as agreed upon in the last meeting of the Working Group on Fertilizers held in Paris from 19 to 23 June 1978. They may suffer some usually minor amendments during the final clearing process. The figures cover the thoroughly cross-checked 5-year period to 1982/83 and the estimated figure for 1987/88. Based on them, Annexes D-2 to D-4 were prepared showing the demand share by region and nutrient, the growth rate and the nutrient ratio, in order to become comparable with the analytical structure given in section 2.4.3.

(a) Regional consumption growth pattern

By comparing Annex D-3 with B-5, a view on the demand growth rate evolution during 37 years can be obtained.

- The developed market economies reduce their nitrogen consumption growth to 76 per cent of that achieved in 1970/76 and from there on remain steady at 3.2 per cent per annum until 1987. Conversely, their potash consumption grows 35 per cent faster than in the period 1970/76, reaching 3.5 per cent per annum, and for the first time faster than nitrogen. This is a remarkable feat. Phosphate consumption from 1976 to 1982 makes some recovery from the very depressed 1970/76 levels, but almost reverts back to them in 1982/87. This situation shows the troubles this region has due to market saturation in some nutrients and the erosion of benefit-cost ratios to farmers. The current trend towards absorbing a larger share of cheaper fertilizer imports, mainly fertilizer intermediates, will continue.

- The developed centrally planned economies show a steady growth during 1976/82 for all nutrients but potash, that drops to 53 per cent of the 1970/76 period. During 1982/87, phosphate consumption growth drops to 35 per cent of its 1970/82 rate, nitrogen consumption drops to 78 per cent of the 1970/82 growth rate while potash has a 23 per cent growth recovery over the 1976/82 period. This situation points out this region's difficult phosphate supply situation and the strain it poses on its limited foreign exchange reserves. The overall diminished consumption growth rates on all nutrients show its rather fast approach to market saturation in comparison to historical growth levels.

- The developing market economies show very healthy growth rates throughout 1976/87 for all nutrients. The more dynamically growing regions are Far East and Latin America but Near East and Africa come close.
- The Asian centrally planned economies also **have healthy growth rates** during 1976/87 for all nutrients except potash in the 1982/87 period. Nevertheless the average growth rates in 1976/87 for all nutrients is smaller than that of the developing market economies. This situation shows the relative slowing down of consumption growth in China which is the largest consumer of all three nutrients among developing countries.

The developments described above are reflected in the consumption structure of the regions given by their nutrient ratio in Annex D-4.

- The developed market economies show an N-P-K ratio stabilized at 1.7 : 1 : 1 between 1970/87 but with potash gaining over phosphate and overtaking it for the first time in 1987.
- The developed centrally planned economies tend towards an unbalanced N-K-P consumption structure of 1.4 : 1 : 0.9 ratio, and away from the about even nutrient consumption structure during the 50's and 60's. This is a significative development pointing out their emphasis in grain production, with nutrient ratios approaching those of the developed market economies.
- The developing countries kept about the same unbalanced N-P-K consumption structures. Africa and Latin America have about the same 2 : 1.6 : 1 structure; Near East maintains its extreme imbalance against potash that shows even slightly deteriorating terms in 1987; Far East and the Asian centrally planned economies continue with their imbalanced structures against potash but keeping a ratio of about 3 : 1 between N - P.

(b) Regional share in fertilizer consumption

Annex D-2 presents the evolution of fertilizer consumption share by region. The consumption share of developing countries grows from 30.5 per cent in nitrogen, 23.1 per cent in phosphates and 11.3 per cent in potash in 1976/77 to 39, 32 and 16.6 per cent respectively in 1987/88. This shows that nitrogen grows 1.24 times, phosphates 1.39 times and potash 1.47 times during 1976/87. It points out a marked slow-down in comparison to the 1960/76 period, with phosphates showing the biggest drop to less than half its 1960/76 share increase. Nitrogen presents a small redution in share increase, thus showing its fast growth in quantitative terms and healthy consumption situation. By contrast, during 1976/87 the developed market economies substantially dropped their consumption share 1.22 times for nitrogen, 1.27 for phosphates and 1.14 for potash, while the developed centrally planned economies show a modest share increase for the same period: 1.09 times for nitrogen, 1.17 for pohsphates and 1.06 for potash.

This market situation points out that in quantitative terms by about 1985 the developing countries will become the world's biggest market for nitrogen, while by 1987 the developing market economies will have a consumption of nitrogen equal to that of the developed centrally planned economies.

In phosphates, the developing countries and the developed centrally planned economies markets grow almost as fast, with the first overtaking the latter in 1986, and both regions overtaking the developed market economies by 1990 and becoming the world's largest consuming regions with about equal quantitative demand.

In potash, the developed centrally planned economies market becomes the world's largest consuming region by 1988, while the developing countries, despite their faster growth, are so heavily imbalanced against potash that they remain lagging far behind in regional consumption. However, this imbalance cannot be kept for too long lest crop yields suffer for lack of the potash catalytic activities in plant growth.

(c) <u>Fertilizer prices</u>

Although there are strong internal forces pushing for higher fertilizer demand, such as population increase, G.D.P. growth and nutritional improvements, there are also strong external factors - mainly higher fertilizer prices - restricting demand.

Higher prices is a relative notion. Although actual prices are around the price range of the 1973 crisis year and far below the record high prices of 1974, they are still high considering the even more depressed prices the developing countries get for their exports in a recessed world economy. This situation is likely to remain during this medium-term period due to the well-known world economic spiral: prices of agricultural produce lag behind the commulative rise of the industrial inputs in agriculture and they fall deeper than the prices of industrial inputs in agriculture, among them fertilizers, in the down-swing phase of the economic cycle.

Furthermore, the trend in the developed market economies toward diminishing margins of return in the benefit-cost ratio to farmers, puts a heavy lid on fertilizer price increases. Consequently, the difficult situation of the fertilizer industry becomes more acute, since ever rising production and investment costs cannot get attractive enough realization prices, thus the industry cash flow dwindles and makes it more difficult to further invest in needed fertilizer plants. This situation may become critical during this term and may force a solution on all parties concerned including the re-assessment of government support policies.

3.3 MEDIUM-TERM PRODUCTION FORECASTS

3.3.1 Methodology

The methodology used is based on the most accurate information available on the situation of operating plants, plant closures and firmly committed projects for the next five years. It presents the production capacity situation as it is without any data manipulation. However, for estimates of annual nominal capacities the Group adopted the following criteria:

(a) Nitrogen

- The yearly nameplate capacity is obtained by multiplying the daily capacity by 330 days for all countries except North America that has 340 operating days.

- The differences in the effective capacity of the regions are accounted for through varying plant operation rates.

- The phase-in factors of new plants are as follows (based on the agricultural year from mid-year to mid-year): first 6 months of operation is 20 per cent of country average operating rate; next 18 months is 70 per cent and from the third year on it is 100 per cent of country average operating rate.

- Conversion losses in the production of finished products from ammonia are estimated at 7 per cent.

- It was agreed to use 4 per cent to take into account the statistical discrepancy between world production and consumption. This includes distribution losses, product in transit, stock increases etc.

(b) Phosphate

- Yearly nameplate capacity is estimated as for nitrogen.

- The differences in the regional effective capacity are accounted for by plant operation rates.

- The phase-in factors for new plants are estimated as for nitrogen.

- Conversion losses in the production of finished products from phosphoric acid are estimated at 6 per cent.

- The statistical discrepancy between production and consumption is estimated at 3 per cent.

The farmer's demand for fertilizers as a factor input is determined by his cost/benefit analyses. It indicates the equilibrium level where the real cost of fertilizer use (that is higher than the fertilizer market price) equals the marginal value of the produce. The proportion of crop area fertilized and its actual application rate per hectare reflects the farmer's allocation of his means according to his information, farming methods, risk assessment and expected revenues. The demand for fertilizers on any particular country or region depends to a large extent on the existing farming structure, that is, the proportion in which the different farming systems coexist in that region. Of these, only modern farming systems are fertilizer-intensive. The evolution of world fertilizer consumption for the past 70 years is given in Table 18.

Table 18 - World fertilizer consumption
(millions of MT)

Year	N	P_2O_5	K_2O	Total N-P-K	Growth rate a/ (percentage/yr)
1906/06	0.4	1.0	0.5	1.9	
1913/14	0.7	2.2	1.0	3.9	9.40
Decline during World War I					
1919/20	0.8	1.7	1.0	3.6	-1.34
1938/39	2.8	3.6	2.9	9.3	5.12
Decline during World War II					
1945/46	2.0	3.4	2.1	7.5	-3.12
1950/51	4.3	6.3	4.6	15.2	15.17
1960/61	11.0	10.0	8.5	29.5	6.86
1970/71	31.8	19.7	16.6	68.1	8.73
1976/77	45.0	26.5	23.1	94.6	5.63

Source: FAO

a/ Annual percentage change measured against previous entry

At the beginning of this century the fertilizer area was less than 1 per cent of the world's farmland. The consumption of fertilizers was concentrated in the US and Europe, especially in Holland, Belgium and Germany, and was used for cash crops, mainly for tobacco. Nevertheless until the 40 s the main commercial fertilizers were still the traditional low analysis fertilizers such as sodium nitrate, ammonium sulphate, single superphosphate, etc. During this period the increase in crop yields was large and led to popularizing the use of fertilizers

(c) Potash

- Yearly nameplate capacity is estimated at 300 working days, except Canada that has 320 operating days.
- The differences in regional effective capacity are accounted for by plant operation rates.
- Two phase-in patterns are to be used for potash mines:
  (i) for known ore bodies; 30 per cent in the first year, 75 per cent in the second and 90 per cent from the third year on;
  (ii) for unknown ore bodies: 20 per cent in the first year, 60 per cent in the second, 75 per cent in the third and 90 per cent from the fourth year on.
- The statistical discrepancy between world production and consumption is estimated at 5 per cent.

3.3.2 Production outlook to 1982/83

At the time of writing this study, the Group's fertilizer supply figures for all nutrients were not complete. The figures available concern total ammonia capacity including industrial uses; fertilizer grade phosphoric acid capacity and non-phosphoric acid supply; total potash muriate capacity including industrial uses, from 1978 to 1982/83. These figures represent the outcome of a June 1978 meeting of the Group and may suffer minor amendments during the final clearing process. These figures represent the plant capacity situation as it is likely to be in the next 5 years and on this basis Annexes D-5 to D-7 were prepared, showing the capacity share by region and nutrient and the growth rate of capacity,in order to become comparable with the analytical structure given in section 2.3.2

(a) Growth pattern of regional production capacity

Annexes D-5 (a) and (b) and D-7 show the forecasted capacities and growth rate, respectively.

- The developed market economies present a dramatic drop in growth rates during 1978/82. In nitrogen and phosphate they fall to about one third of the 1970/76 growth rate while potash falls to less than half its 1970/76 rate. This situation points out the diminished competitiveness of the region in nitrogen and phosphates, the latter with the exception of the US, and the slower growth in potash in quantitative terms due to its limited domestic market growth and smaller imports of developing countries. Two major events are taking place in this region, specially in Western Europe and Japan: a shift to increase imports of intermediate fertilizers - ammonia and phosphoric acid - and a major rationalization within the fertilizer industry itself in an attempt to boost depressed operating rates.

- The developed centrally planned economies show a moderate growth rate, that is, nevertheless, about half the growth rate in 1970/76 for all nutrients but nitrogen that almost keeps its 1970/76 rate. This situation pinpoints the USSR's massive ammonia development programme aimed at supplying the whole region plus a substantial amount of Western Europe's markets through a huge ammonia pipeline that is scheduled to become operational late in the 80's. The phosphate situation shows a diminishing self-supply from phosphoric acid sources, from 68.2 per cent in 1978 to 62.9 per cent in 1982/83, the balance being made from acid and rock imports from North Africa and the Near East.

- The developing countries present an overall healthy growth picture, where phosphate keeps its historical growth rate, potash makes a dramatic jump through Jordan's new potash facilities, but nitrogen growth diminishes by 37 per cent in comparison to the 1970/76 growth rate due to the Asian centrally planned economies' stagnant ammonia capacity position during the 1978/82 period. In the same period the developing market economies show a heftier 14.45 per cent growth rate up from the 12.8 per cent rate during 1970/76.

(b) Regional share in world fertilizer production

Annex D-6 gives the evolution of fertilizer production capacity share. The developing countries production capacity share grows from 28.1 per cent in nitrogen, 20.35 per cent in phosphate and 1.2 per cent in potash in 1978/79 to 32.48 per cent, 27.33 per cent and 3.33 per cent respectively in 1982/83. The estimation of regional self-supply is difficult because the Group is undertaking a methodological change in the fertilizer supply estimates. In the past, fertilizer supply was given in terms of final fertilizers irrespective of where the main fertilizer intermediates were produced. Since the beginning of the 70's and specially from the 1973 crisis on, the trade in fertilizer intermediates has increased to such extent as to render the past method of supply calculation both difficult to make and questionable in its meaning since the bulk of investments is taken up by the intermediates. Therefore a new method was evolved to calculate fertilizer supply based on its three main intermediates: ammonia, phosphoric acid and potassium chloride, that will begin to be applied in 1979.

Therefore to avoid methodological inconsistencies or wrong conclusions concerning plant operation rates, the ratio was taken between fertilizer intermediate capacity over fertilizer demand in order to estimate the relative growth in fertilizer self-supply. Annexes A-10, D-5 (a) and (b) give the first, while Annexes B-1 to B-3 and D-1 give the latter data.

This ratio in 1973/74 was 1.33 for nitrogen, 0.52 for phosphate based on phosphoric acid, and 0.22 for potash. In 1982/83 the ratio becomes 1.65, 0.86 and 0.27 respectively. This situation points to the increased self-supply which the developing countries are achieving in all three nutrients and that ammonia capacity is adequate to meet the region's nitrogen needs if the plants could be operated at 80 per cent of nominal capacity in 1982/83 (according to chapter 4, production capacity hypotheses for the year 2000),although further capacity additions are required to meet the growing demand.

By contrast, the developed market economies drop their capacity share 1.19 times in nitrogen, 1.16 times in phosphate and 1.09 times in potash between 1978/82, while the developed centrally planned economies increase their share 1.08, 1.03 and 1.05 times respectively during the same period.

3.3.3 Technological developments

There is little likelihood of major change in the forms in which the industry produces its fertilizers. Current trends toward higher analysis fertilizers and compound fertilizers will continue, but the emergence of important new products on the market is unlikely during this medium-term period. The position of raw materials may change significantly in the next twenty years. Reserves of potash and phosphate rock are ample to meet foreseeable demands. The position as regards sulphur is less secure but it is unlikely that severe long-term shortages will occur, though a shift to more difficult sources may be required, with consequent rises in prices. It is in the supply of raw materials for ammonia synthesis that difficulties can be anticipated. Unless there are major new discoveries, crude petroleum and natural gas will be in short supply in the next ten to twenty years. The most probable outcome at the moment appears to be a significant shift towards coal as a raw material. Research into coal-using processes will be intensified and improved processes will undoubtedly become available, but if coal becomes a major raw material, nitrogen fertilizer production costs will increase significantly.

Based on the analysis of the fertilizer industry carried out in chapter 2.3 and current trends, there is at present no indication of the sort of radical changes which mainly affected the nitrogen fertilizer industry in the 1960s. However, there are three possibilities that should be briefly mentioned:

(i) To achieve an improvement in the efficiency of fertilizers in the soil and to reduce losses. A break-through here could considerably reduce the amount of fertilizer required to bring about a given improvement in crop yield, with a consequent reduction in demand. However, the more probable outcome may be a series of steady improvements, none of them spectacular in itself, but cummulatively leading to more efficient use.

(ii) Developments in agricultural technology, specially concerning root crops and pulses oriented tropical and semi-tropical agriculture that require minimum amounts of external farm inputs. Thus one part of food production may grow in poor rural areas without creating a corresponding fertilizer demand. Nevertheless, this possibility may take a long time before becoming economically significant.

(iii) Developments in the field of genetic engineering where plant scientists become able to create the type of plants more suitable for nourishment and which have less problems in growth. The techniques of genetic engineering together with hybridizing and cloning may produce commercial amounts of seeds of the new types of plants in rather short periods, but the biological adaptation of these seeds to varying environments will take a number of years. One of these possibilities is the atmospheric nitrogen fixation in cereals by bacteria that live in their roots. The more promising is the bacteria Spirillum Lipoferum nitrogen-fixing symbiosis with cereals in tropical soils, that has produced positive results with wheat in Brazil and with rice in the Philippines.

IV. THE LONG-TERM OUTLOOK TO THE YEAR 2000

4.1 METHODOLOGICAL CONSIDERATIONS

In general terms three broad categories of methods can be used to explore the long term outlook:

(a) Forecasting models are mechanical "time" series techniques that attempt to forecast based on past trends alone, while all the other variables become "mechanical functions", that is, dependent on the variable "time". This method shows a deficiency in long-term projections because it does not consider the structural changes that could take place in the dependent variables which are marked by the route of the independent variable "time" which determines the cycle according to its diameter.

(b) Simulation models show the interrelationship between the elements of the internal structure that the model depicts, and the relations to the external variables that drive the model. Due to the rigidness created by the limitation of the variables involved and by the difficulty in foreseeing industrial and governmental policies, the risk exists in this method that the optimizing of a model that is somehow out of phase with reality, may lead to optimizing and later to taking the wrong decisions.

(c) Prognostics are futures research techniques that look at the future in terms of alternative possibilities for whole systems without the difficulties of the above mentioned methods because it is an open system which permits its elements to act freely both in their evolution and in their interrelation, assimilating the dynamism of present socio-economic structures.

4.2 WORLD CONSUMPTION OF FERTILIZERS TO THE YEAR 2000

4.2.1 Methodology

The method applied for forecasting to the year 2000 was that of regression analysis. Due to time constraints a multiple correlation set of equations could not be evolved and a modified trend extrapolation model was developed. After analyzing the graphical, mechanical and statistical methods, two new analyses were introduced in the forecasting model: (i) coherence analysis made on the evolution of the structure of fertilizer demand, that is, the trends in the N-P-K nutrient ratio for the region,[a/] and (ii) consistency analysis: based on the evolution trend of the regional growth rate by nutrient.[b/] These two new analyses have allowed us a larger margin of security in the choice of the equations used for the statistical series by taking FAO data[c/] for 1950/1976 and the Group forecast[d/] to 1987 as a given series spanning 37 years to make a 13-year trend extrapolation to the year 2000.

4.2.2 Regional demand trend extrapolation functions

Based on the above methodology the calculation and selection was carried out of the functions for regional trend extrapolation. Furthermore, as the data from 1950 to 1960 is less accurate than the 1960-1976 actual consumption figures, and the 1982 to 1987 forecast is less accurate than the 1978/82 one, an analysis was carried out on trend imbalancing. Sets of equations were tested with and without the 1950/60 and 1982/87 portions in all four combinations per equation to find out their impalancing effects on the longer term trends as depicted by the more accurate data.

The figures and the set of equations by nutrient and region for fertilizer demand for the year 2000 are given in Annex D-1 and Annex D-1(a).

[a/] Annexes B-4(a) to (c) and D-4 give them from 1950 to 1987.

[b/] Annexes B-5 and D-3 give them from 1950 to 1987.

[c/] FAO Annual Fertilizer Review, 1975, 1976.

[d/] IBRD/FAO/UNIDO Working Group on Fertilizers, 1978.

The figures for fertilizer demand for the year 2000 are given in Annex D-1.

4.2.3 Long-term fertilizer consumption outlook to the year 2000

In order to ensure consistency with previous chapters, the regional share, growth rate and nutrient ratio, respectively, are given in Annexes D-2 to D-4.

(a) Regional consumption growth pattern

Annexes D-3 and D-4 give the growth rate and nutrient ratio evolution of fertilizer consumption from 1976 to 2000.

- In the developed countries the trend towards market saturation continues. The market economies moderately reduce their already low growth rates in nitrogen and potash while phosphate remains at its very depressed level, and their consumption structure changes from 1987 onwards, to an N-K-P structure with a 1.6 : 1 : 0.85 ratio.

- In the centrally planned economies a similar shift takes place, with nitrogen and potash showing an important drop while phosphate regains its yearly growth from 3.3 per cent in 1982/87 to 5.3 per cent in 1987/2000, thus becoming the fastest growing nutrient. Their consumption structure resembles that of the market economies but with a lesser imbalanced N-K-P structure with a 1.4 : 1 : 0.9 ratio. Nevertheless, these countries still keep an approximately 50 per cent faster growth rate than the market economies which seem unable to come out from the depressed situation that began in the 1970s. By the year 2000, the centrally planned economies overtake the demand levels of the market economies to become the most important markets of the developed countries for all three nutrients.

- In the developing countries there is a trend towards a healthy but more moderate growth rate level . The developing market economies drop their average nutrient growth rate from about 8 per cent in 1982/87 to 5.3 per cent in 1987/2000. The Far East becomes the fastest growing region in nitrogen because having the largest regional population it requires very large amounts of food grains which in turn are heavy nitrogen consumers. Moreover, as land is relatively scarce, the feeding of its population can only be done by crop yield increases through the intensive use of fertilizers. The relative scarcity of domestic phosphate rock reserves in the Indian sub-continent, the dominant market in the Far East region coupled to its rather chronic foreign exchange limitations, all seem to put a lid on faster phosphate consumption.

In the Near East nitrogen consumption becomes even more imbalanced against phosphate and potash despite their very healthy growth rates during 1987/2000.

- The consumption structure of the developing market economies remains unchanged as N-P-K but with the N proportion in the Far East and Near East becoming more pronounced. The Asian centrally planned economies reduce their growth rates for nitrogen and phosphate by about 27 per cent between 1982/87 and 1987/2000, while potash makes a large recovery from 4.8 per cent in 1982/87 to 8.1 per cent in 1987/2000 which equals their 1970/82 growth rate. It is syntomatic that the nitrogen and phosphate growth rates of this region during 1987/2000 are significantly lower than those of the developing market economies there being no valid explanation except that forecasted growth rates during 1982/87 were by far the lowest growth rates recorded since 1950 which consequently affected the year 20000 estimates.

By the year 2000 fertilizer consumption in the developing countries, in comparison to the two developed regions, would be about 50 per cent more than any developed region in nitrogen; slightly more than the developed centrally planned economies but 25 per cent more than the developed market economies in phosphate; and about half of any developed region in potash.

(b) Regional share evolution in fertilizer consumption

Annex D-2 gives the regional share evolution by nutrient. The growth of the market share in the developing countries between 1987 and 2000 is 1.12 times for nitrogen, 1.14 times for phosphate and 1.11 times for potash. Their share in world fertilizer consumption in 2000 becomes 43.6, 36.6 and 18.5 per cent respectively. The most important fertilizer consuming developing region is the Far East, also the most populated, followed some distance away by the Asian centrally planned economies and Latin America with similar fertilizer consumption levels although the first region has about 2.5 times as much population as the last region.

In the developed countries, the market economies continue to drop their market share in all nutrients, the biggest drop being in phosphate: 1.34 times between 1987 and 2000. The developed centrally planned economies continue gaining market share in all nutrients, but mainly in phosphate consumption that increases 1.15 times between 1987 and 2000. By the year 2000 the developed centrally planned economies would consume more fertilizers than the developed market economies in all nutrients, although they have about half the population of the latter.

4.3 WORLD PRODUCTION OF FERTILIZERS TO THE YEAR 2000

Based on the fertilizer demand estimates to the year 2000, the corresponding production capacity by nutrient was calculated according to the following hypotheses:

4.3.1 Methodology and production capacity hypotheses for the year 2000

With the aim of achieving regional self-sufficiency, if possible, the following production capacity hypotheses have been made, by nutrient and region.

(a) Nitrogen

1. As there are widespread regional capacities, we assume self-sufficiency for all regions. This may not always be the case, but as hydrocarbon sources are widely spread in all regions, naphtha and fuel oil feedstocks are easy to transport, and further developments in synthetic gas from coal may make it more competitive with natural gas, it is difficult to make any other valid assumption with the information on hand.

2. We use ammonia capacity as parameter since practically all nitrogenous fertilizers are directly or indirectly derived from ammonia. Moreover, the nitrogen fertilizer industry usually supplies the industrial uses of ammonia and the technical and/or feed grade ammonia derived products such as ammonium nitrate for explosives and urea for cattle feed.

3. The following operating criteria are assumed based on the recommendations of the UNIDO/FAO/IBRD Working Group on Fertilizers and past experience:

- The yearly average plant operation rate is assumed at 85 per cent for developed countries and 80 per cent for developing countries of nameplate capacity.

- Conversion losses from ammonia production to finished fertilizers is taken at 7 per cent assuming that by this year all regions will become rather efficient producers.

- Statistical discrepancy that accounts for level of stock increases, products in transit, over-formulation etc. is taken at 4 per cent for all regions.

- Industrial use is assumed to be 22 per cent in developed countries and 10 per cent in developing countries.

4. Since nitrogen capacity is calculated starting from the estimated fertilizer demand for 2000, an estimate of nitrogenous fertilizers supply from non-fertilizer sources should be made to avoid double counting of the corresponding proportion of the industrial uses of ammonia. These products are mainly ammonium sulphate as by-product of caprolactam and ammonium chloride as by-product of sodium carbonate. Drawing caprolactam production

figures from our world-wide study on petrochemicals, we estimated that the by-product ammonium sulphate accounted for from 3 per cent up to 7 per cent of nitrogenous demand depending on the region. Therefore we assumed a world average demand of 4 per cent as representative of non-fertilizer supply sources.

5. Based on items 3 and 4 above, the nitrogen supply capacity for regional self-sufficience is calculated as follows: 1.685 times the nitrogen demand for developed countries, and 1.52 times the nitrogen demand for developing countries. The result of the calculations is presented in Annex 5(a).

(b) Phosphorus

1. Although practically all phosphatic fertilizers are derived directly or indirectly from phosphate rock, a distinction should be made between the mining and the industrial operations. On the mining side, 6 countries account for over 93 per cent of world rock reserves while production of phosphate fertilizers is widespread in all regions. Furthermore, the phosphate fertilizer markets are supplied from two main sources, both rock-based: higher analysis fertilizers based on phosphoric acid, and lower analysis fertilizers based on non-phosphoric acid sources such as simple superphosphate, Thomas slag, nitrophosphates etc.

2. In order to estimate the possibilities of regional production self-sufficiency these two sources of fertilizer supply should be analyzed independently. They are both explicitly presented in Annex 5 (b).

3. The non-phosphoric acid sources are estimated by aggregate extrapolations of Thomas slag supply as by-product of steel mills and trend extrapolations of calcium phosphate type of fertilizers such as simple superphosphate, nitrophosphates etc.

4. The fertilizers derived from phosphoric acid are estimated according to the criteria recommended by the UNIDO/FAO/IBRD Working Group on Fertilizers and trends strongly visible in this industry.

(i) Due to advantages in transport cost we assume that phosphoric acid may practically replace rock as input for acid-based fertilizers. As a consequence phosphoric acid production should be carried out mainly on the mine site. Elementary sulphur is readily transportable to rock mining places to produce the necessary sulphuric acid.

(ii) As the phosphoric and sulphuric acids instalations represent the larger proportion of a phosphoric fertilizer complex, the resulting nameplate capacities are credited to the producing regions.

(iii) Based on an analysis of rock reserves, current and foreseeable future plans of the countries and past production capacity share, the probable regional self-supply of acid was arrived at. The supply of the deficit was the one hand and to greater discrimination in the various types of fertilizer on the other. Furthermore, some supply problems were arising in the nitrogenous industry since the Chilean nitrate ores, the main nitrogen carrier at that time, could not continue to furnish the growing farmers' demand. From the early 50's on, new high analysis fertilizers were increasingly available at favourable prices thus spurring its application to food crops which are the main fertilizer consumers. Natural mineral fertilizers such as sodium nitrate faded from the market. The new concentrated fertilizers superseded the traditional ones by offering several advantages such as: avoiding the addition of unnecessary soluble salts and ballast to the soil, enabling a greatly increased amount of nutrient to be applied from about 20-25 Kg/ha to 300-400 Kg/ha, offered substantial reductions in transport and distribution costs that more than offset their higher production cost per unit of nutrient, etc.[34]

At about this time micronutrients began to be applied in various forms since crop results confirmed the findings of the second stage of the doctrine of mineral plant nutrition. Based on the high analysis products new forms of fertilizers were developed with varying degrees of commercial success. The most important new forms are:

(i) Liquid fertilizers, although initially applied in the US as ammonia in the late 30 s, did not spread until late in the 40 s into other countries. These early mononutrient forms are giving way to modern well-balanced multinutrient forms that often contain both macro- and micronutrient formulations. These liquid applications are growing fast in several fertilizer intensive countries like the US, Denmark, France, USSR, Japan and Mexico.

(ii) Multinutrients correspond to any form of artificially compounded fertilizers and are increasingly used for bulk formulations. In normal applications they are carriers of macroelements only but increasingly sophisticated formulations also include micronutrients that can be formulated with the balanced amount needed by crops.

(iii) Suspension fertilizers are multinutrient formulations contained in a suspending agent and can overcome the deficiency of liquid fertilizers as high content potash carriers. These slurry fertilizers can use cheaper sources of micronutrients and are becoming more popular in some developed countries since it is more efficient for fertilizer distribution in the farm.

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[33] "New Fertilizers, their Agricultural and Economic Importance", Y.Araten, Pontificia Academis Scientiarum, 1973.

allocated by halves to the two regions that together account for about 90 per cent of world rock reserves: Africa and the developed countries of market economies. The Near East and the developed countries of centrally planned economies are assumed to become self-sufficient.

(iv) The operating criteria is as follows:

- The effective demand for acid-based fertilizers is calculated by subtracting the estimated non-acid fertilizer supply from the forecasted demand to the year 2000.

- The yearly average plant operation is assumed at 90 per cent for developed countries and 85 per cent for developing countries of nameplace capacity.

- Conversion losses from raw materials to finished fertilizers is estimated at 6 per cent for all regions.

- Statistical discrepancy accounting for stock increases, overformulation etc. is taken at 3 per cent for all regions.

5. Based on items 3 and 4 above, the phosphate supply capacity by region is calculated as follows: 1.22 times the effective acid-based demand for developed countries, and 1.29 times the effective acid-based demand for developing countries. The result of the calculations is presented in Annex 5(a).

(c) Potash

1. Potash fertilizer production is a combined mining-industrial operation usually carried out at the mine site. Currently potash production is concentrated in the two developed countries regions that together account for 98 per cent of world ore reserves and held 97.5 per cent of production in 1976. In the developing countries only the Near East and the Asian centrally planned economies regions have enough reserves to become self-sufficient. Of them, only the Near East through Jordan has production plans to transform it into a net exporting region. The supply deficit has been distributed by halves to the two developed countries regions after taking into account ore reserves and future plans of the countries. Among them, we estimate that the flooded mine in Congo is back into operation and that Brazil's plan is implemented.

2. The following operating criteria are assumed based on the UNIDO/FAO/IBRD Working Group on Fertilizers and past experience:

- The yearly average plant operation rate is assumed at 90 per cent for developed countries and 80 per cent for developing countries of nominal capacity.

- Conversion losses in fertilizer production and statistical discrepancies are estimated together at 5 per cent for all regions.

- Industrial use is assumed to be 3.5 per cent for all regions.

3. Based on items 1 and 2 above, the potash supply capacity by region is calculated as follows: 1.24 times the potash demand for developed countries, and 1.3666 times the potash demand for developing countries. The result of the calculation is presented in Annex 5 (a).

4.3.2 Production capacity outlook to the year 2000

Based on the forecasted fertilizer demand figures and the hypotheses given in the preceding section, the corresponding production capacities for 2000 were calculated by region and nutrient and presented in Annexes D-5 (a) and (b). Capacity figures for nitrogen and potash include fertilizer and industrial uses while phosphate figures include only fertilizers. This non-uniformity is due to lack of actual industrial use figures for nitrogen and potash. Therefore it was considered methodologically preferable to include industrial use estimates for the year 2000 in calculating total nitrogen and potash capacity, than to make those estimates on the more accurate medium term forecasts.

(a) Regional capacity growth pattern

Annex D-7 shows the regional capacity growth from 1978 to 2000.

- The developed market economies markedly recover their capacity growth rate in 1982/2000 after the very depressed 1978/82 period. Their capacity grows parallel with their consumption in nitrogen. In phosphate their capacity growth is smaller than consumption showing that they have enough capacity for a slow growing domestic market and for exports, a part of that capacity exists presently as overcapacity as pointed out by the stagnant position during 1978/82. In potash, their capacity grows a bit faster than consumption showing that Canada continues building up her capacity for exports and a growing domestic market, for this industry is the only one that keeps growing during the depressed 1978/82 period.

- The developed centrally planned economies keep their healthy 1978/82 growth rate through to 2000 for all nutrients except nitrogen that drops its capacity growth in 1982/2000 to half its 1978/82 growth rate. Their capacity in nitrogen grows much less than consumption due to the massive build-up during the 1970's up to 1982 as shown by the growth rate during 1978/82. In phosphate, their capacity grows a bit faster than consumption in order to achieve self-sufficiency by 2000 since this market grows as fast as that of developing countries. In potash, their capacity grows faster than consumption in 1982/2000 reflecting the need to catch up with the earlier fast consumption growth and to cater for exports.

- The developing countries present an average healthy growth during 1982/2000 but far down from the very high rates in 1978/82. The biggest drop is registered in the market economies whose growth rate falls in 1982/2000 to about one third of the 1978/82 rate in nitrogen and phosphate. In potash the situation continues imbalanced for the developing countries count with very few commercially exploitable potash ores.

In general, the capacity growth rates shown are the ones required to attain regional self-sufficiency in nitrogen but the developing countries would continue to be net importers of phosphate and potash. Only the Near East would become self-sufficient in all three nutrients. Latin America and the Far East would become the bigger importing regions in phosphate and potash.

(b) Regional share in world fertilizer production capacity to the year 2000

Annex D-6 presents the evolution of regional capacity share from 1978 to 2000. The developing countries capacity share increases from 32.5 per cent innitrogen, 27.3 per cent in phosphate and 3.3 per cent in potash in 1982/83 to 41.1 per cent, 30.9 per cent and 5.6 per cent respectively in 2000/01. This means that by the year 2000, the total N-P-K capacity of developing countries would become 31.6 per cent of total world capacity, but their N-P capacity would become 38.3 per cent of total N-P world capacity. The latter capacity share may be more representative since potash is tied up to ore producing countries, and developing countries have only 2 per cent of known potash reserves.

In the year 2000, the developing countries would become the dominant capacity in nitrogen with 41 per cent of world capacity. In phosphate, world capacity is about even between the developing countries and the two developed countries regions. In potash, the developed centrally planned economies would become the dominant capacity with 50 per cent of world capacity.

4.3.3 Capital requirements to the year 2000

Based on the estimated regional capacity figures, the corresponding investments for fertilizer production were calculated by nutrient, for the period 1982/2000, according to the following criteria: (it refers only to additional plants but does not cover replacement of old plants)

(a) Nitrogen

As a representative plant a nitrogen complex was taken, composed of a 1000 MT/d ammonia plant and a matching 1725 MT/d urea plant. The capital costs in US dollars of 1977 is given in Table 13, section 2.3.5.1

- The nameplate capacity of this complex is then 270,000 MT/y in terms of nitrogen based on 330 operating days a year.

- The production structure in the year 2000 is based on four main feedstocks: natural gas and refinery off gas, naphtha, fuel oil and coal, in the following proportions: 80, 5, 7 and 8 per cent respectively. This structural distribution is also assumed to fit developed and developing countries alike.

- The average battery limits cost based on the above production structure is 191.6 million dollars for developing countries and 149 million dollars for developed countries, both in US dollars for 1977. For developing countries battery limits costs are assumed for greenfield locations. They include 2.5 per cent for pre-operational expenses and 10 per cent for contingencies. A 10-15 MW power station is included to make the plants independent from outside power supplies.

(b) Phosphate

As a representative plant a phosphate complex was taken, composed of a 600 MT/d phosphoric acid plant, a 1600 MT/d sulphuric acid plant and a matching 1275 MT/d diammonium phosphate plant. The capital costs in US dollars of 1977 are given in Table 16 A, section 2.3.5.2

- The nameplate capacity of this complex is 193,545 MT/y of P_2O_5, in terms of the final product, based on 330 operating days a year.

- The battery limits cost in US dollars of 1977, is 90 million for developed countries and 115 million for developing countries. The latter is for greenfield locations, includes 2.5 per cent for pre-operational charges, 10 per cent contingency and a smaller power station.

(c) Potash

No investment estimates are given since the costs of mine factories are too varied to attempt a modular production approach as was done for the other two nutrients.

The results of these calculations are given in Annex D-8 (a). They show a world requirement of 376 nitrogen complexes and 188 phosphate complexes, with an investment of 64.6 billion and 18.4 billion respectively, that total 83 billion US dollars of 1977.

From these totals the developing countries require 201 nitrogen complexes, and 57 phosphate complexes with a combined investment of 45 billion US dollars of 1977. This represents a 2.5 billion investment per year throughout this 18-year period, and a building of 15 fertilizer complexes per year during 1982/2000. These are very heavy committments that require a foreign exchange financing of about 60 per cent of the total.

4.3.4 Raw materials requirements for the year 2000

Based on total capacity estimates and the corresponding fertilizer production by nutrient, the raw materials required for fertilizer production in 2000 were calculated according the the following criteria:

(a) Nitrogen

- The feed and fuel needs to produce 1 ton of ammonia according to the four main feedstocks is as follows: 800 m^3 of natural gas, 1 ton of naphtha, 1 ton of fuel oil and 2.5 tons of coal.
- No energy equivalent requirements for electric power were calculated in view of uncertainties concerning regional fuel supply situations in 2000. Anyhow, electric power consumption is rather low as shown in section 2.3.4.4.

(b) Phosphate

- The main raw materials needed to produce 1 ton of diammonium phsophate are 1.57 tons of phosphate rock (31.6 per cent P_2O_5) and 0.432 tons of elemental sulphur.
- No energy equivalent for fuel or electric power were calculated in view of their rather low requirements as pointed out in section 2.3.4.4.

(c) Potash

- The raw material requirement is given in terms of K_2O that is mainly provided by potash muriate (KCl) containing 60 per cent K_2O.
- No fuel or electric power requirements were calculated for the reasons given in (b) above.

The results of the calculations are given in Annex D-8 (a).

4.3.5 Manpower requirements to the year 2000

Based on the estimated number of additional plants required for the period 1982/2000, the corresponding manpower estimates are given according to the following manpower structure, by complex:

(a) For developed countries

Complex	Managers	Technical supervisors	Operation and maintenance	General	Total
Nitrogen	15	45	170	70	300
Phosphate	15	22	120	34	191
(b) For developing countries					
Nitrogen	27	115	321	177	640
Phosphate	21	89	270	75	455

The figures for developing countries vary very widely for similar plant capacities in the different regions. After examining various sources adjusted for regional average, the above given manpower structure represents the average of all regions.

The results of the calculations are given in Annex D-8 (b). To man the additional plants the developing countries have to train 6400 technical personnel per year between 1982/2000, and an additional 2200 non-technical personnel per year in the period. These are quite high yearly needs that require a large training capability suitable to train this number of people. At present a training capability exists in various developing countries which is able to train but a fraction of these personnel needs. These estimates are are compounded when considering the several years of training all technical personnel should have for efficient performance in the plants. Without this, plant operating rates will continue at the present low levels, cash-flows will dwindle and more plants will be needed to attain the production targets.

V. THE ESTABLISHMENT OF THE FERTILIZER INDUSTRY IN DEVELOPING COUNTRIES

Considering the important role fertilizers play in increasing food production for growing populations, many developing countries have given this industry higher priorities within their national development plans. Setting up a fertilizer industry is a complex process demanding the combination of technical, commercial and financial skills with management and negotiating abilities. Developing countries face particular problems due to infrastructural limitations, lack of qualified and experienced personnel, and a special structure based upon an agrarian rather than an industrial economy.

The purpose of this chapter is to examine the various ways in which the industry can be established and to identify and discuss the major factors which require consideration and the criteria by which decisions may be taken. The establishment of the industry is considered in terms of the technical, economic and social factors involved. Ideally this industry should be set up along long-term nutritional-agricultural-fertilizer co-ordinated policies within the socio-economic structure of the countries.

5.1 TECHNICAL ASPECTS

5.1.1 The selection of technologies

The choice of technology involves a judicious selection of types of fertilizers, raw materials, plant sizes, processes and production schemes better adapted to the country's local conditions. The technologies most widely used in the fertilizer industry are complex and adapted to the needs of large-scale continuous operations. Their successful utilization depends upon the availability of skilled and experienced technicians, especially instrument technicians, to maintain the equipment and instruments in good working order.

The trend is towards the replacement of manual operator control of processes by automatic instrument control. In modern plants the series of separate manual control points for different process stages, which was normal twenty years ago, has been replaced by a centralized automated control room in which the operator adjusts control points from time to time and takes over by remote manual control when an instrument breaks down. The trend is justified by the increase in process efficiency, because the instrument is more precise in its control than the human operator, and by the reduction in labour costs. Of these, the improvement in efficiency is by far the most important.

An ammonia plant comprises six or seven consecutive process stages in each of which a chemical reaction is controlled. Incorrect or unsteady control in any stage leads to control problems in subsequent stages and may be reflected back into preceding stages. The greater precision and steadiness of instrument control gives higher material efficiencies and reduces loss of output caused by fluctuations in control.

Given satisfactory instrument maintenance the technology is an appropriate technology because it is more efficient. However, if instrument maintenance is unsatisfactory, it ceases to be an appropriate technology because frequent instrument failure causes frequent plant shut-downs with serious loss of both output and efficiency. In this situation there are two possible courses of action. First, to rely on instrument maintenance by expatriate technicians until local personnel have been trained and have the necessary experience - which would take some years. Second, to opt for a simpler technology, now regarded as obsolete in developed countries, which is less dependent on specialized skills in instrument maintenance.

(a) Choice of plant size

An important factor in selecting technologies is plant size. Large modern plants are "single-stream", i.e. they are made up of single pieces of equipment. It is basically for this reason that their capital and operating costs per ton are relatively low. However, a failure of a machine or piece of equipment causes a shut-down of the whole plant. Depending upon the length of the shut-down, it may take two to three days to get the plant on line again, and during the start-up material efficiencies are low. This situation would not arise if two half-size units were used in place of one full-sized unit. Where experience in the operation of large single-stream plants is lacking or has been unsatisfactory, there is a strong case for the use of twin half-sized units in carefully selected cases, particularly where moving machinery is involved. Capital costs will be increased, but the improvement in output and in efficiency may well lead to a reduction in costs per ton of product. The gain does not come from a decrease in plant failures but from a reduction in shut-down time. However, these advantages can be partially or wholly offset when setting up such plants in developing countries, due to the following factors:

- Large sizes of vessels (for ammonia and urea trains of capacities over 1000 t/day, synthesis columns may have diameters as large as 3 m, heights of about 25 to 30 m, weights of about 250 to 300 tons), call for special care in choosing the construction solutions which would lead to increased investments, and longer time for implementation.

- Extra expenses for erection and transport of equipment (very heavy equipment which also exceed the normal overall sizes for transport).

- Extra charges for piping erection, since there being very large lines, the piping are not prefabricated.

- Operation of large plants below capacity (for instance lack of raw materials or utilities, lack of market, accidental shut-downs and a longer time taken to come again in normal operation) causes much higher economic losses than in smaller plants.

- Relatively low fertilizer consumption during the shift from traditional to modern agricultural systems in the developing countries accompanied by a large supply of fertilizers produced by one large plant, result in transportation over long distances for their distribution, with increase in investment effort for transport means and roads, the consequences of which are increased fertilizer costs for the farmer.

- Foreign personnel for plant construction is more expensive due to different salary conditions of local personnel.

- Commissioning time and plant capacity rates obtained (determined by technical reasons) are more disadvantageous than with the smaller trains, as shown by the data given below (according to Kellogg experience):

Plant	A	B	C	D	E
Capacity in short ton/day	600	600	600	1000	1000
Days from gas feed to reformer to first product to storage	18	40	28	45	114
Days from first product to production at capacity	16	5	18	45	75
Stream factor (percentage)	96	88	100	84	83

- Time taken to implement an ammonia plant of 300 short t/day capacity may be about 12 months shorter in a developing country than that taken for one 1000 short t/day plant, which results in a delayed recovery of investment.

For smaller capacity manufacturing trains in the developing countries the following technical and economic arguments are given:

- The system of plants standardization may be better applied with a view to their multiplication, by which cost of licence lowers gradually with each newly-built plant, so that after the third or fourth train it might be eliminated.

- The foreign engineering is paid for only once.

- The buyer's participation share for plant implementation is higher with each newly-built train.

- The capital cost for spare parts purchase is greatly reduced.

- The buyer's personnel acquires experience so that the cost of the foreign technical assistance is lower with each new plant.

- By the experience gained by the buyer's personnel, the time taken for duplicated plant construction is shorter followed by the economic effects known.

- It is possible that part of the equipment might be manufactured in the buyer's country, which would cause a decrease in the foreign currency needed.

The capacity of the manufacturing trains determines also certain technical solutions such as:

- ammonia and urea plants with capacities below [illegible]00 t/d for ammonia and 1000 t/d for urea which usually may not be equipped with centrifugal compressors;

- for the small-capacity fertilizer plants the prilling cannot be applied.

From the above-presented matters, one can realize that the option for the largest manufacturing trains, built all over the world by the fertilizer industry, cannot be an aprioristic condition for the developing countries. Some shortcomings, occurring in the construction and operation of these large plants may cancel or even exceed the advantages expected. Nevertheless, the capacities of manufacturing trains must be over the "profitability limit threshold" whatever the capacity chosen. Moreover, considering the importance of plant size for the economic efficiency of a fertilizer plant over its whole operating life, the following criteria are recommended:

- the choice of plant sizes should be taken on the basis of detailed studies in accordance with the particulars of each country and site location;

- within a global programme for fertilizer industry development in one country or a group of associated countries, average capacity standard plants may be chosen to be duplicated several times.

(iv) Controlled release fertilizers are multinutrients usually in granular form that in one application can supply the same amount of nutrients as given by split applications of soluble fertilizers. This applies specially to sandy soils with high rainfall or irrigation throughout the growing season. Their disadvantage is their high cost.

There are still a number of arguments for and against high analysis fertilizers, but the trends show these fertilizers playing an increasingly important role in agriculture. Three main reasons stand out for it:

(i) These fertilizers can be formulated with the exact amount nutrients needed by crops;

(ii) As fertilizer applications per hectare increase so does the quantity of any toxic material present in the fertilizer. Concentrated fertilizers then provide a means for controlling potential ecological and health hazards.

(iii) The prices and application costs of high analysis fertilizers are cheaper than normal fertilizers based on the price of the nutrients, and provided they are applied in large amounts per hectare. For lower amount of manuring normal fertilizer applications may be cheaper. Nevertheless, despite important developments in fertilizer technology and high analysis formulations the crux of the matter lies in its use by the farmer, where fertilizer efficiency is mainly determined by the way the nutrients are distributed in the soil. Uneven distribution will result in uneven crops and yields. The mechanism of fertilizer distribution at farm level is critical since it could result in major losses in efficiency. For instance, in the US the current average nutrient content is 43 per cent of final fertilizers, which is more than twice the average content of fertilizers made 40 years ago. By cutting by half the tonnage that otherwise would have had to be used with low analysis fertilizers, the savings achieved annually run into about 1 billion dollars, since the present cost of transportation, storage and handling is between $ 20 to $ 25 per ton of fertilizer. Furthermore, costs of plant nutrients in the US in 1976 are only slightly higher than they were 25 years ago, whereas some farm costs such as farm machinery, farm real estate, etc, are 3 to 5 times higher in 1976 than they were in 1950 35/.

35/ "Fertilizer supply and demand", J.R. Douglas and C.H.Davis, TVA, Chemical Engineering, July 18, 1977

- technology and equipment should be matched as closely as possible to local conditions. The level of plant sophistication should be matched to the availability of skilled personnel for achieving high rates of plant operations.

(b) Technological alternatives

The available technologies are not confined to those suitable only for very large plants; there are other and much less complex technologies available which are suitable for entry into the industry on a much smaller scale and with much smaller markets. These are described briefly in Annex F. Their basic characteristics are set out in the table below:

Table 26. Basic characteristics of main types of plants

Plant	Cost ($ m)	Output range (1000 t/yr)	Technical complexity	Added value	Production flexibility	Preferred location	Social Acceptability
Bagging/ blending	3-5	20-100	Low	Low	High	Near market	High
Single superphosphate	4-12	20-100	Medium	Medium	High	Near market	Medium
Satellite	20-50	75-250	High medium	Medium	Moderate	Near port	-
Large scale	150-300	100-500	High	High	Low	-	Low

The first point to note about the table is that it is not necessary to wait until a demand for several hundred thousand tons of fertilizer has been built up before starting a fertilizer industry. Indeed, the ideal way in which to build up the industry is to start with blending and single superphosphate plants, establish satellite plants when the market is large enough, incorporate the satellite plants into integrated units, and then put up large scale units when the demand justifies them. In this way the necessary technical, commercial and management skills are gradually acquired so that as the capital involvement increases, the required skill and experience are there to match it. In choosing between the technologies represented by the different plants in the table and described in Annex F, the principal criteria are:

(a) The size and nature of the market
(b) The technical resources available
(c) The presence or absence of local raw materials
(d) The extent of the infrastructure
(e) The environmental impact
(f) Plant reliability

In considering the markets available to a project, the possibility of exports should be considered and a careful professional market forecast should be prepared. This criterion is dealt with more fully in chapter 5.3 in which economic aspects of plant establishment are considered.

In the selection of technologies the most important factor is the technical resources available. The basic decision in this field is whether to rely for the first few years on purchased resources in the form of specialist expatriate technologies and technicians. If the establishment of a fertilizer industry is considered at an early stage in the development of fertilizer consumption, it is then possible to proceed by the ideal way suggested above, starting with small plants and simple technologies and gradually building up to large plants and complex technologies, relying at each stage primarily on local resources. Often, however, this option is not open, because the need for indigenous fertilizer manufacture, to reduce foreign currency expenditure and to give some control over fertilizer availability and cost, is urgent. In this situation it is necessary for some years to rely on expatriate specialists. It is important to assess realistically the local resources and, if necessary, to accept the need for outside help. Prevention is better than cure.

A consideration of the existing infrastructure is required only for the larger plants, such as satellite plants or large scale units. The latter in particular, make extensive demands on infrastructure, but the demands of the blending and SSP plants are small and those of the satellite plants are not great.

The same is true of the environmental impact. SSP plants do have effluent problems, greater than those of satellite plants, and even on small plants adequate effluent disposal systems must be provided to prevent the plant becoming a public nuisance.

When chosing processes and main equipment, plant reliability is a very important factor. Processes and equipment should be proven ones that hold no experimental bugs, for they offer the most solid guarantee for the operating success of a new plant. Furthermore, the setting-up of a trouble free new plant also rests on the solid experience of the engineering company working out the designs. In some cases a well proven process could not be successfully applied in a plant designed by an engineering company with no or limited experience in the field. The engineering experience acquired in similar fields does not offer a sufficient guarantee.

The application of the listed criteria to the types of plant mentioned in the table is considered below;

Bulk-blending plants provide a low-cost and therefore low-risk method of entry into the industry. They are based on imported products and serve a local market, and their demand on technical resources is minimal. Their demands on infrastructure are small. They need a small power supply and access to road and rail transport. Their main requirement is an enterprising and intelligent manager who gets on well with local farmers and can build up a reliable and efficient distribution and sales system. Apart from this, they require a small laboratory to keep check on product quality, and engineering assistance to maintain the equipment in good working order. If the existing market is mainly for straight fertilizers it will be necessary to run a sales campaign promoting the use of compound fertilizers for some time before the plant is installed.

There is a continuing role for bulk blending plants as the fertilizer industry develops and, because their main product is NPK fertilizers, they help to ensure that an agronomically sound and productive balance of nutrients is maintained.

With single superphosphate (SSP) plants we enter the fertilizer industry proper. The demand on technical resources is greater, but not large. Depending on their size, they require three or four technically qualified and experienced chemical engineers with a small engineering and operational staff and a well-equipped laboratory. Their demands on infrastructure are greater than those of bulk blending plants but are not large. They need a relatively small power and water supply and facilities for liquid effluent disposal and access to road or rail transport. They are particularly advantageous when indigenous phosphate rock of inferior quality is available, because they can operate successfully on rock which would present difficulties to a larger plant manufacturing phosphoric acid. However, in such a situation it is important that adequate pilot plant trials with the local rock are carried out before the plant is designed. If the phosphate rock has to be imported the project will need careful economic assessment to ensure that it can compete with imported ammonium phosphate or triple superphosphate.

Many developing countries have SSP plants and they deserve careful consideration as an economic way of meeting a local demand for phosphate fertilizers. They are a stage ahead of bulk blending plants but, like them, they can be readily integrated into a local community and can be a focus of agricultural co-operation.

A satellite fertilizer plant represents a major step forward in the fertilizer industry. Its added value is considerable, and it gives significant control of the supply and price of fertilizers for the home market at a cost much lower than that of a large ammonia/urea plant or a large phosphate plant. A satellite plant fits well into a country which lacks raw materials and has a fair size market but not one large enough to justify a major independent unit. It is applicable to nitrogen and/or phosphate fertilizers, though nitrogen can be economically produced only as ammonium nitrate. The technology used is advanced and completely up-to-date, but is much less complex than that used in the manufacture of ammonia or phosphoric acid. The demand for technically qualified and experienced people is appreciable, but not large and an opportunity is presented gradually to build up the knowledge and skills needed for the major plants. The water and power supplies needed are moderate, but facilities for the import, probably by sea, of ammonia and phosphoric acid are required. The effluent problems on a well designed plant are small.

This type of plant fits very well into co-operative planning of the fertilizer industry between countries which, as a group but not individually, have the raw materials and markets to justify fertilizer manufacture, because it makes it possible for countries lacking raw materials to have a share in production. It also accords with the growing practice, particularly in the phosphate industry, for countries well endowed with raw materials to specialize in the production of the fertilizer intermediates, ammonia and phosphoric acid.

The economics of satellite plants need careful investigation, particularly in a free market where they have to meet import competition, but they can present a viable option, which builds up technical resources and guarantees an adequate supply of fertilizer at reasonable and stable prices.

The technical requirements of major fertilizer units have already been discussed. They make extensive demands on technical resources but they are the right choice for countries which have the raw materials or markets, the qualified people and the infrastructure to support them. However, they have significant social and environmental disadvantages. These very large plants are always something of an alien intrusion into their environment. Smaller units can be much more easily integrated into the local community and can lead to further development with much less social and environmental disruption.

As this survey has shown, countries with smaller markets or without raw materials can enter the industry in a number of ways which require much less massive capital expenditure and fewer highly qualified people, but which encourage fertilizer consumption by ensuring local interests a stake in the fertilizer industry. In particular, the possibilities of satellite plants deserve much more attention than they have so far received, especially where opportunities for regional or sub-regional co-operation exist, and in countries which do not have the size of market needed for the very large plants.

5.1.2 Transfer of technology, its availability and conditions

The setting up of this industry in developing countries requires the transfer of processes and know-how from its possessors, which are usually the developed countries as described in chapter 2.6. Since the industry concentrates its transferable knowledge in equipment design and catalysis more than in the chemical processes themselves that are already known for many decades, it is advisable to stipulate as accurately and completely as possible the contractual transfer conditions arrived at between the buyer and the seller.

In order to avoid a partial transfer of technology due to the buyer's limited experience and to better define the seller's obligations, it is recommended that the buyer gets qualified impartial advice from experts fully acquainted with the technology to be transferred. To ensure a more complete transfer the buyer should hire, right at the inception, the key personnel responsible for running the plant to thoroughly acquaint them with all operating and maintenance details. A brief review of the main transfer of technology issues in this industry is as follows:

- production processes, chiefly concerning operation and control methods;
- plant start up procedures after short or long shut-down periods;
- operational instructions in case of accidents;
- elements of basic and detailed engineering to enable the buyer to build part of the equipment and later take over plant construction;
- maintenance systems, repairs and spare parts supply;
- methods for special and/or auxiliary operations such as plant washing, catalyst preparation, raw materials testing, corrosion protection, water preparation, air purification, effluent disposal etc.;
- detailed training programmes including vocational, off-the-job and on-the-job schemes;
- methods for environmental protection and pollution abatement, including health hazzards, industrial safety, fire protection etc.;

- marketing and distribution methods, including storage and physical distribution network, extension services etc.;
- applied research methods to test the effects of diverse types of fertilizers and fertilizer application methods on crop growth.

The buyer should take the following steps in order to be able to take over the transfer of processes and know-how:

- organize the company for all departments to fit the conditions set in the contract and covering plant construction, processes development and plant operation;
- involve key personnel at all levels from the inception in the transferring activities: from design to erection to start-up to operations;
- arrange for further communication with the seller's experts so as to gain continuous access to any further technical developments;
- prepare a detailed, contract-binding, training programme for local personnel preferably in similar plants in countries with a comparable industrial development or a step ahead.

The basic check list elements for transfer of technology activities are given in Annex G.

The purchase of "turn-key" plants does not allow for a detailed transfer since the buyer's personnel do not take an active and responsible part in the implementation of the plants. Such a transfer is effectively accomplished only if the buyer already has his own engineering department, where part of the design works could be taken over. The transfer of processes and know-how may be accomplished in several ways: by agreements between governments, by settlements or by trade agreements. Practically, it can be effected in different manners such as:

- acceptance of buyer's personnel in the seller's laboratories, pilot plants and industrial installations;
- technical assistance from the seller's specialists;
- sale of licence, know-how, basic and detail engineering;
- implementation of plants and technical assistance offered by the vendor on commissioning and first period of operation.

The choice of a certain form of process transfer depends on the agreement of the two parties but first of all on the technical level of the buyer, who should be capable of acquiring and then applying the information received. Depending on the amount and detail of the information required and the time needed for a thorough study of the data, the cost of the transfer of technology item can vary widely; and the cost of these services may be rather high in comparison to plant investment. This becomes a supporting argument for setting up engineering departments able to take over part of these services. However, when only the purchase of the license and know-how is desired, it is advisable to directly contact the company that owns and operates the technology. In such a case the transfer may be complete and the cost lower.

5.1.3 Infrastructure

A large fertilizer plant is not a self-contained independent unit. Its satisfactory construction and operation require a supporting infrastructure of roads and railways, power and water supplies, a communications network, and housing, schools, amenities etc. In the past developing countries have experienced severe delays in construction and serious losses of output because this supporting infrastructure was not available or was inadequate. The major programme of construction of fertilizer plant in developing countries which is now under way cannot be effective without a corresponding development of the infrastructure.

In its broadest sense infrastructure may be defined as the non-productive capital equipment and services that are available to maintain the life of a community. In the more limited context of the relevance of infrastructure to a major industrial enterprise we are concerned primarily with:-

a) Transport: railways and rolling stock - roads and road vehicles - port facilities;

b) Utilities: power and water supplies - effluent disposal systems - postal and telephone communications;

c) Housing, including schools and general amenities;

d) Marketing infrastructure: applied agricultural research and extension services.

An adequate and reliable transport system is of major importance. A large fertilizer factory will consume 0.5 to 1.0 million tons of raw materials a year and produce up to 0.5 millions tons of fertilizer. The regular, prompt delivery of raw materials, spares and other supplies, and removal of the product are essential to the steady and continuous operation of the factory.

Prompt delivery is also of primary importance in the construction of the factory. Delays in the delivery of equipment to the site may well lead to very costly delays in the completion of construction. The cost of connecting the factory to road and rail system networks will depend on the distance of the site from the system and the nature of the ground to be traversed. This cost can be quite large, and it is usually necessary to select a site not more than a few kilometers from the nearest adequate road or railway.

It is highly desirable that alternative transport systems should be available so that, should rail connections break down, incoming supplies or outgoing product can be quickly switched to road transport, or vice versa. A site with only one form of transport available to it should be chosen only if its countervailing advantages are very great indeed.

Reliable power and water supplies are essential to satisfactory operation. A large factory will have a power demand of 10 to 20 mW. This can be obtained from an outside supplier or generated in the factory. The trend in developing countries is for power to be generated on site, thus making the factory independent of outside supplies. Although this will increased capital costs, it will normally have little effect on total production costs because it is usually possible to generate power at a cost comparable with that of outside supplies. Independent generation is almost always preferable where a long supply line would have to be installed.

Fertilizer factories are large consumers of water. A large ammonia/urea plant will need 150 to 250 m^3/hr, and the plant must therefore be reasonably close to water supplies of satisfactory quality.

The presence of a developed industrial and commercial community within reasonable distance of a factory is a distinct advantage. It will be a source of labour and of many of the miscellaneous supplies and services which the factory requires, thus helping to integrate the factory into the life of the local community. Perhaps the most important advantage, however, is that it enables factory employees to live a much fuller and more varied social life than they could as members of an isolated factory community. This leads to a socially healthier community, which, in the long term, is more efficient. However, if for reasons of public policy or for economic reasons, a factory is established in an area where housing is inadequate, it will be necessary to provide housing, schools and reasonable recreational facilities. This can be an expensive business. If the site has been chosen for economic reasons, e.g. its closeness to raw material supplies, then it is reasonable for the project to bear the costs, but if the site has been chosen for reasons of public policy, the cost should be borne by public funds.

The general problems of fertilizer marketing are discussed elsewhere in this report. In the context of infrastructure, we should note that the transport facilities provided must cover the transport of fertilizers from the factory to appropriate local depots and down to the farm. However, since one ton of fertilizer will increase crop production by five to ten tons, the major transport problem is not in fertilizer distribution but in crop disposal. The assessment of infrastructural requirements cannot be restricted to the factory itself, but must take due account of its effects upon agriculture.

A further factor affecting marketing is the dependence of a growing fertilizer demand upon agricultural research and extension services. These are particularly important in developing countries where demand is low and where the farmer has to be convinced that increased use of fertilizers will be of benefit to him. The function of the research services is to provide the basic knowledge about rates and times of application of the different nutrients for various crops and soils, and of the extension services to get the results of research demonstrated on the farm and accepted by the farmers. The fertilizer sales force has an important part to play in this process, but the main weight must fall in the public sphere.

In considering infrastructure in general terms there are three basic factors:-

1. It must be available. A fertilizer plant must be sited in an area where investigation has shown that the facilities are available, or the installation of these facilities must precede or be carried out parallel with the construction of the plant.
2. The capital involved in infrastructural development is large. A report prepared by the World Bank for the FAO Commission on Fertilizers (FERT/77/4 - August 1977) gives fixed capital costs for a 1,000 t.p.d. ammonia/1,650 t.p.d. urea plant in a developing country with limited existing infrastructure as $230 million. An identical plant in a remote location where all the infrastructure would have to be provided is estimated to cost $320 million. Making some allowances for infrastructure costs in the lower figure we have total infrastructure costs of well over $100 million, about half as much as the cost of the plant.
3. It is not reasonable to charge the infrastructual costs to the fertilizer project. The facilities provided are part of the general development of an area, they serve the local population and other industrial

enterprises already established, or that may be established. Some items, e.g. gas, water and power supply lines and drainage systems from the factory, can legimately be charged to a project when they are constructed specially for the project and do not supply other consumers. However, most of the infrastructural costs are part of the general development of an area and should be financed by public funds.

If the sole objective in establishing a fertilizer industry was to produce fertilizers at prices within reach of the farmer, so as to stimulate their use and to increase agricultural productivity, plants would be erected preferably on already developed industrial sites and certainly only in locations where there was an adequate infrastructure. Such action might conflict with a national development policy, aimed at an avoidance of excessive industrial concentration and a widespread industrial development. If, for reasons of public policy, a fertilizer plant is set up in a location where major infrastructural expenditures is required, it is only reasonable that the additional costs incurred by such a policy should be borne by the state. In assessing the viability of a project it is necessary to define and demarcate clearly the items of infrastructure which are the responsibility of the public authority, and the items which are directly associated with the project and chargeable to it.

5.1.4 Research and development

In a survey which looks as far ahead as the year 2000 the problems of research and development become very relevant. In the short term view, they have little to do with the establishment of the fertilizer industry, but in the long term they are important. The process developments of the last twenty years have sprung out of the applied research and development work of the major manufacturing organizations, sometimes in co-operation with university research departments. A technically progressive and thriving industry cannot be maintained without considerable expenditure on research and development.

At present most fertilizer manufacturing organizations in developing countries rely on the ability to purchase technical improvements and do relatively little research. The basic reason for this is shortage of qualified people, both scientifically trained staff and also technicians. The demand for staff to run the rapidly increasing number of plants is, at present, of paramount importance. This is the fundamental constraint to the growth of research and development activities and it is likely to continue for some years.

2.4.3 Regional development of fertilizer consumption

The preceding chapter presents an overview of the evolution of fertilizer consumption. In order to gain insight into the development of the various regions, Annexes B-1 through B-12 were prepared. Annexes B-1 to B-3 present world and regional consumption figures for the three main nutrients for the period 1950/51 to 1976/77 based on FAO data[36/] unless otherwise referenced. They show in quantitative terms that fertilizer consumption for all nutrients was, and still is, concentrated in the developed countries although the developing countries are rapidly increasing their consumption. In 1950, the developed countries consumed 9.8 times nitrogen, 27.5 times phosphates, and 45.2 times potash more than the developing countries. By 1976, the developed countries consumed 2.27 times, 3.32 times, and 7.81 times respectively more than the developing countries. Although the developing countries' gain in phosphate consumption appears impressive, their increase in nitrogen consumption was even more dramatic for in 1950 world phosphate consumption was 1.45 times that of nitrogen, but in 1976 nitrogen consumption was 1.70 times that of phosphate. The appearance of the green revolution between 1960 to 1965 marked the highest growth rate period in consumption and production in the developed countries. By contrast, in the developing countries the highest growth rate in consumption was between 1950/60, followed by its peak growth rate in production during 1960/65, to be continued by the second highest growth rate in consumption between 1965/70 due to the slow spreading of the green revolution methods coupled with an increased domestic supply of fertilizers.

It is significant that in the period 1970/76, the developed market economies and the fast growing Far East regions showed a very distinct drop in growth rates, while the rest of the regions kept a little below their average growth rates except for the Near East that shows an above the average growth, and the developed and Asian centrally planned economies' regions that had a drop in nitrogen growth rates. This situation reflects the disturbed price and apprehensive buying conditions of 1974/75 that affected the above first two regions most, while the centrally planned economies' regions were starting to gear up for their massive ammonia plant building programmes. This also affected the regions of other developing countries but to a lesser degree. It may be that this decline in growth rates is a warning to developing countries to put more attention into the distribution and marketing of

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36/ op.cit. in 28.

This judgement needs some qualifications. Some of the larger organizations in developing countries have appreciable research and development departments which are concerned primarily with the application of research and development to existing processes and to the problems of the technical and economic extraction and use of local raw materials. Nevertheless, developing countries that have commissioned fertilizer plants have the need to constantly improve plant efficiency by process improvements, enhanced maintenance and repair activities, improvements in fertilizer performance according to market demands etc. The attainment of these aims requires the existence of a well qualified force in the country able to carry out these tasks effectively. Attainment of a good technical and scientific work force for research and development would enable the buyer to gradually participate in the design and construction of fertilizer plants based on imported processes at country and/or regional levels. This qualification of the buyer's staff is usually speeded up through on-the-job training programmes with the seller's specialists. By setting up a suitable research and development capability the foundations for the search and application of more advanced methods and solutions are laid. Thus boosting the progress of the fertilizer industry and the techno-scientific standing of the country.

The organization of research in fertilizer-related fields such as environmental protection, corrosion, equipment manufacture etc, would form an "intellectual capital" that can have far-reaching impacts in the overall development of a country. Alternatively, fertilizer research and development may initially be organized in technical institutes and universities with the active participation of all fertilizer-interested parties. Later on, further activities may be developed within the fertilizer industry itself and at factory level in order to identify and solve specific commercial time-pressing problems. In this way a co-ordinated linkage can be formed involving all facts of this industry.

At present, as far as the fertilizer industry is concerned, the major need for research and development work in developing countries lies in the area of fertilizer application rather than in fertilizer manufacture. Before long, many developing countries may find that growth of the fertilizer industry is limited not by production problems but by lack of markets. If this situation arises it may be overcome only by the building up of a body of quantitative reliable knowledge through applied research, operating in co-operation with agricultural extension services.

5.2 PLANT OPERATION ASPECTS

5.2.1 Plant capacity utilization

Section 2.3.3.3 and the survey of Annex E shows an average plant utilization of a little over 60 per cent in developing countries. This is a very unsatisfactory situation. Considering that in a large 1000 MT/d ammonia plant, fixed costs account for between 51 and 70 per cent of production cost at full capacity and 15 per cent return of investment depending on feedstock, it is easy to realize the adverse economic effects when operating under full capacity. Actions to improve it requires a separation of causes for the loss, into internal factors under management control, and outside factors outside their control. The main causes of loss can be classified as follows:

(a) Errors of conception, imputable to licensor and equipment supplier such as:

- supply of an unproven process;
- use of unproven equipment or equipment having a low viability;
- wrong engineering solutions, e.g. use of construction materials which are not corrosion resistant;
- neglect of particularities of raw materials used or quality of the utilities, especially of cooling water;
- incomplete transfer of know-how;
- insufficient and incomplete technical assistance during commissioning period and first period of plant operation;

(b) Causes entailed by operation, such as:

- lack of well-trained and skilled technical personnel for operation and maintenance;
- non-observance of technological rules;
- inadequate maintenance of the plant;
- repairs and spare parts of an unsuitable quality; raw materials and utilities (cooling water, demineralized water, instrument air, steam, lubricating oils) supplied of qualities other than those specified in the project.
- frequent shut-downs in the supply with utilities (electric power, steam and water).

(c) Causes entailed by the commercial activity such as:

- break of supply with raw materials;
- lack of product outlet;
- transport means not provided in due time.

From the causes above, an early conclusion may be drawn as regards the three causal factors, namely:

- The choice of a responsible supplier having a wide experience and who is to be engaged and committed by a comprehensive and well-conceived contract.
- The buyer must have well-trained technical personnel not only for operation, but also for maintenance; this should be done by a systematic training performed in due time.
- A suitable infrastructure must be available.

A special case in the operation of plants would be represented by the plants integrating a fertilizer complex. In order to restrict the effects and to reduce the number of accidental shut-downs, measures can be taken at the early stage of design, such as:

- to provide buffer storages able to take over the intermediate products (NH_3, HNO_3, H_2SO_4, H_3PO_4);
- in case of one single manufacturing train, to provide at least two units for the process stages failing more frequently (e.g. two oxidation elements in the nitric acid plants, two pyrite burners in the sulphuric acid plants, etc);
- to provide stand-by moving equipment at the critical points (e.g. pumps, blowers, fans, elevators etc);
- to provide double supply in the plant utility system;
- to provide additional sources of electric power for the main consumers in plants, such as ammonia, urea etc .

The measures indicated for higher reliability in operation of the units in integral fertilizer plants imply additional investment efforts. Consequently the decisions of solutions must be made on the basis of thorough economical studies to avoid unreasonable expenses.

Whilst quantitative information on the causes of low capacity utilization is lacking based on the above mentioned causes, the following guidelines for new plants are laid down:

1. Perhaps the most important requirement is thorough and comprehensive initial planning, involving technical, economic and financial assessment. If local resources are not sufficient for this task expert consultants should be employed. Particular attention should be paid to a careful estimate of the available market. A project hastily planned or inadequately investigated will be a continuing source of trouble. This may seem obvious, but it is a basic precaution which is not always observed.

2. For the construction of the plant only reliable and experienced contractors with a proven "track record" should be employed. The design and erection of a large fertilizer factory to tight time limits is a complex operation calling for a skilled and experienced team. Even experienced contractors occasionally make mistakes. The use of inexperienced contractors is too risky.

3. Whenever possible plants should be located in areas with adequate infrastructural resources. They should normally have their own power generating facilities. The investigation of infrastructural resources should be thorough and detailed covering, for example, the carrying capacity throughout the year of transport systems with an estimate of the vehicles and rolling stock required, the quantity and quality of water supplies and seasonal variations in these, the frequency of power failures and voltage surges on power supplies, the adequacy of drainage systems etc.

4. Plants should adopt only proven processes and should avoid novel variations of these processes. When utilization on existing plants has reached 80 to 90 per cent some process risks may be justifiable, but not at 65 to 70 per cent.

5. The emphasis should be on process and plant simplicity, Plants should preferably use only one feedstock and make only one product. Process complications giving only a minor gain in efficiency should be avoided.

6. Standard plant sizes should be chosen whenever possible. In this way the plant uses not only proven processes, but also proven items of equipment.

7. When single-stream plants are used, some key items should consist of two half-size units. This will increase capital costs, but increase utilization.

8. A generous allowance of spares for key imported items should be made. A quick and stream-lined procedure for importing urgent spares should be agreed beforehand with the appropriate authority. Factories should examine their spare parts lists and, whenever possible, should arrange for the pooling of joint spares.

5.2.2 Maintenance and instrumentation

It appears that the single major internal cause of lost output in developing countries is inadequate plant and instrument maintenance. The key to fuller capacity utilization and to improved efficiency is a regular system of preventive maintenance, backed by trained manpower and a quick and reliable flow of spare parts. Consequently, the organization of the maintenance and instrumentation systems should be conceived from the beginning along the plant design, and should be part of the transfer of technology activities. It must comprise basically the way in which the special works are to be performed, such as: welding methods; treatment methods for stainless steels; alignment and adjusting to the admissible clearance of turbounits; maintenance and repair of corrosion - proof and refractory coatings; cleaning and washing of plants etc.

The maintenance should be carried out by providing the following:

- maintenance basic units (section shops and one central shop specialized for various operations);

- availability of skilled personnel, well-trained by schooling in the contractor's similar plants;

- working out of a thorough schedule for the maintenance operations for each equipment and piping lines;

- availability of frequently wearing out parts and materials stocks;

- conclusion of contracts for special works "services", first of all for machines (elastomers corrosion - proof protections; instrumentation including periodical testing, gauging and calibration);

- conclusion of agreements with other enterprises for works of reduced volume, but having a specific technical character (founding, forging, special building-in, corrosion-proof protections etc.)

- contractor's commitment to meet orders for spare parts over a longer period of time (about 10 years);

- organizing the book-keeping of maintenance and repair operations performed, equipment responsiveness, life of spare parts, wear-out degree etc.;

- periodical reports on maintanance activity and its improving on the basis of data gathered so that the maintenance programme can be adjusted as experience grows;

- periodical training of maintenance personnel by up-dating courses and exchange of information with similar plants (in the country, in the neighbouring countries and/or plants of the supplier);

- organizing the overhaulings by sequential schedules so that they might be performed by the plant specialists in a brief space of time.

To carry out successful maintenance activities the basic requirement is the training of maintenance personnel from managers to tradesmen. The second is a carefully worked out maintenance system including preventive, corrective and unplanned maintenance set up before plant start-up in co-operation with plant contractors and with experienced maintenance people from existing plants showing a good maintenance record. Once the plant is on-stream, if particular items are found to be responsible for high output losses, contractors and operators of similar plants should be consulted with a view to obtaining more reliable equipment.

As developing countries often experience difficulties in obtaining spare parts, it is desirable that in cooperation with contractors and with experienced maintenance men from existing plants, they should ensure that their workshops are equipped to fabricate spare parts whenever possible. In single-stream plants the organization of maintenance systems presents problems because equipment is only available when the plant is shut down. In this situation it is very difficult to carry out all the programmed work in the time available. This situation can be alleviated by keeping a generous stock of instrument and small pump spares so that complete units can quickly be changed, and then checked and maintained at leisure. A better solution is joint maintenance planning by two or more factories, so that the maintenance force can be augmented by skilled people from other factories during a plant shut-down.

5.2.3 Personnel training

The complexity of modern fertilizer plants, the high degree of automatic process control, the corrosive feature of some of its products and the advanced technology used, require very skilled personnel. These plants also tend to be single-stream plants with a greatly reduced number of items of equipment. Both of these factors reduce the number of people required for operation and maintenance, but they increase the responsibility carried by each each worker and the qualifications and training required for satisfactory operation. On large ammonia/urea plants the investment per worker is about $ 0.4 million. Such a plant would employ about 650 people about 5 per cent of whom are managerial, 20 per cent supervisory and 50 per cent engaged in operation and maintenance.

Annex H shows the specific training scheme for a recent ammonia/urea plant.

The great losses caused by frequent shut-downs of the plants, the high costs of repairs and replacing of machines, inadequate operation due to non-observance of procedures and regulations, the possibility of occurrence of serious accidents in the plants etc., caused by insufficiently-skilled operation and maintenance personnel emphasizes the importance of personnel training. Likewise, an unsuitable management of such plants or inadequate market outlets may affect greatly the economic performance of the plant. This situation points out that in many developing countries not enough attention has been paid to the training of the operation and maintenance personnel in the fertilizer plants. The idea that this personnel will be trained on the spot by simply working in the plant is very risky and much too expensive. Expenditures on carefully planned training, contrary to some ideas that they are not justified, may pay out a very high dividend.

In view of the large number of personnel to be trained in the long run (see chapter 4), it is doubtful whether adequate facilities can be provided by individual enterprises: some form of co-operative effort is required. This might cover the co-operation of existing factories in the training where the use of existing training facilites are not fully utilized, and the organization of national and/or regional training capabilities. At present training is usually provided by the following means:

(a) Training by the contractor's specialists according to a training contract negotiated within the overall transfer of technology scheme. This usually includes in-plant training abroad in the contractor's plants for key personnel and spot off-the-job and on-the-job programmes for the rest of the staff.

(b) Sending some personnel abroad for specific training in specialized institutes and enterprises.

(c) Through government agreements and international organizations, including fellowships, in-plant training programmes etc.

(d) Long-term training agreements with the contractor or other specialized institutions to develop an in-company, country or regional training capability.

(e) Co-operation agreements such as joint ventures; the more knowledgeable partner should be responsible for setting up and operating the training programmes of the new venture.

The principal general points to note about training programmes are:

1. No expenditure of fertilizer plant pays as high a dividend as expenditure on carefully planned training.

2. Programmes should begin some 1 to $1\frac{1}{2}$ years before the start-up of a plant. They should be continued after the start-up to provide for new recruits and to give refresher courses to employees.

3. Arrangements for training should allow for "drop-outs". In general, an allowance of at least 20 per cent extra is advisable.

4. Particular attention should be paid to emergency shut-down procedures and to safety in operation and maintenance.

5. Whenever possible training should include visits to operating plants.

6. The use of process control board simulators has been found invaluable in the training of operating personnel. In some cases it has proved to be three times more efficient than practical in-plant instruction in developing the operator's skills to control the plant through instruments.

7. Training programmes should be preceded by a survey of local educational facilities so that the specific requirements of the programme can be identified. Whenever appropriate and practicable training courses should be run in co-operation with local educational institutions.

An important training factor is the instructors' education and aptitude. The methodological expertise and teaching ability of the instructors is considered as important as the content of the training programme. A good specialized training usually takes up to two years for operation personnel and longer for maintenance personnel. An effectively trained operation and maintenance personnel can be achieved if training starts during plant design, continues in practical work from plant construction to start-up to on-stream operations, for only thus will they get thoroughly acquainted with the plant down to the last bolt.

During plant operation it is advisable that supervisory staff undergo rotation training through several departments not only for career development purposes but to be able to cope with a wider range of emergencies. The training of skilled workers should cover, in addition to practical know-how, a good theoretical knowledge of the technical principles necessary to understand the production processes in order to achieve a better mastery over the processes they are to supervise or control. In addition, periodical refresher programmes should be organized for all categories of skilled personnel. During the start-up period, about 20 per cent excess trained personnel should be provided; later on it will gradually be reduced to the quantity required by normal operations.

5.3 ECONOMIC ASPECTS

In considering the economic aspects of establishing fertilizer plants in developinng countries there are three main factors that affect any new plant: infrastructural costs, plant utilization and inflation. The first two have been discussed in previous sections; the last one is discussed below.

The first consideration is that inflation is here to stay and we have to learn to live with it; there seems little prospect of rolling back the world-wide inflationary tide. It introduces an additional uncertainty into all forward planning and complicates the task of presenting a realistic and useful picture of the current position of an industrial enterprise. A major effect is that continuous increase in capital costs with which project planners are faced. At an inflation rate of 10 per cent, capital costs double every seven years, i.e. in about the time taken from the inception of a project to its completion. This calls for a continuous increase in the financial resources available for plant construction. These resources, particularly those available to international organizations, do not always increase at a rate commensurate with that of world-wide inflation. A further consequence is the search, particularly in developing countries, for some method of reducing capital costs. This issue was raised at the January 1977 fertilizer consultation meeting and will be separately reported on to the November 1978 consultation meeting. It has also caused particular emphasis to be put on the cost of infrastructural development which becomes so large in many projects in developing countries.

The problem for planners is that the assessment of fertilizer projects covers a long period of time during which major cost changes occur. A typical large project will cover six to seven years from its beginning to the start-up of the plant, and a further three years are normally required before the plant is running at full output. To produce meaningful forecasts some form of discounting technique is essential. Particular difficulties arise with such techniques because capital costs of fertilizer plant,and especially commodity prices, e.g. the prices of raw materials, finished fertilizers and grain, do not by any means march in step with inflation rates. There is some evidence that capital costs, particularly in the early 1970's, increased more rapidly than would be expected from inflation indices.

A factor of importance in assessing fertilizer projects, which is in part due to inflation, was noted in chapter 2.3.5, and that is that world market prices and the import prices derived from them are an inadequate yardstick for estimating project viability. There is a considerable time lag before inflated capital costs, and the higher capital charges to which they gave rise are reflected in world fertilizer prices. Consequently, prices calculated for new projects nearly always turn out significantly higher than current prices. This is of particular importance for projects with an appreciable reliance on export markets but, in inexpert hands, can also be a deterrent to otherwise viable projects.

In subsequent sections the economic problems of fertilizer industry establishment are discussed in relation to markets and plant size, plant location, fertilizer distribution, plant construction and financing.

5.3.1 Markets and plant size

The basic determinant of plant size is the available market. The first step is to examine the available data on the growth of the market as a whole and to forecast its likely growth in the future using well known statistical techniques. This normally gives reasonable short-term forecasts but it needs to be used with caution, particularly if consumption is low and is rising rapidly, and if extensive historical data is not available. Its defect is that it assumes that the future will resemble the past, that the same combination of forces which led to growth in the past will be operative in the future and to the same extent. This is rarely true, but when consumption is large and fertilizer use established, radical changes are less likely. It needs to be supplemented by other methods. These require a detailed breakdown of existing fertilizer use, crop by crop and area by area, together with estimates of the optimum types and rates of use for each crop and each area. These estimates are not always readily available. Some information can usually be obtained from university departments of agriculture and from ministries of agriculture, but often this has to be supplemented by data for similar areas and crops elsewhere. Critical account must also be taken of plans for extension of agricultural areas for specific crops and for the increase of irrigated areas. A realistic assessment is then made for each crop and area of the rate at which, year by year, the optimum rate of use will be approached. This gives a detailed estimate for each year. A report (FPI/76/1-7) issued by the Consultative Group on Food Production and Investment in Developing Countries on 2 December 1975, gives a table illustrating a typical approach to an optimum level of 160 Kgs per hectare from an existing level of 20 Kgs/hectare.

Table 27. Typical approach for attaining optimum nutrient application levels per hectare

Year	0	5	10	15	Optimum
N	12	21	36	53	98
P_2O_5	7	12	17	24	44
K_2O	1	3	5	8	20
Total	20	36	58	85	162

fertilizer than has so far been necessary. Although many developing countries are individually aware of their distribution and marketing problems, in general much less effort has gone into this aspect of fertilizer consumption than has gone into fertilizer production.

In 1955 the developing countries supplied 39 per cent of nitrogen, 55 per cent of phosphate and 11 per cent of potash of their domestic demand. In 1976 they supplied 71 per cent, 75, and 23 per cent respectively of their domestic demand. These higher self-supply percentages point out that production as a limiting factor may be giving way to consumption as the limiting factor, so that a considerable shift of emphasis may be in the offing.

Nevertheless, fertilizer consumption in the developing countries still lags far behind consumption in the developed countries, both on a per capita and on a per hectare basis. Tables 19 and 20 show the very wide variation in application rates between regions and countries. In developed countries the variation in total consumption in 1975 was from 80 to 180 Kgs/hectare, and in developing countries it was from 6 to 50 Kgs/hectare. Table 20 shows the very great differences between selected countries. Egypt is an exception among developing countries, very few of which have nutrient applications as high as 100 Kgs/hectare. The very high rate of 751 Kgs/hectare in the Netherlands is due to its heavy fertilization programme in a relatively small area of arable and permanent crop land, and with considerable fertilization on pasture land. The Federal Republic of Germany, with a nutrient application rate about half that of The Netherlands, has an area ten times as large. This illustrates a defect in the use of Kgs/hectare of arable land as an index of the intensity of fertilizer use. When an appreciable proportion of fertilizer is used on pastures, which is rarely the case, artificially high figures are obtained. The Kgs per capita index has the defect that its correct use requires accurate information on population density per arable land. Annex B-9 shows the countries whose demand weight determine the shape of world fertilizer consumption and therefore help shape the evolution of the world fertilizer production structure along a time axis.

- For nitrogen, in 1965 there were 5 developing countries within the 17 most important markets accounting for 14.6 per cent of world consumption. In 1975 there were 4 developing countries out of the 18 most important markets but accounting for 18 per cent of world consumption. The USSR, China, India and Romania had the larger consumption increases at the expense of the US, Federal Republic of Germany and Japan. These shifts reflect the dominating position that the US, USSR, China and India have on world food grain production in modern farms, where they account for over half the world total.

When an estimate of this type has been made it is compared with the estimate obtained by statistical extrapolation and any obvious discrepancies reconciled or explained, to arrive at an agreed forecast. In this process the detailed estimate carries more weight. Having obtained an estimate of demand year by year, it is possible to calculate the optimum economic size of plant. This is a complex process and in view of the uncertainties of any market forecast, coupled with the effect of inflation upon plant costs, it is doubtful whether the exercise is justified by its results. A plant which meets demand at the point when it reaches full output, after about three years of operation is too small and its production costs unnecessarily high. On the other hand, a plant capable of meeting demand ten years after its start-up is going to be operating below capacity and at correspondingly high costs for a long time. Depending on the rate of market growth, a capacity equal to demand five or six years after start-up is probably reasonable.

The production cost in table 14., section 2.3.51, shows that urea costs at full output from a 600/1300 t.p.d. ammonia urea plant are $ 20 to $ 30 a ton higher than the cost from a 1000/1725 t.p.d. plant. The difference is important and emphasizes the penalties of choosing an unnecessarily small plant.

It is interesting to note the cumulative results of decisions on plant sizes over the developing world. An analysis of the list of projected ammonia and phosphoric acid plants given in the FAO Annual Fertilizer Review for 1976 is presented below.

Table 28. Analysis of capacity of new projects listed in FAO Annual Fertilizer Review 1976

	Capacity range					
Ammonia						
Capacity (t.p.d.)	> 1,000	1,000	900	600/900	600	Total
Number of plants	11	33	20	4	9	77
Total capacity (t.p.d.)	14,600	33,000	18,000	2,600	2,500	70,700
% of total capacity	20	47	26	3.5	3.5	100
Phosphoric acid						
Capacity (t.p.d.)	> 500	500	300/500	Total		
Number of plants	6	11	7	30		
Total capacity (t.p.d.)	4,800	5,500	2,500	13,800		
% of total capacity	35	40	18	100		

93 per cent of ammonia is provided by large plants 900 t.p.d. or larger and only 3.5 per cent by "small" plants; 75 per cent of phosphoric acid capacity is provided by plants of 500 t.p.d. or larger and only 7 per cent by "small" plants. It is probable that some small plants have been omitted from the list, but the table shows clearly the trend towards very large plants, particularly for ammonia manufacture.

A contractor will supply a plant of any capacity required by the client, but the practice of using standard sizes is growing rapidly because it reduces costs and construction time. Contractors have standard designs for the layout of these plants as well as for the individual items of equipment, thus considerably reducing design charges. Furthermore, since the equipment has already been tested in many plants and any design, weaknesses subsequently remedied, the client is in effect purchasing a plant of proven design. These advantages are important and, under normal circumstances, clients would be well advised to select the plant size most closely suited to their requirements.

5.3.2 Plant location

The selection of a site for a fertilizer factory has a significant effect upon the cost of the fertilizers the plant produces. It affects the cost of building the factory, the cost of operating it, and the cost of supplying the fertilizers to the farmer. Any increase in costs caused by the uneconomic location of fertilizer plants will restrict the increase in fertilizer consumption, leading to lower food production and higher food costs.

However important the economic factors are, it must be recognized that other factors have to be taken into account, which on occasion may not lead to the choice of a minimum-cost site. Governments with a paramount responsibility for the welfare of their people, have found it both necessary and desirable to restrict the free play of economic forces, and this applies to the selection of industrial sites as well as to other aspects of economic life. However, it is important that the economic consequences of such decisions should be known beforehand, so that a decision can be reached in the light of all the relevant facts.

In selecting a site, a reasonable balance should be struck between economic and social or political factors. A private commercial organization will naturally attach greatest weight to the economic factors, and may pay insufficient regard to social factors. If a government wishes to ensure that these factors receive due weight, it must exercise some form of control, either directly through a "license to build" or indirectly through various forms of financial incentive or penalty. With a governmental organization, on the other hand, the danger is that the economic factors may be under-emphasized since such organizations are frequently free from the ultimate financial accountability to which private commercial organizations are subject.

The selection of a site has to be seen not only in the choice of sites within national boundaries, but also in the light of the possibilities opened up by international co-operation. The development of many regional and economic groups or associations is leading to an increased awareness of the advantages of international co-operation and regional planning. This is particularly important to the development of the fertilizer industry where, owing to the economies of large-scale operation, the uneven distribution of raw materials, and the very high capital costs, the benefits of international co-operation and the penalties of independent action are considerable.

In selecting a site the principal factors to be considered are:

- Transport: availability and cost, raw materials and markets.
- Utilities: availability and cost of electric power and water, effluent disposal.
- Nature of site.
- Labour.
- Infrastructure: housing, roads, railways etc.
- Environmental conditions and regulations.

A distinction has to be drawn betwen the effect of these factors on capital costs and their effect on production and distribution costs. The latter costs enter directly into the selling price of the fertilizer, whereas capital costs enter only indirectly and to an extent determined by company policy.

The factors which affect capital costs are: the choice between a new and a developed site; the cost of making road and rail connections to the site; the availability and reliability of power and water supplies and effluent disposal systems; the cost of transporting equipment to the site; and the suitability of the site for building operations.

The choice between a developed site and a new site is one which arises more frequently in developed than in developing countries. However, when it does arise, very thorough investigation is necessary because such features as the availability of road and rail connections, the existence of internal roads, offices, workshops, and the presence of water and power supplies make a developed site much cheaper. It is unlikely that a developed site will be in the ideal position with respect to raw material supplies and markets. However, since the capital costs of a developed site can be as much as 30 per cent lower than those of a new site, considerable extra transport costs can be borne.

The cost of road and rail connections, power and water supplies and effluent disposal systems have been discussed in general terms in the context of infrastructural costs in chapter 5.1.3. The cost of transporting equipment to the site may be a significant item in total capital cost. In developing countries as much as 80 per cent of the equipment may come from overseas and the cost of moving it to a site remote from the port of entry may be appreciable. If there is a limitation on the size of individual items that can be shipped by rail or road, it may prove necessary to transport major vessels in two parts and to weld them together on site, or to use two smaller vessels in place of one large one. These expedients increase capital costs.

The qualities of a good building site are known. It should be level, have good load-bearing properties and be free from abnormal occurences, such as floods, earth tremors or very high winds. The disadvantages most commonly experienced are the necessity for levelling, back-filling or piling, and the obstruction of access by major roads or railways. In case of grounds with moderate load-bearing properties, buildings and heavy equipment will require specially reinforced foundations entailing high extra costs and longer plant construction periods.

In summary, and assuming that a developed site is not available, the ideal minimum cost site is close to existing road and rail systems as well as to water supplies; it is not subject to unusually stringent effluent standards; it has reasonable facilities for the disposal of liquid and solid wastes; it does not entail excessive equipment transport costs; it is level and has good load-bearing properties. Such a site will not often be found; usually it is necessary to strike a balance between various advantages which, in order to compare different sites, should be set out in terms of the extra costs entailed.

The most important factor is transport costs. Differences in transport costs between one site and another frequently outweigh all other cost differences, and the location of a fertilizer factory is often determined by transport costs. In this context "transport costs" are given a wide interpretation. They cover the cost of operating a natural gas, oil or water pipe-line, as well as of effluent or waste removal: all the costs of transporting raw materials and supplies from their point of origin to the site, and of moving products and by-products from the site to their point of consumption or disposal. The only way to compare transport costs for different sites is to obtain quotations for the different classes of traffic and the various methods of transport, including, where relevant, the cost of transporting gas, oil and water by pipeline, on the basis of which total transport charges can be estimated.

The amount of time and effort required to select a site obviously depends on the number of sites chosen for detailed comparison. This is much less than might at first be expected since the choice of sites is usually quite restricted. If a factory has to compete with other manufacturers or imports, the areas in which it can operate economically may be few and fairly clearly defined. The factory must be reasonably close to its raw materials and/or its markets - a coalfield several hundred miles from a fertilizer market is not likely to be a suitable source of raw material for fertilizer manufacture. It must be within reasonable distance of an adequate water supply and close to a road and/or rail system, and the cost of connecting it to that system must not be excessive. The site itself must be suitable for building operations. Factors such as these usually determine the area in which the factory can be built and reduce the number of possible sites to two or three. Only when this process of elimination has been completed, can the detailed comparison of sites begin.

It is useful to distinguish three stages in this process. In the first stage, competition, the location of markets and raw materials, and government policy combine to define the general area. In the second stage, the need for a site close to water supplies and to a satisfactory transport system, and which is also suitable for building, leads to the identification of two or three sites in the general area selected in the first stage. In the third stage, a detailed cost comparison of the sites is made to enable the cheapest and most suitable site to be identified.

The first stage is general, whereas the second and third stages are specific. The initial stage takes the form of a general survey which can be carried out from an office desk, provided that the necessary information is available. The subsequent stages require detailed investigation and analysis, and much field work is involved. The distinction between the first and second stages is most relevant in complex situations where considerable competition and a well-established fertilizer industry already exists.

5.3.3 Fertilizer distribution

(a) Markets

As pointed out in chapter 2.4.3 the level of fertilizer consumption in developing countries is low in comparison to developed countries. This situation reflects several causes such as predominance of traditional agricultural systems over modern ones, the farmer's lack of purchasing power, lack of knowledge on fertilizers and their effect on crop yields, lack of physical infrastructure etc. Most of these factors lie outside the control of the fertilizer industry as they involve agricultural extension services, financing and government support. However, this industry has direct influence on two main areas: (i) the interaction and feedback with the agricultural extension services to continuously improve the types and performance of fertilizer products and formulations according to prevailing agronomic conditions; and (ii) establishing an efficient fertilizer distribution network.
This section deals with the second area since the first one has already been dealt with in general terms in chapters 2.3.2 and 2.4.2.

(b) Fertilizer distribution network

An integrated fertilizer distribution system comprises production, marketing and physical distribution, and fertilizer application in farms. Figure 3 gives a schematic view of this system. From it, one can notice that concentration on fertilizer output alone is not sufficient to expand fertilizer consumption by farmers, although this has been the main concern of many developing countries. In fact, it becomes ever more critical to obtain the efficient organization of the physical distribution network in order to achieve a lower cost balance between continuous production output and seasonal fertilizer consumption by farmers.

In general terms, the best argument for fertilizer consumption is a favourable benefit-cost ratio to farmers. Recent studies have determined that the minimum benefit-cost ratio should be about 2:1. Table 29 shows some

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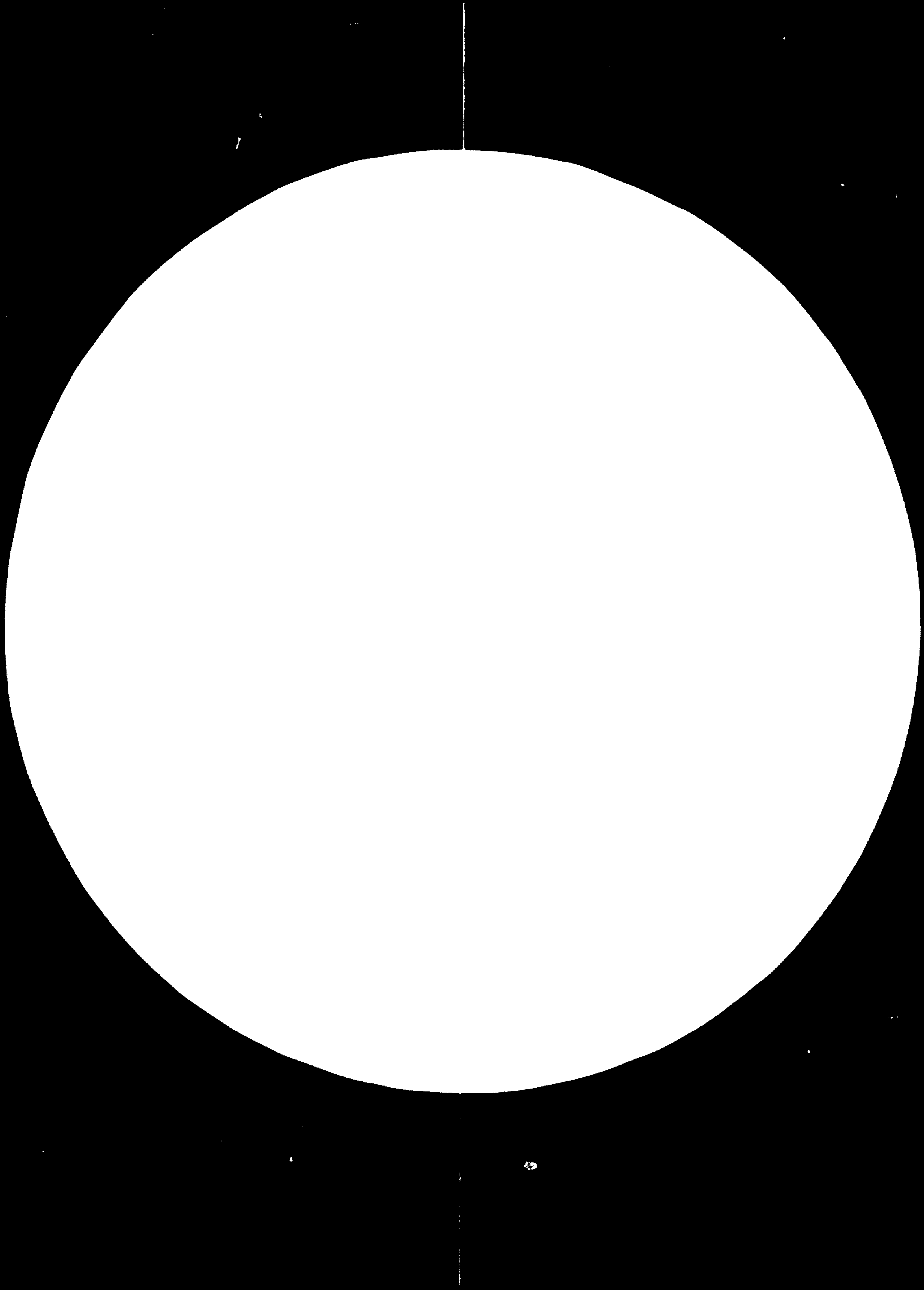

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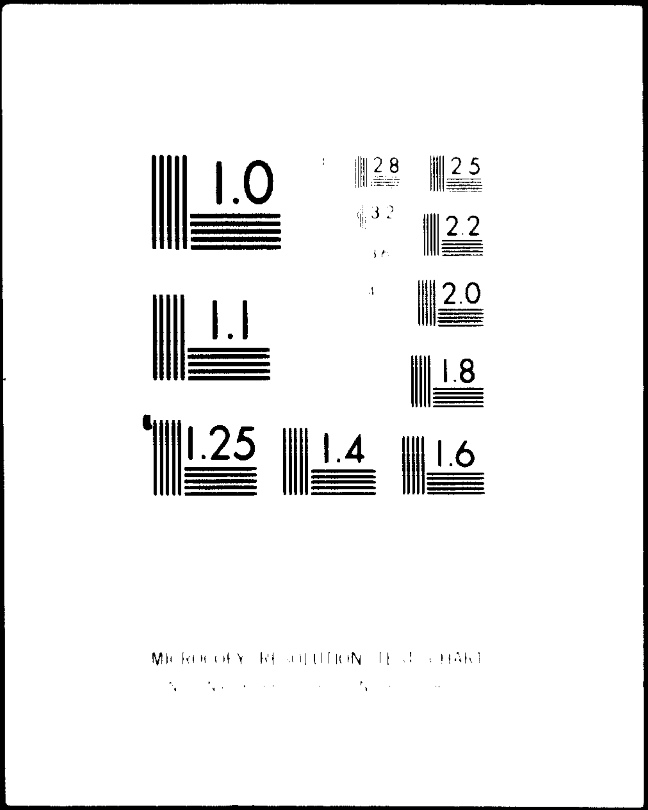

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(c) partial supply contract, with buyer's participation in supplying part of the equipment and materials, made on the basis of the contractor's design and under his direct control;

(d) licence, know-how and engineering contract, with buyer's taking over the procurement construction under the contractor's technical assistance;

(e) licence, know-how and basic engineering contract;

(f) licence and know-how contract.

The contract types under (d), (e) and (f) imply a great deal of participation accompanied by the corresponding responsibility for the buyer, which means sharing the risk with the contractor. Generally these types are adopted in countries with a higher technical competence since they offer a number of advantages such as:

- by buyer's participation in the plant implementation, the foreign exchange needs are lower and the plant investment cost is lower too;
- a more complete transfer of technology is achieved and invaluable experience is acquired, which will be turned to advantage when implementing other plants in the buyer's country or in other developing countries.

These forms of contract with buyer's participation also have disadvantages such as: longer time of implementation and the quality of the work becomes conditioned by the buyer's competence and technical level, which in many cases are under the contractor's technical competence.

Any contract should provide:

a) Guarantees of output, product quality, and efficiencies in the use of raw materials and utilities, with penalty clauses;

b) Penalties for delay in completion;

c) Provision for arbitration;

d) Provisions, preferably quantitative, for the use of local personnel and local equipment and services;

e) Arrangements for training;

f) Insurance cover for accidents involving property or persons;

g) Arrangements for access to the site and for the supply of utilities during construction;

h) An agreed procedure, with dates and time limits, for the handling of specified categories of documents.

The list could be continued indefinitely. The most important general factor is that the contract should be both clear and comprehensive, and should leave no doubt about the allocation of responsibilities. Besides the contents of the contract, the success of its implementation is conditioned by the degree of supervision of work in progress and the way the works outside the contract limits are performed. These works committed outside the contractual terms must be properly estimated concerning cost and delivery schedules. If they fall behind schedule, the contractor is acquited from the pertinent contractual obligations and consequential losses. The more frequently committed works outside contractual terms concern the infrastructure, utilities, local supplies, training programmes and civil works.

Once a contractor is appointed both parties should nominate arbiters who have the ultimate power of decision in disputes. The construction of a fertilizer plant is a very complex affair and it is inevitable that a multitude of issues of varying degrees of importance,will arise. A speedy settlement of these issues is necessary for the development of that mutual confidence which, associated with a clear understanding of the rights and obligations of both parties, is the best guarantor of a successful completion of the project.

5.3.5 Financing sources

The fertilizer industry is capital intensive and requires very substantial investments. In developing countries it usually involves importing from the developed countries of most, if not all, the equipment required, thus posing a heavy strain on the foreign exchange availability. In a number of cases this last condition has induced some developing countries to sign less advantageous contracts because of drawbacks in trying to secure untied foreign exchange financing in favourable terms.

In selecting the best financing combination for fertilizer projects in developing countries, the most important considerations are: the availability of funds, especially foreign currency, the conditions in which such funds may be raised, and the opportunity for participation of reputable foreign companies in the venture. Since securing financing may prove difficult in some cases, the following points should be carefully considered:

- It is important to make the most realistic estimate of investment in current terms during the whole period from plant design to start-up to first years of operation, taking account of all relevant factors and inflation in particular.

- To present detailed feasibility studies made by a reputable firm which makes it easier to obtain credits, and in fact it is often a precondition stipulated by credit organizations.

- Associations with prestigious foreign companies in joint venture arrangements may be regarded as a valid techno-economic guarantee for the project based on the foreign partner competence, thus making credits more readily obtainable.

(a) Debt-equity ratio in financing schemes

The debt-equity ratio is an index to the capital structure of the company and the degree of financial leverage it exerts. A high debt proportion will cause prospective lenders to view their loans as substitutes for the missing equity and this creates high debt servicing risks, therefore their credit conditions will reflect this assessment. Conversely, a conservative debt proportion would improve the credit rating of the company, but this should be appraised against the weighted average capital cost of the company in order to maximize the cash flow within risk assessment levels that the company feels comfortable with.

However, it is very important for a project to obtain the best credit rating possible for that will entitle it to borrow at the most favourable rates and conditions prevailing in the market. Typical financing schemes in developing countries show equity participation of between 25 and 43 per cent of total investment given a debt-equity ratio of between 3 : 1 and 1.5 : 1. Most financial institutions consider a 2 : 1 ratio satisfactory provided that fertilizer realization prices and their corresponding discounted cash flow are realistically estimated. A recent analysis of some typical fertilizer project financing in developing countries point out the following characteristics:

1. Large-scale projects in developing countries include the participation of the following elements:

- foreign enterprises through technology, know-how, equipment, training and marketing;

- the determined commitment of the government of the host country demonstrated by financing, loan guarantees, provision of local labour and infrastructure;

- international financing whether provided by the World Bank Group, Regional and Commercial Banks, Eximbanks or a consortium thereof.

2. Five other elements were included in financing fertilizer projects:

- equity participation of foreign companies;
- local commercial institutions;
- regional development banks or regional funds;
- bilateral government and/or concessional loans;
- supplier's credits.

3. A foreign company taking an equity position is usually restricted to a minority partnership.

4. Financing committed by host governments or local enterprises is generally in local currency.

5. Large-scale project financing is increasingly international.

(b) Loan financing

A further analysis of typical fertilizer project financing reveals the following trends concerning loan financing:

- each project must be considered individually on its own merits;
- financing seems more readily available for countries of about $ 500-2000 income per capita, for at this level the fastest rise in gross domestic product appears to occur;
- fertilizer projects in virtually all developing countries are more successful where governments co-operate in the projects;
- the financing of fertilizer plants in developing countries will continue to be different from financing in the developed countries because few developing countries possess a fertilizer industry able to generate the cash flow necessary for a majority self-financing;
- the proliferation of joint ventures in many developing countries.

In general terms, financing can be arranged from several sources, the most important being the World Bank Group, Regional Development Banks and certain forms of government assistance such as the export-import banks of many developed countries. Other sources include regional funds, commercial banks and other international lending institutions such as eurocurrency loans, supplier's credits and barter deals that require payment in kind. Each of these sources has a range of terms and conditions for their loans that are negotiated and agreed upon according to the intrinsic merits of the project.

5.4 SOCIAL AND POLITICAL ASPECTS

This chapter aims at analyzing the effect of the fertilizer industry at country and regional levels. Due to time constraints, the analysis has been limited to two main aspects: the institutional framework and governmental policies at national and regional levels, and the environmental problems in the fertilizer industry in view of the important current and future development sin this area that are already affecting the fertilizer industry.

5.4.1 Institutional framework and government policies

World fertilizer consumption is expected to grow steadily during the next two decades, reaching a level 3.1 times that of the 1976 figure by the year 2000. However, the expansion of production capacities needed to satisfy this requirements calls for the immediate adoption of action-oriented policies by the developing countries at the national and regional levels, which will be referred to below:

5.4.1.1 National level

The developing countries exercise varying degrees of control over the fertilizer industry and agriculture, ranging from moderate control of private enterprise to complete control of fertilizer production, distribution and use. Although the applicability of the policy measurements in each country is different, the purpose here ould be to focus attention on policies that have a direct bearing on increased production and equitable distribution.

5.4.1.1.1 Policies related to raw materials

(i) Exploration programmes

It is the prerogative of any government to determine how to make maximum and effective use of its own resources in order to achieve a certain degree of self-sufficiency, but in many developing countries only minimal exploration for mineral resources has taken place to date. This, in spite of the fact that one of the first requirements for asserting domestic control over natural resources and assuring that their utilization is compatible with long-run national objectives is a reliable indication of quantity, quality and the rate of depletion. Without this information, the formulation of effective policies and development plans is impossible. Serious encouragement of exploration, therefore, should be a primary policy objective.

Resource requirements in the case of fertilizers include natural gas, petroleum, coals, oil shale, oil sands, hydroelectric and hydrothermal energy, phosphate rock, and sulphur and potash minerals. Other useful resources are liming materials (calcite, dolomite, wollastonite) and micronutrient elements. Sodium minerals (natron or trona) are sometimes used as inputs for Rhenania-type processes. Magnesium silicate minerals (olivine or serpentine) may be used in the production of fused calcium-magnesium phosphate. In some cases, mineral resources may have dual uses; for instance, metal sulphide ores, such as copper sulphide, can supply sulphuric acid for fertilizer as well as valuable metals.

It may be government policy in some countries to have the public sector conduct the exploration programmes and extract and process the mineral resources, either through state-owned corporations, or directly, through government agencies. Similarly, government-supported institutions may be formed to engage in the exploration programme and research at subsequent production stages, or Governments may choose to have the private sector undertake both exploration and production. Relevant policies in this case might take a variety of forms, such as subsidies and capital allowances. However, whether the exploring is done publicly or privately, the Government's policy must take into account (a) the implications of resource ownership, and (b) the need to incorporate the findings of the explorations in the country's long-term plans for resource utilization and the development of resource-dependent sectors, such as the fertilizer sector.

(ii) Pricing policy

Indigenous raw materials for fertilizer manufacture may be subject to special price controls. This is often the case with ammonia feedstocks that have alternative applications as energy sources or petrochemical feedstocks. Pricing policies must reflect the priorities given to foreign exchange requirements and the development of domestic industries that are dependent on inputs of local raw materials.

The pricing of indigenous raw materials may be subject to a variety of development objectives, in addition to that of the fertilizer sector. Prices may be based on:

(a) The material's value for alternative uses. For example, the price of ammonia feedstock may be based on its value as a fuel for electricity generation. When there is no alternative use, the price may be zero or even negative. For instance, by-product sulphuric acid from smelter operations must be recovered to prevent atmospheric pollution; in some cases, using this by-product may be the only alternative to disposing of it;

(b) The import price of the same material or close substitutes;

(c) The export price of the resource which, in turn, can be based on international prices, a concept of market sharing with other major exporters, or the import price level for the country's major imports, such as manufactures or capital goods;

(d) A socially acceptable rate of return.

It is beyond the scope of this report to recommend one general pricing policy; a diversity of such policies exist in both developing and developed countries. Their impact, however, on development plans for priority sectors such as fertilizer must be given serious consideration. Price policy objectives for natural resources must be co-ordinated with sectoral development objectives.

(iii) Utilisation of indigenous raw materials

A well-defined strategy for natural resource extraction is essential. This is especially true in the case of fertilizer, where domestic production and resource requirements may grow rapidly. Production responses to international price fluctuations must be evaluated in terms of foreign exchange requirements, resource endowments and domestic needs. In addition, an optimal policy for the use of depletable resources must be weighed against the need to raise food production where fertilizer inputs are vital.

Although the extraction of indigenous raw materials can, at times, be expensive in relation to the purchase of foreign supplies, other development objectives may make this step advisable. The decision may be justified by, inter alia, the limited foreign exchange available, the desire to increase domestic employment, or the need to safeguard against foreign manipulation of supplies or prices. In the case of fertilizers, policies to increase domestic resource content may have to be supplemented by policies that will ensure prices to the final domestic consumer being at least competitive with international prices.

When domestic resources are limited, it becomes necessary to allocate them among possible alternative uses. To take natural gas as an example:

since this is worth much more as ammonia feedstock than as an energy source, it may be appropriate in many cases to give priority to its use for ammonia production. On the other hand, when sulphur or sulphuric acid is in short supply, governments may choose to select fertilizer processes that do not use it, or that need minimum inputs of it.

The conservation of resources should also be taken into account. Practices such as flaring of natural gas or "high-grading" of ore deposits for quick, short-term exploitation should be discouraged as far as practicable. When low-grade ore must be removed in order to mine high-grade ore, thought should be given to stockpiling the low-grade material for future use, when conditions or technology warrant.

(iv) Import and export policies

Fertilizer responses to long-run fluctuations in international prices should be determined in the context of the formulation of a country's over-all resource policy. Specific trade policy considerations may include long-run plans regarding the export of resources which form fertilizer input and the proportion which could be allocated to the domestic fertilizer sector. One policy variant might involve the restriction of primary resource exports to levels sufficient to meet foreign exchange requirements, the residual being used locally. When resources are available locally, the government strategy should include plans for their eventual export in a processed form, i.e. as fertilizer.

Regional co-operation in the utilization of fertilizer raw materials may often be advantageous. It is particularly recommended in regions where raw materials of adequate quality and quantity are scattered among several countries, or where the fertilizer requirements of individual countries are not large enough to justify an economical scale of production.

(v) Raw materials from other industries' by-products

Very often, by-products or co-products from other industries can be used as raw materials for fertilizer production. Examples are:

- Sulphur, recovered from sour gas, oil, or coal

- Sulphur or sulphuric acid from smelting sulphide ores of zinc, lead, copper, or nickel
- Apatite, from beneficiation of iron ore
- Basic slag or ammonium salts, from the steel industry
- Coke oven gas, refinery tail gas, or LPG for ammonia feedstock
- Ammonium sulphate, from caprolactum production
- Ammonium chloride, from soda ash production

Government policy can influence the utilization of these by-products in several ways. For instance, the government may require that sulphide ore be smelted in the country in order to recover sulphuric acid for fertilizer production, rather than export it for smelting elsewhere. If necessary, it may subsidize one industry, such as copper smelting, to ensure development of a phosphate industry. It is evident that government planning and co-ordination can be helpful in ensuring optimum use of by-products, and the integration of other industries with the fertilizer industries.

5.4.1.1.2 Policies related to fertiliser production

(i) Planning for efficiency and economy

Fertilizer production, as with many other lines of production, is usually sensitive to economies of scale. Gains in efficiency are likely to come from encouraging economies of scale resulting from increased plant size. Much depends on the market and the competitive structure of the industry. Many multi-plant industries could, in theory, achieve greater economies of scale. The mere fact that demand is sufficient is no guarantee that these economies are being realized. In some case, the number of plants has proven to be too great for economies to be easily realized. Such a situation is sometimes the consequence of government policy: indiscriminate encouragement for example, through subsidies, of the fertilizer sector may lead to an overabundance of plants, thereby preventing the realization of economies of scale. Selective subsidization may be called for.

The types of fertilizer to be produced is another important consideration. Government policy should relate product demand at the farm level with products that can be produced most efficiently and economically by the industry. Sometimes this decision may involve a compromise between agronomic, economic, and technical factors. For instance, NP products (ammonium phosphates or nitrophosphates) are often more economical to produce and transport than straight materials. Again, the direct application of ground phosphate rock may be economically preferable in some cases to using expensive water-soluble phosphates. In any event, sufficient flexibility should be provided to permit leeway for future changes in types and quantities of product.

Plant location is another consideration which is subject to policy influence. For instance, the extent of regional co-operation or trade agreements will influence the choice of market area and source of raw materials, and hence the plant location. Or, a government may wish to locate a plant in an area of high unemployment, for either social or political reasons, or in market areas to minimize transportation problems. Government plans for improving transportation systems, waterways, and port facilities should also be taken into account.

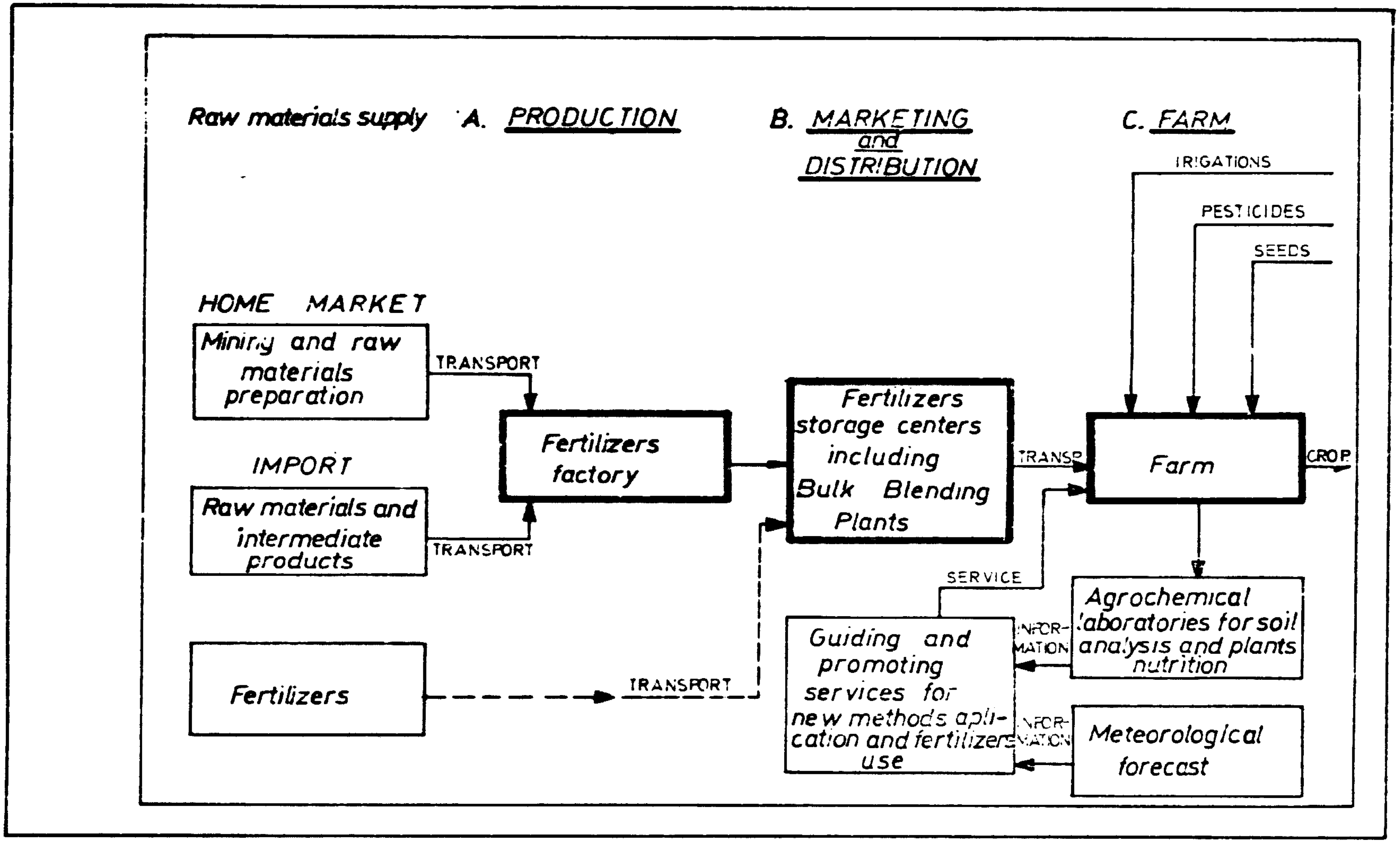
When raw materials are to be imported, it is generally poor policy to build a facility that is dependent on a single source. In planning a phosphoric acid plant, for instance, provision should be made for the possibility of using phosphate rock from a variety of sources.

(ii) Maximizing capacity utilization and minimizing production cost

Capacity utilization of fertilizer production facilities averages only about 60 per cent in developing countries - even in those countries where fertilizer is in short supply and imports are required to make up the deficit. Low capacity utilization has a disastrous effect on production costs. Nevertheless, in several cases, plants in developing countries have operated for extended periods (several years) at, or above, rated capacity.

Figure 3

Integrated fertilizer distribution system



5.4.1.1.3 Policies related to distribution and marketing

(i) Organizing a marketing system

The organization and policies that influence fertilizer distribution and marketing are diverse and not easily generalized. Several salient characteristics which serve to categorize country approaches can be mentioned, however.

One is the choice of public or private sector ownership of the distribution agency. In many developing countries, distribution is the responsibility of a government agency. Private distributors, where they operate, are usually general trading firms. Co-operatives, owned by the consumer, and wholesale outlets operated by foreign suppliers, may also be found.

The degree of centralization and co-ordination at the national level is a second distinguishing feature. Alternatives for centralization range from a highly centralized government monopoly to a private monopoly. The other extreme is a completely decentralized and unintegrated system. A country's distribution programme may also be geared to a specific group of consumers determined according to the crops they produce, to regional development programmes, or to other criteria.

A final organizational characteristic is the extent to which these institutions are vertically integrated. Integration may combine fertilizer procurement with crop collection, processing and marketing. Distribution of fertilizers may be combined with rural credit and handled under the auspices of local lending institutions.

More specific economic or policy features may serve further to distinguish the approach adopted by a given country. For example, where fertilizer export is a prime consideration, collection may be centralized under one institution. In countries where distribution costs are high, public rail systems have sometimes been delegated the responsibility for local distribution. In so doing, preferential freight rates may be given to fertilizers, and the transportation costs are subsidized through rates paid for other non-essentials. Distribution channels may also be organized to follow the crop pattern. Where the agricultural sector exhibits marked "dualism" (i.e. two distinct sub-sectors, one producing cash crops for export, the other producing subsistence crops for home consumption), such a system can be effective.

There is often a need for a variety of fertilizer products. Different soils and crops may require different N:P_2O_5:K_2O ratios, and one or more secondary elements or micronutrients may be needed. Large plants seldom have the flexibility needed to produce a variety of products. Also, the basic manufacturing facilities can be widely separated. A nitrogen plant may be located near a source of natural gas, a phosphate plant near a phosphate rock deposit or source of by-products sulphuric acid, and potash may enter the country at ports. Assembling these materials at a single location involves unnecessary transportation costs. The solution to this problem will vary from one country to another. One system that has several advantages involves the further processing of basic products by mixing, bulk blending, or granulation. Although it is possible to classify the further processing of basic or intermediate fertilizer materials as a part of the production system, such processing more commonly is included in the marketing system. The type of marketing system, then, can often be influenced, either directly or indirectly, by government policy. Careful thought should be given to selecting a production-distribution-marketing system that will meet both present and future needs.

It is important that the type of marketing system used ensure the availability of fertilizer products with the proper nutrient ratio for each use. Failure to supply needed ratios is one of the major causes of inefficient fertilizer use. For example, in the State of Alabama, U.S.A., during the 1974-75 crop year, 83 per cent of the fertilizer sold had a P_2O_5:K_2O ratio of 1:1, but only 27 per cent of the soils tested needed this ratio. This situation was caused mainly by a lack of availability of other ratios.[47/] Obviously, over one half of the farmers used fertilizer inefficiently by supplying either an excess of one nutrient or a deficiency of the other, or both. Increasing efficiency of fertilizer use (discussed further below)

[47/] Engelstad, O. P., and W. L. Parks. 1976. "Building of P and K in Soils and Effective Use of These Reserves". In TVA Fertilizer Conference (held 27-28 July 1976, Cincinnati, Ohio); Bulletin Y-106, pp. 50-58, July 1976, National Fertilizer Development Center, Tennessee Valley Authority, Muscle Shoals, Alabama.

should be a major goal. At the same time, it must be realized that increasing the number of ratios increases both the confusion for the farmer and the general cost of the fertilizer. Unless farmers are able to test their soils, or otherwise obtain reliable information about the specific nutrient ratios needed for each crop, there is little need for more than about three $P_2O_5:K_2O$ ratios. New ratios add to the cost of fertilizer because each grade must be registered, properly labelled, separately stored, and profitably marketed. Therefore, the policy should be to provide an adequate number of grades, but to avoid excess.

(ii) Development of infrastructure

When plans are made for expanding the production and use of fertilizer, one of the first bottlenecks in many countries is that of transportation. Movement each year of a few hundred tons of imported fertilizer from a dock poses few problems compared with moving a thousand tons per day from a modern plant. Even this daily movement is not a full indication of the transportation problem. Each ton of plant nutrients can be expected to increase grain production by approximately ten tons. Presumably, most of this increased production will need to move out of the production area and into the commidity marketing channels. Food problems cannot be resolved unless increased production of fertilizer is accompanied by a major improvement in transportation facilities. Similar improvements are needed in other aspects of infrastructure: electricity, communication, storage silos, warehouses, markets, etc. Again, the policy implications are clear: there must be a balanced development of infrastructure and fertilizer production, and the need for effective disposal of the additional food supplies must be considered.

(iii) Realistic requirement estimates

Realistic estimates of fertilizer requirement are a necessary basis for planning efficient production facilities, as stressed above. These data are equally important in planning an efficient marketing system. Future fertilizer requirements need to be detailed by region, district and season. The extent to which the calculation of national requirements is centralized or left to lower levels in the distribution chain varies from country to country.[*/] In developing countries, however, the main issue is the co-ordination of national supply. For this purpose, some centralized authority may be required for the development of a marketing system that can accommodate planned production and still ensure an equitable distribution among regions, districts, and large and small farms.

In cases where supply is not sufficient, the government may allocate fertilizer in accordance with various criteria such as the following:

(a) When the food supply is critically short, priority may be given to the country's staples (which may include non-cash crops). Among these, the policy may favour those crops or varieties that respond most to fertilizer. Alternatively, policy may favour crops that provide the best balance of nutrients;

(b) Allocation may aim at achieving equitable distribution among provinces or districts, or among individual farmers in order to ameliorate the existing distribution of income or, perhaps, to reduce the rural-to-urban rate of migration by raising farm incomes;

(c) Allocation may favour crops that are largely intended for export and will have a favourable effect on foreign exchange. Such an approach might not be feasible, however, if food production for domestic purposes is jeopardized or if the country is already dependent on food imports.

Any system of allocation has its drawbacks. However, the unrestrained operation of market forces may seriously jeopardize agricultural development through a highly inequitable allocation of fertilizer inputs. Careful study of the allocation effects of specific policies and the over-all distribution programme are required.

[*/] A distinction should be made between studies estimating fertilizer requirements and demand estimates. Demand estimates are not likely to reflect a region's optimum requirements since: they can be biased due to the relative importance of high-income farms whereas estimated requirements are based on acreage, crop types etc., and are not influenced by the ability to buy.

(iv) Quality control

It is a function of government to draw up and enforce regulations relating to the quality of fertilizers. Enforcement of such regulations usually involves a system of inspection by government agents, at the manufacturing facility, in the distribution channels, or on the farm. Obviously, the closer to the farm the inspection, the less the opportunity for adulteration. The inspection may consist of checking the weight and taking samples for chemical analysis and determination of physical properties. A prescribed "tolerance" is usually permitted for deviation from guaranteed analysis, which allows for probable minor errors in manufacturing, mixing, or sampling.

Deficiencies in weight or analysis are penalized by a system of fines and/or payment of damages. The manufacturer, mixer, or distributor may be penalized for repeated violations by having his licence revoked. Criminal penalties may be imposed when there is clear evidence of intent to defraud.

Government regulations should not be so restrictive as to impose unnecessary hardship or expense on the manufacturer, or to prevent farmers from taking advantage of low-cost materials. For instance, a regulation that only water-soluble P_2O_5 can be claimed in a phosphate fertilizer may be unnecessarily restrictive and is seldom justified by agronomic data. A similar situation applies to water-insoluble nitrogen derived from either natural or synthetic sources. Such materials often are sold at a premium price because of their slow-release quality, which makes them more effective fertilizers in some situations. However, the nitrogen in some organic compounds is so slowly soluble as to be nearly worthless as a fertilizer.

In summary, government regulation of fertilizer quality should protect farmers against fraudulent practices and inferior products and provide necessary information about the quantity and quality of nutrient content. It should be flexible enough to permit the sale of low-cost materials or by-products while providing adequate information about their value.

5.4.1.1.4 Government policies to expand fertilizer usage

Fertilizer use is determined primarily by fertilizer and agricultural product prices, the fertilizer response, and the presence or absence of constraints to its use, such as lack of knowledge, risk and uncertainty, lack of credit and limited availability. Successful government policy aimed at encouraging use must either provide the farmer with an economic incentive or remove or reduce the effect of existing constraints to obtaining potential economic benefits from expanding use.

Normally, economic incentives take the form of a reduction in fertilizer prices to the farmer, an increase in agricultural product prices or an increase in the agronomic response to fertilizer through better balance of nutrients, better timing or placement of application, and other inputs (water supply, improved varieties etc.).

The appropriate policy approach to increased fertilizer use depends, to some extent, upon the degree to which the farming community has already adopted commercial fertilizers. Farmer awareness is the most significant consideration in the early stages. Prices, even if kept at reasonable levels, can seem prohibitive to farmers lacking experience in the use of commercial fertilizers and knowledge of their effect on yields*/. Once general acceptance is achieved, however, credit becomes a useful policy tool.

(i) Reducing fertilizer prices to the farmer

Lower fertilizer prices would normally increase fertilizer usage unless the presence of certain constraints prohibit such an increase. Although fertilizer price elasticity estimates are subject to considerable uncertainties due to incomplete and/or inaccurate data, it appears that it ranges between 0.5 to 1.0 in the short term and between 1.0 to 2.0 in the long term. Government policies aimed at increasing the efficiency in fertilizer production and marketing should make decrease in fertilizer prices at farm level possible, which in turn reverts in incremental fertilizer usage and agricultural output. This fertilizer price reduction at farm level may be achieved through: direct price subsidies paid directly to farmers, to the distribution outlets and/or to fertilizer producers; indirect subsidies through several ways such as preferential interest rates for credits to farmers, tax concessions, preferential freight rates; and price differentiation schemes.

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*/ The price elasticity of fertilizer has been found to be relatively low during the introductory period. Only after acceptance has been achieved does it rise.

(ii) Increasing agricultural product prices

Agricultural price support policies are common in developing and developed countries. While some aim at price stabilization (discussed further below), others focus on raising agricultural product prices above free market prices in order to stimulate production. Increases in product prices make it profitable for the farmer to expand fertilizer use, but could be inflationary and run counter to other development objectives.

Many developing countries are faced with severe nutritional deficiencies, due mainly to lack of purchasing power. In others, even where malnutrition is not a major problem, food accounts for a large portion of the family income. The level of food prices is therefore of extreme importance in the development process of these countries. In such circumstances, policies to increase agricultural produce prices may not be in the best interest of the country - if the price increase is to be passed on to the consumer, as is usually the case.

(iii) Increasing agronomic response

The agronomic response to fertilizer depends on a number of factors, including: soil characteristics; climatic variables such as rainfall pattern; irrigation; plant variety; disease and insect attacks; type and nutrient balance of fertilizer; and timeliness and form of application. Government policy aimed at increasing the response may focus on (a) research to improve fertilizer materials and application methods; (b) research to modify the factors mentioned above; and (c) extension work to assist farmers in applying current knowledge, materials and methods aimed at improving fertilizer efficiency. Only research to improve fertilizer materials and application methods (a) is discussed here; (b) and (c) are discussed later.

(iv) Removing constraints to fertilizer use

In addition to high fertilizer and crop prices and poor agronomic response, fertilizer use is affected by a number of constraints that may reduce profitability or dissuade the farmer. Constraints commonly encountered in developing countries include: unavailability of fertilizer where and when needed; lack of knowledge; risk and uncertainty; lack of credit; insecurity of land tenure; and lack of complementary inputs.

(a) Unavailability. Failure to deliver the proper type of fertilizer at the time and place required is a significant impediment to expanded use. Activities aimed at increased fertilizer demand (e.g., price and credit subsidies) must be backed up by guarantees that sufficient supplies will be available. This element is frequently overlooked, resulting in fertilizer scarcities, black market operations, and reduced effectiveness in fertilizer promotion activities.

(b) Lack of knowledge

Farmers and extension workers are often inadequately informed about the kind and quantity of fertilizer to use and how and when to use it. Policy support for agronomic research is needed in order to generate the type of information farmers need regarding appropriate type of fertilizer, optimim quantities and timing, placement, etc. under various climatic, environmental, economic, and soil conditions. The results of such research should be disseminated through close collaboration between farmers and extension agents. In addition, the economic returns to be expected from increased fertilizer use should be clearly demonstrated. To facilitate on-farm trials and demonstrations, small quantities of fertilizer, at subsidised prices, should be made available to farmers not currently using it, along with information regarding its use.

(c) Risk and uncertainty. The major natural or environmental hazards are rainfall, disease and insect attacks. Government policy aimed at improving irrigation, at developing and/or diffusing resistant varieties, at making pesticides available, and at improving crop management practices in general may have considerable impact on reducing risks and uncertainties resulting from such hazards.

While fertilizer price fluctuations may reduce the quantities used, they do not contribute greatly to risk because the farmer in most cases knows the actual price before purchasing and can react accordingly. Price fluctuations in agricultural products, on the other hand, introduce considerable risk and uncertainty. The economic optimum quantity of fertilizer varies according to the price of the agricultural product. Farmers faced with large product price fluctuations will tend to limit fertilizer use to levels that are approximately optimum at relatively low product prices. Thus, price stabilization programmes for agricultural produce can have a beneficial effect on fertilizer use.

(d) Lack of credit. This factor can be a considerable constraint to fertilizer use and it is particularly important that it be rectified at the early stages of a fertilizer acceptance programme. Assuming that supplies of fertilizer are efficiently distributed, numerous credit system outlets at the local level will encourage fertilizer use as a continuous practice. Credit is of special significance to the small farmer with extremely limited working capital and borrowing ability. Policy alternatives, however, do not have to be restricted to commercial lending channels; financing mechanisms employing a credit-in-kind scheme for distribution of the fertilizer (along with other inputs, such as seed) can be introduced.

Government policy oriented toward providing guarantees to financial institutions and limiting the consequences to the farmer of crop failures is needed in many countries. Government-supported crop and credit insurance programmes should also be effective.

(e) Insecurity of land tenure. When the same person or family owns the crop as well as the land on which it is produced, fertilizer use tends to be greater than when land and crop are separately owned. Tenant farmers often pay for all inputs, including fertilizer, but deliver a proportion of the crop to the landlord. Therefore, the tenants gains only a part of the return on his fertilizer investment. In such cases, the economically optimum quantity of fertilizer used is smaller for tenant farmers than for landowners. Output sharing between tenants and landlords should result in increased fertilizer use and agricultural output. Land reform policies oriented towards a shift from tenancy to ownership by the farmer, or at least towards promoting cost sharing between tenant and owner, would encourage fertilizer use.

The benefits of fertilizer use usually extend beyond one cropping season, but short-term tenancy arrangements and consequent uncertainty as to who will be the beneficiary of further fertilizer application.

(f) Lack of complementary inputs. The importance of proper irrigation and the use of pesticides, herbicides, and other production and management inputs to the reduction of risk and uncertainty was mentioned before. These factors are also important determinants of total fertilizer response. Varietal improvement is probably even more important, however; fertilizer response is far greater among improved rice and wheat varieties than among traditional ones. While increased response is a genetic characteristic (related to dwarf varieties and corresponding reduction to lodging), the farm-level response of traditional varieties may be further increased if they are made more resistent to certain diseases and insects. Government policy aimed at: promoting research on varietal improvement; testing and modifying improved materials from international and national agricultural research; and diffusion of improved materials to farmers, are likely to be effective in expanding fertilizer use and agricultural production. The distribution of these complementary inputs, like the distribution of fertilizer itself, is often geared to the needs only of the large farmers. Policy efforts should endeavour to ensure that the benefits of such research are available to small farmers as well.

(v) Subsidies

The practice of providing subsidies to encourage the production or use of fertilizer is a widespread one. The objectives of subsidy programmes are often related to the theme of the preceding section, "Measures aimed at increasing use". In developing countries, fertilizer subsidies may take many forms. In some, they may be regarded as a government obligation and become a semi-permanent feature of government policy. There is the danger, however, that, once instituted, the practice may be prolonged beyond the period when the initial objectives have been realized. On the other hand, there is a good reason to believe that subsidies can be an effective means of achieving development objectives when properly monitored and implemented. In view of the complexity of various subsidy programmes and the diversity of approaches to them, the subject is treated separately, and in considerable detail, in the Annex I to this chapter.

5.4.1.1.5 Investment and human resources policies

(i) Investment policies

It is estimated that fertilizer production objectives for the end of the century will require capital investment in major nitrogen plants of over US$ 40 billion over the period 1982-2000. If the developing countries are to become net exporters, however, capital costs will exceed this figure. Additional investment will be required for phosphate production, mining and beneficiation of raw materials and potash salts, in distribution and transport facilities and in infrastructure. Clearly, therefore, the total investment requirements will exceed $ 40 billion by a substantial amount.

New forms and mechanisms for investment will be required to channel such a large amount of capital into the development of the fertilizer sector and to ensure that over-all development objectives (e.g. minimal rates of inflation or sovereignty over natural resources) are not jeopardized in the process. Loans and grants have played a prominent role in financing the development of fertilizer plants in the past. At times,

TABLE 29

Representative Crop Yield Increases and Financial Returns from Fertilizer Use on Six Field Crops in Eight Developing Countries

Crop	Country and Season(s)		Fertilizer Applied	Average Crop Yield Increase (1)			Financial Returns (2)
				per hectare		per kg $N+P_2O_5+K_2O$	
			(kg/ha $N+P_2O_5+K_2O$)	(kg)	(percent)	(kg)	(percent)
Cotton (seed yield)	Iran		90	1,278	11	14,2	570
	Turkey	1962-66	240	797	47	9.0	270
Groundnuts	Ghana	1961-65	22,4	352	33	15.7	820
	Senegal	1964-66	45	403	39	8.9	320
Maize	El Salvador	1962-65	90	973	38	10.8	370
Millet	Senegal	1962-66	42	237	40	5.6	290
Rice (paddy)	Bangladesh	1971	100	-	124	11.6	1,160 (3)
	Ghana	1963-65 major seasons	22.4	659	43	29.4	950
	Iran		120	1.000	-	8.3	1.750
	Philippines	1973-74	30	319-489 (4)	9-12 (4)	10.6 - 16.3 (4)	220-330 (4)
	Senegal	1961-66	45	333	30	7.4	290
Wheat, unirrigated	Iran		30	300	-	10.0	560
	Morocco	1964-65	60	721	72	12.0	450
	Turkey	1962-66	60	536	58	8.9	250
Wheat, irrigated	Iran		120	800	-	6.7	350
	Turkey	1964-65	60	1.056	77	17.6	520

(1) Yield increase over unfertilized crop grown under similar condition

(2) Value of crop yield increase expressed as a percent of cost of fertilizer to farmer

(3) Financial returns based on subsidized fertilizer costs and market price for rice in 1974

(4) Variation is due to regional differences in field trials

Source: Fertilizer subsidies - alternative policies FAO - F I A C - 1976 pag.36

these have been on concessional terms for interest rates or repayment schedules. Often, however, their total cost has been considerable, and it is unlikely that this source will be adequate to provide funds of the magnitude mentioned above.

Investment capital falls into two general types: loans (bonds or debentures) that pay a fixed rate of return, and equity capital in which the rate of return depends on the profitability of the enterprise. The investor may not necessarily expect to receive his return directly in the form of cash. For instance, farmers, co-operatives, and plantation owners may invest to ensure a supply of fertilizer at a reasonable price. Their return may consist of a system of rebates or discounts on fertilizer used. Foreign organizations or governments may invest for the same reason. Raw material suppliers may invest to ensure a profitable market for their product (natural gas, phosphate rock, sulphuric acid, etc.).

(ii) Investment incentives through tax laws or concessions

The adjustment of tax laws is a common method of attracting investment to priority sectors. Such practices, however, call for continuous scrutiny and should be subject to certain qualifications. The following is a short list of policies frequently used to attract investment:

(a) Partial or complete exemption from industrial income tax levied on interest on bonds and debentures, or on dividends from fertilizer manufacturing operations;

(b) Tax holidays that permit new plants to operate for a specified number of years without paying property or income tax;

(c) Depletion allowances for organizations that own and use indigenous raw materials. (In theory, this allowance compensates the company for the diminishing of its raw material resources and encourages exploration for new resources);

(d) Development rebates based on the contribution to the national economy, or on the development of natural resources;

(e) Exemption from severance or excise taxes on raw materials used;

(f) Exemption from import duties on plant equipment, raw materials, spare parts and supplies;

(g) Exemptions from export taxes on fertilisers to make the products competitive on the world market. (Encouraging export of production in excess of domestic needs to keep plants operating at a high percentage of capacity and thereby lowering production costs); and

(h) Generous depreciation rates for tax purposes.

Such policies offer investors the prospect of relatively rapid recovery of their investment. Careful consideration should be given to their effect on the national economy, however, before implementing them.

In the fertilizer sector, foreign investment, and the role of transnational corporations, in particular, has been steadily increasing. The objectives of these corporations may not always be consistent with national strategies and policies. In the case of the developing countries, however, the consequences can be particularly serious in view of the relatively weak position of these countries vis-a-vis the transnational corporations.

Co-operation in harmonizing national policies on foreign investment could serve to improve the negotiating position of the developing countries. Yet, despite the difficulties that these countries encounter in their relations with the transnationals, they continue to compete to attract them. One type of competition practised is to offer a variety of concessions, such as those listed above. Only in rare cases, however, do these concessions raise the total flow of foreign investment into the developing country. The flow may be increased, for example, where transnational firms are under pressure to find new, cheap ways of processing goods for re-export. However, there are many instances where costs are less critical.

Examples include import-substitution industries and industries producing for export to oligopolistic markets. In such cases, the total flow of investment into the developing countries is not likely to be affected by competition among them. But, the distribution of investment among these countries may be substantially altered by the granting of concessions to the foreign investors. A country that fails to offer benefits to match those offered by other countries in the region risks losing its share of the foreign investment. Returns to the developing country from foreign investment can be considerably reduced through excessive competition of this sort. As mentioned above, however, the situation may be alleviated by co-operation among the developing countries affected. The problem is essentially a regional or sub-regional one that could be addressed by groups of developing countries. Such groups might endeavour to determine if their efforts to attract foreign investment in fertilizer tend to cancel one another. This could be one component in a larger regional or sub-regional approach to the development of the industry.

Developing countries might attempt to reach agreement, perhaps initially on a regional basis, on such matters as the maximum length of tax holidays, the extent of corporation income tax incentives, limits to accelerated depreciation, and the level and scope of investment credits.

(ii) Industrial employment and training

The development of a work force consistent with the planned growth in production capacity of an industrial sector requires policy action in much the same way as demand, investment and supply in that sector. Some policies and procedures that would be appropriate to the fertilizer industry are:

(a) The co-ordination of employment plans with the industry's short- and long-term objectives; and

(b) The development and implementation of training programmes that will ensure continuous and competent manning.

Specific features of the above might include:

- Management and supervisory training programmes;
- Extension programmes for dealer and farmer education;
- Training programmes for technicians, plant operators, and maintenance personnel;
- Marketing programmes, including distribution promotion, and sales, when and if appropriate;
- Definite commitments to and from foreign organizations that allow them to plan work force development programmes without the fear of their being terminated in mid-programme. (This will avoid high built-in costs to prevent losses and guarantee a trained work force);

(c) The development of personnel policies and/or practices to encourage efficiency and provide incentives. Examples are:

- Position descriptions that clearly define the work to be done;
- Salary scales that assure competitive pay and fringe benefits;
- Incentive plans that are challenging and attainable, based on standards of performance that are mutually acceptable; and
- Communication to the work force of alternative paths for advancement.

5.4.1.2 Regional Level. The recent instability in the world fertilizer market and the growing importance of fertilizer as a strategic policy tool has generated interest in developing adequate, dependable, and low-cost fertilizer supply alternatives. Of the alternative solutions, the concept of regional complementation or economic cooperation offers opportunities for substantial gain to areas with key fertilizer raw materials and markets, as well as the necessary attitude toward regional integration.

Although there are no distinguished cases of regional cooperation in the field of the fertilizer industry, several attempts have already been made by different countries for integration and cooperation. A representative case is the ASEAN Group, which is composed of the countries of Indonesia, Malaysia, the Philippines, Singapore and Thailand.

The justification for cooperation by the ASEAN Group in the field of fertilizer has been outlined as follows: (1) indigenous supplies of key raw materials (natural gas, sulfuric acid, and potentially exploitable potash deposits); (2) nearby sources of phosphate rock (Australia, Nahru, and Christmas Island); (3) developed and growing markets capable of supporting efficient plant sizes; and (4) the required disposition towards cooperation as demonstrated by the ASEAN charter itself. This investigation was made to demonstrate the potential benefits that could accrue to the region through a regionally harmonized fertilizer capacity expansion policy.

To accomplish this task a mathematical programming model was employed to determine the investment, production, importation, and transportation patterns that minimize the cost of meeting the ASEAN 1985 fertilizer requirements. This involved the selection of plant sites, plant sizes, feedstocks, fertilizer intermediates and end-products, and most appropriate transportation patterns under varying degrees of regional economic cooperation and integration.

This preliminary analysis indicated there are significant economic benefits to be derived from a regionally harmonized capacity expansion policy. The benefits can be obtained from efficient utilization of the region's relatively low-cost by-product sulfuric acid and abundant natural gas supplies, capitalization on the physical geography of the region, and the economic integration of markets which permits exploitation of the economies of size that exist in fertilizer production. For example, full regional cooperation as compared with severely resticted cooperation "saves" $180 million in total initial investment and another $117 million in annual operation cost. Though full regional cooperation minimizes total cost, substantial gains can still be made with limits placed on the degree of cooperation in order that certain national objectives can be met. For example, instead of full regional cooperation, the members of the ASEAN Group may agree that each country should be 75% self-sufficient in nitrogen, but open to free trade for the remaining market share. To do so would "cost" an additional $71 million in total initial investment and $10 million in annual operating costs as compared with full regional cooperation. This arrangement would still save $112 million in initial investment and $8 million in annual operating costs over the severely restricted trade case. It should be noted that in all cases the relaxation of trade restrictions in order to achieve the economies of a more efficient organization and allocation of ASEAN resources increases the dependence on the transportation system.

The results indicate that the optimal product mix for the region is centered about urea and monoammonium phosphate (MAP). (The dominance of MAP over diammonium phosphate [DAP] is marginal and may change when technical coefficients are refined through more detailed study.) Additional production cost analyses confirm the plausibility of these results and support the study results which indicate that the advantage of Indonesia in ammonia and urea production and of the Philippines in phosphate production **may** dominate rational regional industry adjustments to the anticipated 1985 supply-demand situation.

5.4.2 Environmental problems in the fertilizer industry

This presentation is designed to give an overview of environmental problems in the fertilizer industry and their effective management. An environmental impact evaluation procedure raises the key environmental issues that should be dealt with in the initial stages of planning a new fertilizer plant. Pollution regulations and the importance of maintaining pollution control standards are discussed. Air and water pollution problems are summarized and some costs of pollution abatement are given.

In general, pollution control measures taken by the fertilizer industry should aim to:

(1) protect the health and welfare of employees in the plant by controlling in-plant atmospheric quality and minimizing contact with toxic substance;

(2) prevent damage to crops, animals and people, from atmospheric pollution;

(3) preserve the quality of rivers, lakes and other bodies of water so that fishing and other industries and people who use the water will not be adversely affected.

5.4.2.1

Evaluating the environmental impact of a new fertilizer plant

An environmental impact evaluation procedure should form part of the planning procedure for any new fertilizer plant. The purposes of evaluating environmental impact are two-fold:

(1) To prevent the deterioration of natural resources, such as the river which is to receive plant waste waters, so that these resources can continue to provide a basis for further economic development; and

(2) To give ample warning of deleterious side-effects of the project, which may result in economic or social costs not normally identified in the project review procedure.

The environmental impact procedure sets out a series of analytical steps applicable to environmental problems that may occur during the raw materials phase right through to the final disposal of materials produced. The definitions of these steps are:

1. Raw materials linkage: Environmental considerations beginning with extraction or arrival in country to project under evaluation;
2. Site assimilative capacity: Present or baseline analysis of air, land and water carrying capacity to determine original conditions and effects of the project;
3. Project design and construction: Analysis of alternative possibilities for unit operations and energy sources;
4. Operations: Maintenance of project and monitoring (analysis of outputs, including byproducts and wastes for treatment and re-use; monitoring waste discharges);
5. Social aspects: Social implications of project;
6. Health aspects: Safety and welfare of the work force and the population affected by plant;
7. Place of ultimate deposit: Recycling, re-use or disposal of wastes;

8. Long-term considerations: Plant expansions;

9. Optimization: Cost analysis of alternatives.

The environmental impact guidelines include a broad array of concerns. They are designed to assess costs that would result if the project were to impair the future productivity of a country's natural resource base or result in other adverse side effects of investments. The evaluation of the impact of a new plant on the environment requires a systematic and integrated view focusing on materials flow within production processes and outside the plant.

Proceeding through the nine steps from the raw materials linkage to optimization calls attention to the interrelationship between the choice of process and recycling and/or re-use potential, between plant location and urbanization issues, between waste management and process design. These conditions are an effort to impress upon the project manager the need to design an integrated project which is sensitive to environmental needs.

5.4.2.2
Pollution regulations

In recent years, more and more countries have expanded or adopted new environmental legislation. Governments have created official bodies which are responsible for the elaboration of new legislation and its application and enforcement. As a guide to present practice, a comprehensive listing of air quality and pollutant emission standards from a number of countries, including Japan, USSR, the United States, and several European countries, are to be found in a recent World Bank publication */, which also refers to criteria for maximum concentrations of various water pollutants in public waterways.

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*/ Environmental, Health and Human Ecologic Considerations in Economic Development Projects -

A problem specific to the developing countries when endeavouring to protect the environment through regulations is a lack of experience. Never previously having had to face environmental problems due to industrial pollution, a large number of the developing countries have no specific regulations at hand. Such regulations are, however, indispensable to the contractor for the design of pollution control systems and should be in effect at the time the tender documents are sent out. It is recommended therefore that the ministries concerned, such as those of industry, health or development, should draw up the relevant regulations, referring as necessary to the experience of other countries cited in the previous paragraph.

5.4.2.3
Air pollution

Air pollutants emitted by the fertilizer industry include the following:

(1) Effluents from the combustion of fossil fuels
(2) Ammonia
(3) Nitrogen oxides
(4) Sulphur dioxide
(5) Fluorides
(6) Mists and particulates

The following are commonly used means of reducing air pollution in the fertilizer industry:

(1) Process changes
(2) Catalytic converters
(3) Molecular sieves
(4) Scrubbers
(5) Condensers
(6) Absorbers
(7) Bag filters (for particulate control)
(8) Cyclones (for particulate control)
(9) Electrostatic precipitators (for particulate control)

Ammonia

Exhaust gases containing ammonia are normally scrubbed. The resulting liquid effluent can be often profitably recycled in the process. However, it is often discharged to plant sewers. Discharges of gaseous ammonia are usually the result of faulty equipment or a spill. High concentrations of ammonia irritate the mucous membranes of the body.

Nitrogen oxides

Nitrogen oxides (NO, NO_2, N_2O_4) are discharged from nitric acid plants which use ammonium oxidation and ammonium nitrate and NPK plants which used the nitrophosphate process.

Nitrogen oxides can produce photo-chemical smog and can cause irritation to the respiratory tract. A one-hour exposure to 1 mg/m^3 can cause damage to certain vegetation. The emission standard in France is 3.3 kgs of NO_2 allowable emission per ton of 100% nitric acid. The American standard allows only about half that quantity.

Sulphur dioxide

Sulphur dioxide and trioxide and acid mists are emitted from sulphuric acid plants associated with the manufacture of phosphoric acid. Sulphuric acid mists from absorption tower stacks can be eliminated using fibre mist and Brink eliminators, as well as electrostatic precipitators. Double catalytic conversion coupled with double absorption systems reduce sulphur dioxide emissions. Alkaline scrubbing can also be used to remove sulphur dioxide from tail gases.

The emission standards for sulphuric acid plants in the Federal Republic of Germany call for a SO_2 conversion efficiency of greater than 99.5% and no more than 0.5 kg of SO_3 released per ton of product.

representative cases for about ten developing countries where the ratio has ranged from 2.5 : 1 to 17 : 1. In India, for instance, a ratio between 1.9 : 1 and 2.5 : 1 is considered satisfactory. The benefit-cost ratio can be improved either by lowering fertilizer costs to farmers and/or increasing crop income. The latter is a sensitive point since crop prices are growing much slower than prices of industrial commodities, therefore crop yield increases must bear the biggest proportion in obtaining incremental crop incomes. However, increased fertilizer use is no substitute for unsound agronomic practices where lack of attention will adversely affect crop yields and diminish fertilizer efficiency.

The cost of fertilizers to farmers has three main components: factory selling price, total distribution costs and fertilizer application costs. The first two form the fertilizer retail price. Table 30 presents representative distribution costs for 7 Far East countries. It shows that distribution costs vary from 22 $/ton to 89 $/ton of urea, which represent between 21 and 45 per cent of retail price, with an average of 35 per cent of retail price. This means that fertilizer distribution costs represent, for the countries studies, about half the factory selling price.

Figure 4 shows the major types of fertilizer marketing systems according to the degree of participation of the various sectors of activity. Table 31 presents the estimated market share of private, co-operative and state fertilizer marketing companies in 29 countries, 17 of them developing countries. Basically a fertilizer marketing system comprises four main functions: extension services, physical distribution, financial services and selling.

(i) The extension services are advisory-collaboration activities with farmers, aiming at advising them and demonstrating on the practical application of the more suitable agronomic practices, crops and crop inputs (such as fertilizers, pesticides etc.) for their particular situations and problems. In practically all developing countries these are mainly government provided services belonging to their ministries of agriculture.

(ii) Physical distribution involves the transport, storage and handling of fertilizers from the source to the farmer. The way in which fertilizers are distributed depends on several factors such as: seasonal application of fertilizers; avoidance of fertilizer degrading during transport, handling and storage; production of suitable fertilizer grades and formulations to facilitate their farm application and increase their nutritional efficiency to crops; the peculiarities of the geographical area where fertilizers are

Gaseous fluorides

Fluorides are released during the processing of fluoride-containing phosphate rock to produce phosphoric acid. Cattle are known to be affected by fluoride concentrations of more than 30 mg/m^3. Fluoride concentrations as low as 0.015-0.04 mg/m^3 will damage gladioli, pine and fruit trees.

Fluoride emissions can be eliminated by use of wet scrubbing equipment. Sometimes fluorosilicic acids can be recovered and sold.

Mists, fumes and dust

The fumes and dusts emitted from prilling towers for ammonium nitrate and urea have presented a major problem in the past. Modern pollution control technology incorporates a dust collection system with a Brink filter. New processing technology has been developed to produce a product by granulation rather than the prilling tower. This process presents less difficulty in controlling fumes and dust. Wet scrubbers or bag filters are adequate.

Fertilizer plants producing mixed NPK, monoammonium phosphate or diammonium phosphate fertilizers generally produce gaseous effluents which contain particulate matter mixed with the vent gases from the reactors. High efficiency cyclones and bag filters are both used for dust control.

Process fumes from ammonium nitrate plants are normally scrubbed in wet scrubbers.

5.4.2.4

Water pollution

The fertilizer industry is a large consumer of water. The gross water usage of the fertilizer industry in the United States, for example, exceeded one trillion gallons in 1970. The recycling of water is widely practiced by the fertilizer industry. In the United States, 75% - 80% of the gross water requirements were supplied by recycled water. The tendency for water recycling should increase in the future. About 70% - 80% of all water used by the fertilizer industry is for cooling purposes.

Waste water discharges from a fertilizer plant can be categorized into four general types. These are:

(1) Cooling water;
(2) Steam condensate;
(3) Sanitary wastes;
(4) Process effluents.

The category of process effluents can be further subdivided into five general classes:

(a) By-product streams;
(b) Scrubber solutions;
(c) Process spills;
(d) Equipment washing solutions;
(e) Barometric condenser water.

Inorganic substances constitute the major pollution problem encountered in fertilizer plant waste water. Conventional water pollution parameters such as BOD*, COD*, and coliform bacteria count are relatively unimportant because of the low organic materials content of most fertilizer plant waste waters. Principal pollutants generally found in fertilizer plant waste waters are nitrogen sources (such as ammonia and nitrate ion), phosphates, and lesser amounts of toxic material (such as fluoride and chromate ions). Thermal pollution is also a problem which sometimes occurs. Lubricating oils are the only major organic pollutants. Other pollutants which occasionally occur are urea, monoethanolamine and organic biocides. Overall, nitrogen sources represent the main pollutants in nitrogen fertilizer plant waste waters. Phosphate and fluoride ions are the major contaminants in phosphate fertilizer plant waste waters.

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* Biochemical oxygen demand and
Chemical oxygen demand

is carried out to control the build up of dissolved solids. It is this blow down stream which is contaminated with the dissolved solids, chemical additives and materials which may have leaked from process equipment.

Process effluents

Waste waters containing process effluents account for only about 20% - 25% of the waste waters generated by the fertilizer industry but contain the majority of the wastes. All fertilizer processes generate one or more of the following five general classes of waste waters:

(a) By-product streams

The number of aqueous by-product waste streams generated by the various processes in the fertilizer industry are relatively few. These are usually large in volume and highly contaminated. A typical example is the large volume of gypsum slurry which results from wet process phosphoric acid production.

(b) Scrubber solutions

The concentrations of pollutants in the aqueous waste streams from scrubbing operations can vary over wide ranges. In some cases, the scrubbing solution is used on a once-through basis and the concentration of pollutants is relatively low. In other cases, the scrubbing solution is recycled and the concentrations of pollutants can accumulate to high levels. An example of scrubber solution wastes in the fertilizer industry is the solution used to scrub fluoride-containing gaseous effluents from the phosphate rock reactors.

(c) Process spills

In most large, efficiently run fertilizer processing plants, spills account for less than 1% of the waste load. In small plants, however, spills can account for a substantial portion of the total plant waste load.

Most nitrogen fertilizer plants currently rely on dilution as a disposal method for plant waste waters. Treatment of these waste waters is usually restricted to the use of separators for oil removal and settling ponds for solids removal and cooling. Cooling water blow-down is often treated to remove chromate ions using sulphur dioxide and lime. Ammonia removal by stripping is practiced in some plants. Experimental studies have evaluated the use of ion exchange to remove ammonia and nitrate from nitrogen fertilizer plant waste waters.

Phosphoric acid and phosphate fertilizer plant waste waters normally require treatment in order to remove fluoride and phosphate ions. All contaminated waste waters normally discharge to the gypsum pond when one has been prepared. The pond water discharge is then treated by lime neutralization in order to reduce the fluoride and phosphate ion concentration to acceptable levels. As an alternative to gypsum pond disposal, fluoride is sometimes recovered to produce a saleable by-product.

Waste stream volumes for a given product can vary widely between different fertilizer plants due to different extents of water recycle, minor process variations, and operating philosophies.

Cooling water

The major portion of the water used by the fertilizer industry is for cooling purposes. This water is ordinarily relatively low in contaminants and is usually kept separate from other more concentrated waste water streams. In the wet process for phosphoric acid manufacture, however, cooling water is frequently passed into the gypsum pond. Standard practice is to pass the water through cooling towers or ponds and then recycle it. Principle contaminants in the cooling water come from leaks in equipment, build up of dissolved solids from the feed water and chemicals added to control biological growth, scale, and corrosion. Blow down of the cooling water system

(d) Equipment washing solutions

Equipment cleaning operations produce an aqueous washing solution contaminated with the various materials from the processing operation. In bulk blending and liquid mix plants, a variety of fertilizer formulations are produced in the same equipment. Clean up operations produce a major portion of the waste water loadings for these plants.

(e) Barometric condenser water

Operations such as evaporation, drying, or process reactions can generate condensible gas streams, principally water vapor. Volatile contaminants are frequently present. When the condenser water is recycled, contaminants can build up to substantial levels.

5.4.2.5

Control and treatment of waste waters

Methods used for treating waste waters in the fertilizer industry do not include those biological treatment methods which are so widely used in treating other industrial and municipal wastes. Since the fertilizer industry waste waters are primarily inorganic materials, biological treatment methods are ineffective.

The segregation of the various waste water streams within a plant is a common pollution control technique. Relatively uncontaminated waste waters are usually kept separate from more contaminated streams. Examples are once-through cooling water and clean rain water run-off.

Disposal methods for untreated or partially treated waste waters include:

(a) Dilution

Disposal of concentrated waste water streams by simple dilution is a wide practice in the fertilizer industry. However, as more countries adopt water quality regulations and effluent standards particularly regarding discharge of nutrients, this form of disposal will become unacceptable.

(b) Ocean disposal

Ocean disposal is utilized often by fertilizer companies located on coast lines. This procedure is also becoming less acceptable as pollution control criteria are adopted.

(c) Discharge to municipal sewage systems

Fertilizer plants with small waste loads sometimes discharge waste waters into municipal sewage systems. One example would be a small liquid mix plant which might discharge equipment washdown waters and spill clean ups into the local sewage system.

Cost of pollution control

Cost estimates for reducing SO_2 emissions by 70% from an ammonium plant in Sweden using fuel oil with a sulphur content of 2.5% are $ 10* per ton of NH_3.

Air pollution control for a nitric acid plant in Sweden has been estimated to cost in a range of $ 1.25 - $ 6.93 per ton of product.

In the manufacture of sulphuric acid, sulphur dioxide emissions can be reduced by using the double contact process. The additional cost of building a 1,000 ton per day plant compared with a single contact process plant in Finland was $ 1.3 million. Increased production costs are $ 0.84 per ton of sulphuric acid. The increased production cost is partly offset by a 1.5% decrease in sulphur usage.

In the case of controlling water-borne discharge from an ammonium plant, experience in the United States has shown that additional production costs in the range of $ 0.6 - $ 1.8 per ton of product are estimated for condensate steam stripping.

For the manufacture of phosphoric acid at a modern fertilizer complex in Finland with water recirculation, the total cost of complete fluoride removal is $ 4.34 per ton of P_2O_5 produced. Also the cost of transport of gypsum for 2 kilometers amounts to $ 4.56 per ton of P_2O_5.

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* All costs are given in terms of 1974 US $ unless otherwise stated.
Source: Emission Control Costs in the Fertilizer Industry, OECD, Paris, 1977.

The condensate from ammonium nitrate synthesis for a Swedish plant is treated by ion exchange at a cost of $ 1.39 per ton of product.

At an NPK plant in Finland, the recirculation system for scrubber solutions costs about $ 2.15 per ton of product. Fertilizer dust recovery in the bag filters gives a credit of about $ 0.50 per ton of product to offset the pollution control cost.

A plant survey conducted in the United States in 1971 showed that costs for treating nitrogen fertilizer plant waste waters ranged up to $ 0.78 per ton of product. This range reflects the rather low level of treatment which these waste waters receive.

Estimated costs for pollution control in various segments of the fertilizer industry have been calculated utilizing information from the OECD publication "Emission Control Costs in the Fertilizer Industry" (Paris '77) and from the fertilizer prices contained in the "Chemical Economics Handbook". All cost data utilized were from 1974. The pollution control cost data were from plants located in the United States, Sweden, Finland and the Federal Republic of Germany. Fertilizer prices were from the United States.

The pollution control level for which the control costs have been adopted is termed the best practicable control technology currently available. (BPCTA). This consists of control techniques already in use on a commercial scale, although experience may be restricted to a small number of plants. As applied to the United States, this level of control was scheduled to be adopted by the fertilizer industry by 1977.

Within the nitrogen fertilizer industry the operating costs of pollution control stated as a percentage of the sales price of the product for BPCTA is of the order of magnitude of 0.5% for ammonia, ammonium nitrate, and ammonium sulphate. For urea the figure is about 2%.

For phosphate fertilizers the costs of BPCTA pollution control, as a percentage of sales price, are of the order of 0.5% for phosphoric acid and triple super phosphate. This figure is about 2.0% for single super phosphate and about 3% for diammonium phosphate.

The cost figures are given as approximate because they are based on average fertilizer selling prices in 1974. Fertilizer prices fluctuated substantially during 1974 and were considerably higher that year than either 1973 or 1975. Thus, the pollution control cost estimates presented above reflect a high rather than a low estimate of costs.

VI. CONCLUSIONS AND RECOMMENDATIONS

The main conclusions and recommendations to be drawn from the study are the following:

1. The objective of regional self-supply has two main drawbacks:

(i) It substantially modifies current trends that shift intermediate fertilizer production to countries producing raw materials, without any commitment from the parties concerned to redress this shift, and obstructs capacity development which otherwise might take place. This affects developed and developing countries alike, although for different nutrients.

(ii) It poses a great imbalance in additional plant building programmes that will therefore not likely be implemented. For instance, the developed centrally planned economies should build 6 nitrogen and 6 phosphate complexes per year, for 18 consecutive years. So far, about 5 ammonia plants per year are scheduled, between 1973 and 1982, with heavy financial commitment and buy-back agreements. The extra burden occasioned by the urea plants and the doubling of the effort period to 18 years in 1982/2000, makes it unlikely that a similar and parallel effort could be made for phosphate. Hence the very long term agreements signed with Morocco, Tunisia, Jordan and the United States to import both phosphate rock and phosphoric acid that implicitly recognize this situation as permanent.

Conversely, the relatively recent massive infrastructural developments that are taking place in North African phosphate rock and phosphoric acid producing countries, may create, in the long run, locational advantages for the phosphate industry resembling those in the Gulf Coast of the United States. Thus they could later accommodate a larger number of plants than the 27 plants envisaged during 1982/2000.

2. The need to adequately analyze the meaning and consequences of trends and aims such as the ones described above, requires sophisticated forecasting methodologies able to accommodate a number of quantitative and qualitative variables. In this way, true independent alternatives could be appraised, not like the widespread practice of evaluating what are, in fact, branched-out variations of basically one alternative.
To undertake this task, the co-operation of all parties concerned is needed in order to present the reality as it is.

3. The study shows that developing countries need to increase their average plant operation rates, otherwise the aim for self-sufficiency, at least in nitrogen, will not be fulfilled. In fact, if developing countries could operate at an average of 80 per cent of plant capacity, they could achieve self-sufficiency by 1982/83. If not, more plants will be needed through to the year 2000 just to attain the same production targets.

4. The current conjunctural problem of fast-rising capital and production costs and slow-growing fertilizer prices is becoming ever more critical. Its outcome is uncertain and may take several possible directions, one of which is fertilizer price rises in the long run commensurate with production costs and cash flow needs to finance new plants. However, as long as there is surplus capacity, international prices will remain rather lower than domestic prices in fertilizer producing countries.

5. The requirements to attain the target figures set for the year 2000 are very many and need the firm commitment of the parties concerned plus stronger co-operation schemes to help cater to them. No country seems to be able to carry out its programmes in isolation, based on its own resources alone.

6. Since the plant requirements of developing countries between 1982 and 2000 are very large, comprising 258 complexes with a minimum of 1290 plants or 72 new plants per year for 18 years, it may be possible to negotiate with engineering companies and equipment manufacturers, for the production of scaled-down equipment that incorporates the latest technological advances designed for average operating conditions prevailing in developing countries. In this manner, plant sizes can be reduced without losing economic competitiveness, production and distribution costs are minimized, and higher plant operating rates may be obtained since smaller plants are easier to operate than large ones.

Table 30 . A comparison of distribution costs in selected Asian countries

	Afghanistan (1977)		Indonesia (1977)	Korea (1974)	Malaysia (1976)	Nepal (Dec.'75-July'76)	Sri Lanka (1975/76)	Thailand (1977)
	Urea	DAP	Urea/TSP	Urea	Urea	Urea	Urea	16-20-0
I Total Distribution Costs (TDC)	44.21	74.21	59.05	21.80	57.94	89.01	68.55	30.41
- as % of retail price	21.00	30.92	35.01	22.71	35.20	45.42	35.86	19.91
(1) Taxes	-	-	-	-	5.33	-	15.16	2.25
- as % of TDC	-	-	-	-	10.87	-	22.11	7.40
(2) Transportation costs	18.95	44.15	12.85	12.74	5.00	35.37	6.85	4.44
- as % of TDC	42.86	59.49	21.76	58.44	8.63	39.74	9.99	14.60
(3) Storage	n.a.	n.a.	1.04*	3.03	3.85	3.31	n.a.	2.37
- as % of TDC			1.76	13.90	6.64	3.72		7.79
(4) Credit (Bank's interest charge)	n.a.	n.a.	6.14	2.52	3.23	15.44	n.a.	n.a.
- as % of TDC			10.39	11.56	5.57	17.35		
(5) Losses	n.a.	n.a.	1.72	0.19	n.a.	4.62	n.a.	1.22
- as % of TDC			2.91	0.87		5.19		4.01
(6) Distributors' mark up	n.a.	n.a.	5.29	0.83	11.29	3.61	n.a.	3.39
- as % of TDC			8.96	3.80	19.48	4.05		11.14
(7) Retailers' mark up	8.42	8.42	6.02	n.a.	6.33	11.75	4.84	3.94
- as % of TDC	19.04	11.34	10.19		10.92	13.20	7.06	12.95
- as % of retail price	4.00	3.50	2.30		3.84	6.00	2.53	2.58
II. Retail Price	210.52	240.00	168.67	95.96	164.61	195.98	191.13 (112.14)**	152.71

Source: 1. ARSAP's Reports on Fertilizer Marketing, Distribution and Use, 1976 and 1977
2. The Proceedings of National Workshops on Fertilizer Marketing, a joint ESCAP/FAO project executed in 1976.
3. Country reports prepared by officials attending the ESCAP/FAO consultative meeting on Fertilizer Marketing and Promotion held in Bangkok, 24-29 October 1977.

Note: * Storage cost at district level ** Subsidized price

Annex A-1 - World production of nitrogenous fertilisers, by region
(millions of MT)

Year	DEVELOPED COUNTRIES			DEVELOPING COUNTRIES							WORLD TOTAL
	Market economies	Centrally planned economies	Total	Market economies					Asian centrally planned economies	Total	
				Africa	L.America	Near East	Far East	Total			
1950/1951	3.41	0.74	4.15	-	0.29	0.001	0.01	0.30	0.02	0.32	4.47
1955/1956	5.79	1.17	6.91	-	0.24	0.03	0.10	0.37	0.10	0.47	7.38
1960/1961	8.49	1.91	10.40	-	0.26	0.06	0.15	0.47	0.53	1.00	11.40
1965/1966	13.65	4.25	17.90	-	0.51	0.20	0.46	1.17	0.94	2.11	20.01
1966/1967	15.09	4.97	20.06	-	0.50	0.25	0.55	1.30	1.07	2.37	22.43
1967/1968	17.05	5.84	22.89	0.003	0.54	0.27	0.72	1.53	1.14	2.67	25.56
1968/1969	18.32	6.81	25.13	0.004	0.62	0.28	1.08	1.98	1.27	3.25	28.38
1969/1970	18.78	7.58	26.36	0.04	0.74	0.28	1.36	2.42	1.39	3.81	30.17
1970/1971	19.73	8.83	28.56	0.08	0.75	0.36	1.59	2.78	1.63	4.41	32.97
1971/1972	19.94	9.66	29.60	0.14	0.79	0.52	1.82	3.27	2.07	5.34	34.94
1972/1973	21.17	10.34	31.51	0.15	0.84	0.82	2.04	3.85	2.48	6.33	37.84
1973/1974	22.28	11.23	33.51	0.15	0.86	0.72	2.16	3.89	3.03	6.92	40.43
1974/1975	22.40	12.21	34.61	0.18	1.10	0.85	2.35	4.48	3.34	7.82	42.43
1975/1976	21.55	13.52	35.07	0.17	1.25	0.98	2.85	5.25	3.56	8.81	43.88
1976/1977	22.09	13.95	36.04	0.16	1.32	1.04	3.20	5.72	4.12	9.84	45.88

Source: FAO Monthly Bulletin of Statistics, Vol. 1, January and March 1978
FAO Annual Fertiliser Review, 1975, 1976

Annex A-2 - World production of phosphorous (P_2O_5) fertilizers, by region

(millions of MT)

Year	DEVELOPED COUNTRIES			DEVELOPING COUNTRIES							WORLD TOTAL
	Market economies	Centrally planned economies	Total	Market economies					Asian centrally planned economies	Total	
				Africa	L.America	Near East	Far East	Total			
1950/1951	5.45	0.60	6.05	0.04	0.06	0.01	0.01	0.12	0.01	0.13	6.18
1955/1956	6.78	1.05	7.83	0.07	0.08	0.03	0.01	0.19	0.02	0.21	8.04
1960/1961	8.16	1.55	9.71	0.11	0.13	0.04	0.06	0.34	0.12	0.46	10.17
1965/1966	11.74	2.76	14.50	0.22	0.19	0.09	0.12	0.62	0.56	1.18	15.68
1966/1967	12.59	3.03	15.62	0.29	0.21	0.09	0.18	0.77	0.64	1.41	17.03
1967/1968	13.17	3.23	16.40	0.34	0.24	0.10	0.27	0.95	0.66	1.61	18.01
1968/1969	13.11	3.52	16.63	0.39	0.28	0.13	0.37	1.17	0.69	1.86	18.49
1969/1970	13.37	3.84	17.21	0.37	0.28	0.13	0.41	1.19	0.79	1.98	19.19
1970/1971	14.05	4.37	18.42	0.35	0.37	0.17	0.44	1.33	0.93	2.26	20.68
1971/1972	14.81	4.81	19.62	0.42	0.48	0.25	0.49	1.64	1.11	2.75	22.37
1972/1973	15.57	5.07	20.64	0.47	0.61	0.35	0.56	1.99	1.18	3.17	23.81
1973/1974	16.29	5.20	21.49	0.53	0.71	0.33	0.55	2.12	1.26	3.38	24.87
1974/1975	15.95	5.89	21.84	0.49	0.76	0.53	0.58	2.36	1.50	3.86	25.70
1975/1976	14.17	6.73	20.90	0.41	0.82	0.57	0.61	2.41	1.46	3.87	24.77
1976/1977	15.61	7.09	22.70	0.43	1.16	0.59	0.78	2.96	1.63	4.59	27.29

Source: FAO Monthly Bulletin of Statistics, Vol. 1, January and March 1978
FAO Annual Fertilizer Review, 1975, 1976.

Annex A-3 - **World production of potash (K_2O) fertilisers, by region**

(millions of MT)

Year	DEVELOPED COUNTRIES			DEVELOPING COUNTRIES							WORLD TOTAL
				Market economies					Asian centrally planned economies	Total	
	Market economies	Centrally planned economies	Total	Africa	L. America	Near East	Far East	Total			
50/1951	3.28	1.65	4.93	-	0.02	-	-	0.02	-	0.02	4.95
55/1956	4.84	2.34	7.18	-	0.02	-	-	0.02	-	0.02	7.20
60/1961	6.01	2.75	8.76	-	0.01	-	-	0.01	-	0.01	8.77
65/1966	9.48	4.29	13.77	-	0.06	-	-	0.06	0.13	0.19	13.96
66/1967	9.77	4.63	14.40	-	0.05	-	-	0.05	0.17	0.22	14.62
67/1968	10.11	5.07	15.18	-	0.02	-	-	0.02	0.17	0.19	15.37
68/1969	10.34	5.41	15.75	-	0.02	-	-	0.02	0.19	0.21	15.96
69/1970	10.98	5.59	16.57	0.06	0.02	-	-	0.08	0.23	0.31	16.88
70/1971	10.94	6.51	17.45	0.12	0.02	-	-	0.14	0.24	0.38	17.83
71/1972	11.66	7.23	18.89	0.26	0.02	-	-	0.28	0.30	0.58	19.47
72/1973	11.69	7.89	19.58	0.28	0.02	-	-	0.30	0.30	0.60	20.18
73/1974	13.17	8.47	21.64	0.27	0.02	-	-	0.29	0.30	0.59	22.23
74/1975	13.65	9.45	23.10	0.29	0.01	-	-	0.30	0.30	0.60	23.70
75/1976	11.93	10.96	22.89	0.27	0.01	-	-	0.28	0.30	0.58	23.47
76/1977	13.19	11.47	24.66	0.27	0.02	-	-	0.29	0.32	0.61	25.27

rce: FAO Monthly Bulletin of Statistics, Vol. 1, January and March 1978
FAO Annual Fertilizer Review, 1975, 1976

Annex A-4(a) - **Evolution of the fertilizer production structure (N-P-K interrelations)**
(thousands of MT)

Year	WORLD			DEVELOPED COUNTRIES (Average)			DEVELOPING COUNTRIES (Average)		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
1950/1951	4481	6196	4943	2079	3008	2466	65	28	4 (*)
	0.91	1.25	1	0.84	1.23	1	16.25	7.00	1
	0.72	1		0.69	1		2.32	1	
1955/1956	7365	8049	7200	3454	3915	3592	92	44	4 (*)
	1.02	1.12	1	0.96	1.09	1	23.00	11.00	1
	0.92	1		0.88	1		2.09	1	
1960/1961	11388	10170	8772	5198	4853	4379	198	93	4 (*)
	1.30	1.16	1	1.19	1.11	1	49.50	23.25	1
	1.12	1		1.07	1		2.13	1	
1965/1966	20007	15678	13965	8950	7251	6888	422	235	38
	1.43	1.12	1	1.30	1.05	1	11.11	6.18	1
	1.28	1		1.23	1		1.80	1	
1970/1971	32971	20671	17828	14279	9207	8724	883	451	76
	1.85	1.16	1	1.64	1.06	1	11.62	5.93	1
	1.60	1		1.55	1		1.96	1	
1976/1977	45884	27286	25262	17533	11349	12330	1968	917	117
	1.82	1.08	1	1.42	0.92	1	16.82	7.84	1
	1.68	1		1.54	1		2.15	1	

(*) The Asian region of centrally planned economies is not included.

Note: The first lines of each year show the nutrients in 10^3 MT, and the two other lines give the nutrient ratio.

Source: Calculated from the data in Annexes A-1, A-2, A-3.

Annex A-4(b) - Evolution of the fertiliser production structure in the developed countries (thousands of MT)

Year	Developed market economies			Developed centrally planned economies		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
1950/1951	3409	5453	3284	749	602	1648
	1.04	1.66	1	0.45	0.37	1
	0.63	1		1.24	1	
1955/1956	5739	6780	4842	1168	1050	2342
	1.19	1.40	1	0.50	0.45	1
	0.85	1		1.11	1	
1960/1961	8487	8157	6007	1909	1549	2751
	1.41	1.36	1	0.69	0.56	1
	1.04	1		1.23	1	
1965/1966	13649	11743	9482	4250	2759	4294
	1.44	1.24	1	0.99	0.64	1
	1.16	1		1.54	1	
1970/1971	19730	14046	10942	8827	4368	6506
	1.80	1.28	1	1.36	0.67	1
	1.40	1		2.02	1	
1976/1977	22093	15613	13188	13949	7085	11471
	1.68	1.18	1	1.22	0.62	1
	1.42	1		1.97	1	

Note: The first lines of each year show the nutrients in 10^3 MT, and the two other lines give the nutrient ratio.

Source: Calculated from the data in Annexes A-1, A-2, A-3.

Annex A-4(c) - **Evolution of the fertilizer production structure in the developing countries**
(thousands of MT)

	A F R I C A			LATIN AMERICA			NEAR EAST			FAR EAST			ASIAN CENTRALLY PLANNED ECONOMIES		
ar	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
50/1951	-	38	-	294 18.38 4.59	64 4.00 1	16 1	1 0.06	16 1	-	8 0.57	14 1	-	20 2.22	9 1	-
55/1956	-	77	-	237 14.81 3.08	77 4.81 1	16 1	31 1.00	30 1	-	88 7.33	12 1	-	102 4.43	23 1	-
60/1961	-	114	-	256 18.29 2.03	126 9.00 1	14 1	56 1.40	40 1	-	148 2.39	62 1	-	532 4.36	122 1	-
65/1966	-	224	-	511 9.13 2.66	192 3.43 1	56 1	197 2.19	90 1	-	458 3.98	115 1	-	942 7.08	555 4.17 1	133 1
70/1971	84 0.68 0.24	348 2.83 1	123 1	749 46.81 2.05	365 22.81 1	16 1	359 2.06	174 1	-	1591 3.65	436 1	-	1631 6.77 1.75	933 3.87 1	241 1
76/1977	155 0.58 0.36	430 1.61 1	267 1	1315 82.19 1.13	1159 72.43 1	16 1	1045 1.79	585 1	-	3205 4.14	775 1	-	4122 12.88 2.52	1637 5.11 1	320 1

e: The first lines of each year show the nutrients in 10^3 MT and the other two lines give the nutrient ratio.

rce: Calculated from the data in Annexes A-1, A-2, A-3.

Annex A-5 - Average annual growth rate of production, by nutrient and region
(percentage)

Region	1950/1960			1960/1965			1965/1970			1970/1976		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Developed countries												
Market economies	9.6	4.1	6.2	9.9	7.5	9.5	7.6	3.7	2.9	2.0	1.8	3.2
Centrally planned economies	9.9	9.9	5.2	17.3	12.2	9.3	15.7	9.6	8.6	7.9	8.4	9.9
Total developed countries	9.6	4.8	5.9	11.5	8.4	9.4	9.8	4.9	4.9	3.9	3.5	5.9
Developing countries												
Africa	-	10.6	-	-	14.9	-	-	9.7	-	12.2	3.5	14.5
Latin America	-1.1	8.0	-7.1	14.4	7.9	43.1	8.0	14.2	-24.5	9.9	20.9	1
Near East	19.6	14.9	-	27.2	17.6	-	12.5	13.6	-	19.3	23.0	-
Far East	31.1	19.6	-	25.1	14.9	-	28.2	29.7	-	12.4	10.0	-
Total market economies	4.6	10.9	-7.1	20.0	12.8	43.1	18.9	16.5	18.4[2]	12.8	14.3	12.9
Asian centrally planned ec.	38.8	28.2	-	12.1	36.1	-	11.6	10.7	13.0	16.7	9.8	4.9
Total developing countries	12.1	13.5	-7.1	16.1	20.7	80.2[1]	15.9	13.9	14.9	14.3	12.5	8.2
World production	9.8	5.1	5.9	11.9	9.0	9.7	10.5	5.7	5.0	5.7	4.7	5.9

[1] The growth rate for the 1960-1965 period makes a quantum jump due to the first appearance of a substantial production for 1964 in the Asian centrally planned economies.

[2] The growth rate for the 1965-70 period includes the first appearance of a substantial production in Africa in 1969.

Source: Calculated from the data in Annexes A-1, A-2 and A-3.

Annex A-6 - Regional share of world nitrogenous fertilizer production

(percentage)

Region	1950/1951		1955/1956		1960/1961		1965/1966		1970/1971		1976/1977	
	Regional	World	Regional	World	Regional	World	Regional	World	Regional	World	Regional	World
Developed countries												
Market economies	82.2	76.3	83.1	77.8	81.6	74.5	76.3	68.2	69.1	59.8	61.3	48.1
Centrally planned economies	17.8	16.5	16.9	15.8	18.4	16.7	23.7	21.2	30.9	26.8	38.7	30.4
Total developed countries	100	92.8	100	93.6	100	91.2	100	89.4	100	86.6	100	78.5
Developing countries												
Africa	-	-	-	-	-	-	-	-	1.81	0.25	1.62	0.36
Latin America	90.6	6.51	51.1	3.26	26.0	2.27	24.2	2.54	17.0	2.28	13.4	2.88
Near East	-	-	6.38	0.43	6.0	0.54	9.48	1.02	8.16	1.09	10.6	2.28
Far East	3.15	0.24	21.3	1.35	15.0	1.34	21.8	2.32	36.1	4.82	32.5	6.98
Total **market economies**	93.75	6.75	78.8	5.04	47.0	4.15	55.5	5.88	63.1	8.44	58.1	12.50
Asian centrally planned ec.	6.25	0.45	21.2	1.36	53.0	4.65	44.5	4.72	36.9	4.95	41.9	8.99
Total developing countries	100	7.20	100	6.40	100	8.80	100	10.60	100	13.39	100	21.49
World total		100		100		100		100		100		100

Source: Calculated from the data in Annexes A-1, A-2, A-3.

Annex A-7 - Regional share of world phosphate (P_2O_5) fertiliser production

(percentage)

Region	1950/1951		1955/1956		1960/1961		1965/1966		1970/1971		1976/1977	
	gional	World	Regional	World	Regional	World	Regional	World	Regional	World	Regional	World
Developed countries												
Market economies	90.1	88.2	86.6	84.3	84.0	80.3	81.0	74.9	76.3	67.93	68.8	57.2
Centrally planned economies	9.9	9.7	13.4	13.1	16.0	15.2	19.0	17.6	23.7	21.13	31.2	26.0
Total developed countries	100	97.9	100	97.4	100	95.4	100	92.5	100	89.06	100	83.2
Developing countries												
Africa	30.7	0.65	33.3	0.87	23.9	1.08	18.6	1.40	15.5	1.69	9.4	1.58
Latin America	46.2	0.97	38.1	1.00	28.3	1.28	16.1	1.21	16.4	1.80	25.3	4.25
Near East	7.7	0.16	14.3	0.37	8.7	0.39	7.6	0.57	7.5	0.82	12.8	2.16
Far East	7.7	0.16	4.8	0.12	13.0	0.59	10.2	0.77	19.5	2.13	17.0	2.86
Total market economies	92.3	1.94	90.5	2.36	73.9	3.34	52.5	3.95	58.9	6.44	64.5	10.85
Asian centrally planned ec.	7.7	0.16	9.5	0.25	26.1	1.18	47.5	3.57	41.1	4.50	35.5	5.97
Total developing countries	100	2.10	100	2.60	100	4.50	100	7.52	100	10.94	100	16.82
World total	-	100	-	100	-	100	-	100	-	100	-	100

Source: Calculated from the data in Annexes A-1, A-2 and A-3.

Annex A-8 - Regional share of world potash (K_2O) fertiliser production

(percentage)

Region	1950/1951		1955/1956		1960/1961		1965/1966		1970/1971		1976/1977	
	Regional	World	Regional	World	Regional	World	Regional	World	Regional	World	Regional	World
Developed countries												
Market economies	66.5	66.3	67.4	67.2	68.6	68.5	68.8	67.9	62.7	61.4	53.5	52.2
Centrally planned economies	33.5	33.3	32.6	32.5	31.4	31.4	31.2	30.7	37.3	36.5	46.5	45.4
Total developed countries	100	99.6	100	99.7	100	99.9	100	98.6	100	97.9	100	97.6
Developing countries												
Africa	-	-	-	-	-	-	-	-	31.5	0.66	44.2	1.07
Latin America	100	0.40	100	0.30	100	0.10	31.6	0.45	5.3	0.11	3.3	0.08
Near East	-	-	-	-	-	-	-	-	-	-	-	-
Far East	-	-	-	-	-	-	-	-	-	-	-	-
Total market economies	100	0.40	100	0.30	100	0.10	31.6	0.45	36.8	0.77	47.5	1.15
Asian centrally planned ec.	-	-	-	-	-	-	68.4	0.95	63.2	1.33	52.5	1.25
Total developing countries	100	0.40	100	0.30	100	0.10	100	1.40	100	2.10	100	2.40
World production		100		100		100		100		100		100

Source: Calculated from the data in Annexes A-1, A-2, A-3.

Figure 4 Major types of fertilizer marketing systems according to degree of government intervention

Type	A	B	C	D
Marketing condition	Competitive	Partly Competitive	Single Marketing channel (non-competitive)	Competitive at import level only
Marketing Channel				
	FACTORY			
National level	National wholesale offices ↓	National govt. controlled sales organization ↓	National marketing board ↓	Private importer ↓
Regional level	Regional wholesalers ↓	Regional wholesalers ↓	↓	Govt. extension service ↓
Village level	Retailer ↓	Retailer ↓	↓	Agent ↓
	FARMER			
Examples	Most high consumption countries Kenya, India, Thailand, Brazil, Colombia	Iran, Mexico Peru, Venezuela	Senegal, Zambia, Ghana (extension service), Hungary (state input marketing)	Nigeria
Further remarks	Competitive at all levels and between coop. and private trade	Competitive mainly at retail level		Competitive at import level, but limited competition at retail level

This graph has been taken from the FIAC/FAO study published in 1974, entitled "The Scope for Improving Fertilizer Marketing and Credit Systems in Developing Countries."

Annex A-9 - **Countries that accounted for approximately 80 per cent of the world production, by nutrient**
(percentage)

NITROGENOUS				P_2O_5				K_2O			
1965/1966		1975/1976		1965/1966		1975/1976		1965/1966		1975/1976	
Country	%	Country	%	Country	%	Country	%	Country	%	Country	%
USA	25.4	USA	21.0	USA	29.8	USA	26.8	USA	18.6	USSR	33.8
USSR	13.6	USSR	19.3	USSR	10.1	USSR	16.5	Germany FR	17.2	Canada	20.6
Japan	8.1	China	7.5	Australia/ New Zealand	8.1	France	5.1	USSR	17.0	Germany DR	12.9
Germany FR	8.0	Japan	3.5	France	7.8	China	5.0	Germany DR	13.8	USA	8.9
France	5.3	India	3.4	Germany FR	6.1	Poland	3.7	France	13.4	Germany FR	7.9
Italy	4.5	France	3.1	Japan	3.8	Australia/ New Zealand	3.3				
China	4.1	Germany FR	2.9	Italy	3.3	Canada	2.6				
UK	3.3	Holland	2.6	China	2.8	Germany FR	2.6				
Holland	2.8	UK	2.4	UK	2.7	Japan	2.3				
Poland	2.0	Italy	2.3	Belgium	2.6	Belgium	2.1				
Canada	1.9	Canada	2.1	Canada	2.6	UK	1.9				
		Spain	1.9	Poland	2.2	Spain	1.8				
		Belgium	1.4			Italy	1.5				
		Mexico	1.3			South Africa	1.5				
		Hungary	1.3			Brazil	1.5				
		Korea	1.2			India	1.3				
		Germany DR	1.2								

Source: FAO Annual Fertilizer Review, 1976

Annex A-10 - World installed capacity of fertilizers
(thousands of MT)

Region	AMMONIA				PHOSPHORIC ACID				POTASH[1]			
	1973/74	%	1977/78	%	1973/74	%	1977/78	%	1973/74	%	1977/78	%
Developed countries												
Market economies	32768	50.75	38400	45.30	12490	68.77	17134	64.01	15109	61.13	15990	56.41
Centrally planned economies	16983	26.30	23513	27.74	3166	17.43	5029	18.79	9050	36.62	12030	42.44
Total developed countries	49751	77.05	61913	73.04	15656	86.20	22163	82.80	24159	97.75	28020	98.85
Developing countries												
Africa	386	0.60	386	0.46	730	4.02	1554	5.81	265	1.07	-	-
Latin America	2105	3.26	3865	4.56	774	4.26	994	3.71	21	0.85	21	0.74
Near East	1646	2.54	2569	3.03	502	2.76	782	2.92	-	-	-	-
Far East	3545	5.49	5983	7.06	465	2.56	1206	4.51	-	-	-	-
Total market econom.	7682	11.90	12803	15.11	2471	13.61	4536	16.95	286	1.16	21	0.74
Asian centrally planned economies	7132	11.05	10044	11.85	34	0.19	67	0.25	270	1.09	306	1.08
Total developing countries	14814	22.95	22847	26.96	2505	13.80	4603	17.20	556	2.25	327	1.15
World total	64565	100	84760	100	18161	100	26766	100	24715	100	28347	100

[1] Supply capability including 3.5% for industrial use and 5% for losses, lags, stocks etc.

Source: UNIDO/FAO/World Bank Working Group on Fertilizers, March 1978., Zürich.

Annex B-1 - World consumption of nitrogenous fertilizers, by region
(millions of MT)

Year	DEVELOPED COUNTRIES			DEVELOPING COUNTRIES							WORLD TOTAL
				Market economies					Asian centrally planned economies	Total	
	Market economies	Centrally planned economies	Total	Africa	L.America	Near East	Far East	Total			
1950/1951	3.26	0.67	3.93	0.02	0.13	0.05	0.11	0.31	0.09	0.40	4.33
1955/1956	4.71	1.01	5.72	0.05	0.27	0.16	0.37	0.85	0.32	1.17	6.89
1960/1961	6.95	1.63	8.58	0.08	0.44	0.26	0.72	1.50	0.88	2.38	10.96
1965/1966	10.85	3.92	14.77	0.15	0.73	0.44	1.13	2.45	1.60	4.05	18.82
1966/1967	12.06	4.56	16.62	0.17	0.81	0.44	1.59	3.01	2.14	5.15	21.77
1967/1968	13.40	5.23	18.63	0.18	0.95	0.53	1.71	3.37	1.94	5.31	23.94
1968/1969	13.85	6.06	19.91	0.20	1.12	0.64	2.19	4.15	2.56	6.71	26.62
1969/1970	14.58	6.57	21.15	0.23	1.18	0.71	2.56	4.68	2.85	7.53	28.68
1970/1971	15.63	7.52	23.15	0.27	1.36	0.77	2.70	5.10	3.50	8.60	31.75
1971/1972	15.83	8.28	24.11	0.37	1.45	0.87	3.16	5.85	3.39	9.24	33.35
1972/1973	16.48	8.96	25.44	0.39	1.63	1.03	3.52	6.57	3.70	10.27	35.71
1973/1974	17.85	9.68	27.53	0.42	1.68	1.18	3.49	6.77	4.39	11.16	38.69
1974/1975	17.08	10.34	27.42	0.41	1.88	1.03	3.46	6.78	4.38	11.16	38.58
1975/1976	19.22	11.52	30.74	0.44	1.97	1.32	3.94	7.67	4.82	12.49	43.23
1976/1977	19.99	11.28	31.27	0.52	2.27	1.64	4.35	8.78	5.01	13.79	45.06

Sources: FAO monthly Bulletin of Statistics, January and March 1978.
Annual Fertilizer Revue 1975, 1976.

Annex B-2 - **World consumption of phosphorous (P_2O_5) fertilizers, by region**

(millions of MT)

Year	DEVELOPED COUNTRIES			DEVELOPING COUNTRIES							WORLD TOTAL
				Market economies					Asian centrally planned economies	Total	
	Market economies	Centrally planned economies	Total	Africa	L.America	Near East	Far East	Total			
1950/1951	5.32	0.73	6.05	0.05	0.10	0.03	0.02	0.20	0.02	0.22	6.27
1955/1956	6.34	1.10	7.44	0.07	0.17	0.04	0.06	0.34	0.05	0.39	7.83
1960/1961	7.71	1.57	9.28	0.10	0.28	0.08	0.18	0.64	0.13	0.77	10.05
1965/1966	10.43	2.79	13.22	0.11	0.46	0.16	0.35	1.08	0.64	1.72	14.94
1966/1967	11.06	3.06	14.12	0.13	0.53	0.18	0.52	1.36	0.63	1.99	16.11
1967/1968	11.49	3.30	14.79	0.16	0.63	0.23	0.52	1.54	0.63	2.17	16.96
1968/1969	11.82	3.69	15.51	0.17	0.74	0.29	0.77	1.97	0.70	2.67	18.18
1969/1970	11.97	3.86	15.83	0.20	0.77	0.31	0.86	2.14	0.83	2.97	18.80
1970/1971	12.34	4.19	16.53	0.23	0.92	0.31	0.78	2.24	0.97	3.21	19.74
1971/1972	12.75	4.63	17.38	0.26	0.99	0.37	0.98	2.60	1.11	3.71	21.09
1972/1973	13.36	4.86	18.22	0.28	1.24	0.44	1.11	3.07	1.19	4.36	22.48
1973/1974	14.05	5.31	19.36	0.32	1.34	0.53	1.19	3.38	1.42	4.80	24.16
1974/1975	11.78	5.93	17.71	0.32	1.48	0.49	1.10	3.39	1.58	4.97	22.68
1975/1976	12.21	6.69	18.90	0.35	1.56	0.69	1.13	3.73	1.48	5.21	24.11
1976/1977	13.36	7.00	20.36	0.42	1.89	0.93	1.24	4.48	1.65	6.13	26.49

Sources: FAO monthly Bulletin of Statistics, January and March 1978.
Annual Fertilizer Review 1975, 1976.

Annex B-3 - World consumption of potash (K_2O) fertilizers, by region

(millions of MT)

Year	DEVELOPED COUNTRIES			DEVELOPING COUNTRIES							WORLD TOTAL
				Market economies							
	Market economies	Centrally planned economies	Total	Africa	L.America	Near East	Far East	Total	Asian centrally planned economies	Total	
1950/1951	3.44	1.08	4.52	0.02	0.05	-	0.02	0.09	0.01	0.10	4.62
1955/1956	4.95	1.59	6.54	0.04	0.12	0.01	0.05	0.22	0.02	0.24	6.78
1960/1961	6.21	1.80	8.01	0.06	0.23	0.01	0.12	0.42	0.05	0.47	8.48
1965/1966	7.99	3.46	11.45	0.08	0.29	0.02	0.23	0.62	0.20	0.82	12.27
1966/1967	8.45	3.67	12.12	0.10	0.33	0.01	0.30	0.74	0.22	0.96	13.08
1967/1968	8.88	4.10	12.98	0.10	0.37	0.02	0.35	0.84	0.26	1.10	14.08
1968/1969	8.96	4.36	13.32	0.10	0.54	0.02	0.38	1.04	0.33	1.37	14.69
1969/1970	9.29	4.67	13.96	0.12	0.56	0.02	0.46	1.16	0.35	1.51	15.47
1970/1971	9.88	5.09	14.97	0.14	0.65	0.03	0.49	1.31	0.36	1.67	16.64
1971/1972	10.16	5.64	15.80	0.16	0.66	0.03	0.59	1.44	0.38	1.82	17.62
1972/1973	10.62	6.08	16.70	0.18	0.77	0.04	0.70	1.69	0.42	2.11	18.81
1973/1974	11.48	6.75	18.23	0.18	0.89	0.04	0.78	1.89	0.61	2.50	20.73
1974/1975	10.11	7.12	17.23	0.21	0.93	0.04	0.79	1.97	0.62	2.59	19.82
1975/1976	10.52	8.72	19.24	0.19	0.87	0.04	0.71	1.81	0.49	2.30	21.54
1976/1977	11.54	8.91	20.45	0.21	1.10	0.05	0.76	2.12	0.50	2.62	23.07

Source: FAO monthly Bulletin of Statistics, January and March 1978
Annual Fertilizer Review 1975, 1976.

Annex B-4(a) - Evolution of the fertilizer consumption structure (N-P-K interralations)
(thousands of MT)

Year	WORLD			DEVELOPED COUNTRIES (Average)			DEVELOPING COUNTRIES (Average)		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
1950/1951	4331	6268	4627	1960	3025	2262	82	44	21
	0.9	1.4	1	0.9	1.3	1	3.9	2.1	1
	0.7	1		0.6	1		1.9	1	
1955/1956	6878	7840	6778	2856	3719	3272	233	80	47
	1.0	1.2	1	0.9	1.1	1	4.9	1.7	1
	0.9	1		0.8	1		2.9	1	
1960/1961	10958	10046	8479	4288	4641	4007	477	153	93
	1.3	1.2	1	1.1	1.2	1	5.1	1.6	1
	1.1	1		0.9	1		3.1	1	
1965/1966	18828	14949	12284	7386	6614	5730	811	344	165
	1.5	1.2	1	1.3	1.2	1	4.9	2.1	1
	1.3	1		1.1	1		2.4	1	
1970/1971	31749	19737	16656	11574	8266	7493	1720	541	337
	1.9	1.2	1	1.5	1.1	1	5.1	1.6	1
	1.6	1		1.4	1		3.2	1	
1976/1977	45088	26493	23064	15642	10182	10226	2761	1226	523
	1.9	1.1	1	1.5	0.9	1	5.3	2.3	1
	1.7	1		1.5	1		2.3	1	

Source: Calculated from the data in Annexes B-1, B-2, B-3.

Annex B-4(b) - Evolution of the fertiliser consumption structure in the developed countries
(thousands of MT)

Year	Developed market economies			Developed centrally planned economies		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
1950/1951	3256 0.9 0.6	5315 1.5 1	3441 1	666 0.6 0.9	734 0.7 1	1083 1
1955/1956	4705 0.9 0.7	6335 1.3 1	4950 1	1006 0.6 0.9	1103 0.7 1	1594 1
1960/1961	6946 1.1 0.9	7708 1.2 1	6211 1	1629 0.9 1.0	1574 0.9 1	1802 1
1965/1966	10850 1.3 1.0	10431 1.3 1	7997 1	3921 1.1 1.4	2797 0.8 1	3463 1
1970/1971	15627 1.6 1.3	12343 1.2 1	9875 1	7521 1.5 1.8	4189 0.8 1	5097 1
1976/1977	19999 1.7 1.5	13364 1.1 1	1543 1	11284 1.3 1.6	7000 0.8 1	8908 1

Source: Calculated from the data in Annexes B-1, B-2, B-3

Annex B-4(c) - Evolution of the fertiliser consumption structure in the developing countries
(thousands of MT)

Year	AFRICA			LATIN AMERICA			NEAR EAST			FAR EAST			ASIAN CENTRALLY PLANNED ECONOMIES		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
1950/1951	23 1.1 0.5	47 2.2 1	21 1	125 2.3 1.3	97 1.8 1	54 1	54 27.0 1.8	30 15.0 1	2 1	173 8.1 6.6	26 1.2 1	21 1	94 18.8 4.9	19 3.8 1	5 1
1955/1956	45 1.3 0.6	74 2.1 1	35 1	271 2.3 1.6	170 1.4 1	120 1	158 17.6 3.6	44 4.9	9 1	375 7.3 6.1	62 1.2 1	51 1	317 16.7 6.1	52 2.7 1	19 1
1960/1961	80 1.3 0.8	99 1.5 1	64 1	444 1.9 1.6	280 1.2 1	225 1	257 25.7 3.4	76 7.6 1	10 1	724 6.1 4.1	176 1.5 1	117 1	878 17.6 6.6	132 2.6 1	50 1
1965/1966	151 1.9 1.3	112 1.4 1	81 1	728 2.5 1.6	457 1.6 1	293 1	440 27.5 2.8	160 10.0 1	16 1	1135 4.8 3.2	352 1.5 1	234 1	1603 8.0 2.5	640 3.2 1	200 1
1970/1971	274 2.0 1.2	229 1.7 1	136 1	1358 2.1 1.5	916 1.4 1	646 1	767 28.4 2.5	305 11.3 1	27 1	2705 5.5 3.4	784 1.6 1	492 1	3495 9.6 3.6	969 2.7 1	362 1
1976/1977	520 2.5 1.3	415 1.9 1	212 1	2275 2.1 1.2	1886 1.7 1	1097 1	1640 3.46 1.75	934 19.0 1	49 1	4356 5.7 3.5	1243 1.64 1	758 1	5013 10.10 3.04	1649 3.32 1	496 1

Source: Calculated from the data in Annexes B-1, B-2 and B-3.

Annex B-5 - Average annual growth rate of consumption, by nutrient and region
(percentage)

Region	1950/1960			1960/1965			1965/1970			1970/1976		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Developed countries												
Market economies	7.86	3.78	6.08	9.32	6.23	5.17	7.57	3.42	4.34	4.18	1.33	2.62
Centrally planned economies	9.43	7.96	5.24	19.18	12.18	13.96	13.92	8.47	8.02	6.99	8.92	9.78
Total developed countries	8.12	4.37	5.88	11.47	7.33	7.41	9.40	4.57	5.50	5.14	3.53	5.34
Developing countries												
Africa	14.87	7.17	11.61	13.40	1.92	5.92	12.47	15.89	11.84	11.54	10.55	6.99
Latin America	12.97	10.84	16.48	10.66	10.44	4.75	13.25	14.87	17.52	8.91	28.48	9.16
Near East	17.92	10.31	-	11.09	14.87	14.87	11.84	14.14	8.45	13.42	20.09	8.88
Far East	20.67	24.57	19.62	9.43	14.22	13.90	19.03	17.38	16.33	8.27	8.03	7.59
Total market ec.	17.07	12.33	16.65	10.31	11.03	8.10	15.79	15.70	16.13	9.48	12.24	8.35
Asian centrally planned economies	25.60	20.58	17.46	12.70	37.54	31.95	16.95	8.67	12.47	6.16	9.26	5.63
Total developing countries	19.52	13.35	16.74	11.22	17.44	11.77	16.25	13.29	15.29	8.19	11.38	7.79
World total	9.73	4.83	6.26	11.42	8.25	7.67	11.03	5.73	6.28	6.01	5.02	5.59

Source: Calculated from the data in Annexes B-1, B-2, B-3.

Annex B-6 - Regional share of world nitrogenous fertilizer consumption
(percentage)

Region	1950/1951		1955/1956		1960/1961		1965/1966		1970/1971		1976/1977	
	Regional	World	Regional	World	Regional	World	Regional	World	Regional	World	Regional	World
Developed countries												
Market economies	83.0	75.3	82.3	68.5	81.0	63.4	73.5	57.7	67.5	49.2	63.9	44.4
Centrally planned economies	17.0	15.4	17.7	17.6	19.0	14.9	26.5	20.8	32.5	23.7	36.1	25.1
Total developed countries	100	90.7	100	83.1	100	78.3	100	78.5	100	72.9	100	69.5
Developing countries												
Africa	5.00	0.5	4.2	0.7	3.4	0.7	3.7	0.8	3.1	0.9	3.8	1.2
Latin America	32.5	3.0	23.1	3.9	18.5	4.0	18.0	3.9	15.9	4.3	16.5	5.0
Near East	12.5	1.2	13.7	2.3	10.9	2.4	10.8	2.3	8.9	2.4	11.9	3.6
Far East	27.5	2.5	31.6	5.4	30.2	6.6	27.9	6.0	31.4	8.5	31.5	9.6
Total market econom.	77.5	7.2	72.6	12.3	63.0	13.7	60.4	13.0	59.3	16.1	63.7	19.4
Asian centrally planned economies	22.5	2.1	27.4	4.6	37.0	8.0	39.6	8.5	40.7	11.0	36.3	11.1
Total developing countries	100	9.3	100	16.9	100	21.7	100	21.5	100		100	30.5
World total		100		100		100		100		100		100

Source: Calculated from the data in Annexes B-1, B-2, B-3.

Table 31 Estimated market share of private, co-operative and state fertilizer marketing enterprises in selected countries
(Market share in percentage of total market sales)

Country	Wholesale Trade			Retail Trade		
	Private	Cooperative	Government	Private	Cooperative	Government
Africa						
Ethiopia	Predom.	...	...	70	3	27
Ghana	-	-	100	...	...	Predom.
Kenya	100	-	-	90	10	-
Morocco	94	6	-	64	-	36
Senegal	-	-	100	-	7	93
Zambia	-	-	100	-	-	100
Asia						
India	...	...	...	40	60	-
Jordan						
Iran			100	50	5	45
Nepal	-	-	100	1/		1/
Thailand	100	-	-	85	15	-
Latin America						
Argentina	100	-	-	75	25	-
Brazil	100	-	-	85	15	-
Colombia	50	25	25	50	25	25
Mexico	...	...	Predom.	82	4	14
Peru						
Venezuela			100	35	15	50
High level consumption countries						
Austria	30	70	-	30	70	-
France	50	50	-	53	47	-
F.R.Germany	45	55	-	50	50	-
Hungary	-	4	96		100	
Japan	31	69	-	13	87	
Israel						
Netherlands	40	60	-	40	60	
Norway	approx.2/3	approx.1/3		35	65	-
Spain						
Sweden	-	100	-	25	75	-
U.K.	...	...	...	75	25	-
U.S.A.					35-40	

1/ A large part is distributed through local agencies of ASC and the rest through cooperatives, village committees, etc.

This table was prepared for the FAO/... publication "The Scope for Improving Fertilizer Marketing and Credit Systems in Developing Countries", 1974.

Annex B-7 - **Regional share of world phosphate (P_2O_5) fertilizer consumption**

(percentage)

Region	1950/1951		1955/1956		1960/1961		1965/1966		1970/1971		1976/1977	
	Regional	World	Regional	World	Regional	World	Regional	World	Regional	World	Regional	World
Developed countries												
Market economies	87.93	84.85	85.22	80.97	83.08	76.72	78.90	69.82	74.65	62.52	65.62	50.43
Centrally planned economies	12.07	11.64	14.78	14.05	16.92	15.62	21.10	18.67	25.35	21.22	34.38	26.43
Total developed countries	100	96.49	100	95.02	100	92.34	100	88.49	100	83.74	100	76.86
Developing countries												
Africa	22.73	0.80	17.95	0.89	12.99	0.99	6.40	0.74	7.15	1.16	6.85	1.59
Latin America	45.45	1.59	43.59	2.17	36.37	2.79	26.74	3.08	28.67	4.66	30.83	7.13
Near East	13.64	0.48	10.26	0.51	10.39	0.80	9.30	1.07	9.66	1.57	15.17	3.51
Far East	9.09	0.32	15.38	0.77	23.37	1.79	20.35	2.34	24.30	3.95	20.23	4.68
Total market economies	90.91	3.19	87.18	4.34	83.12	6.37	62.79	7.23	69.78	11.35	73.08	16.91
Asian centrally planned economies	9.09	0.32	12.82	0.64	16.88	1.29	37.21	4.28	30.22	4.92	25.92	6.23
Total developing countries	100	3.51	100	4.98	100	7.66	100	11.51	100	16.26	100	23.14
World total		100		100		100		100		100		100

Source: Calculated from the data in Annexes B-1, B-2, B-3.

Annex B-8 - Regional share of world potash (K_2O) fertilizer consumption

(percentage)

	1950/1951		1955/1956		1960/1961		1965/1966		1970/1971		1975/1976	
	Regional	World	Regional	World	Regional	World	Regional	World	Regional	World	Regional	World
Developed countries												
Market economies	76.11	74.46	75.69	73.01	77.53	73.23	69.78	65.12	66.00	59.38	56.43	50.03
Centrally planned economies	23.89	23.37	24.31	23.45	22.47	21.23	30.22	28.20	34.00	30.59	43.57	38.62
Total developed countries	100	97.83	100	96.46	100	94.46	100	93.32	100	89.97	100	88.65
Developing countries												
Africa	20.00	0.43	16.67	0.59	12.76	0.70	9.76	0.65	8.38	0.84	8.02	0.91
Latin America	50.00	1.08	50.00	1.77	48.94	2.71	35.36	2.36	38.92	3.91	41.98	4.77
Near East	-	-	4.17	0.15	2.13	0.12	2.44	0.16	1.80	0.18	1.91	0.22
Far East	20.00	0.43	20.83	0.74	25.53	1.42	28.05	1.87	29.34	2.94	29.00	3.29
Total market economies	90.00	1.95	91.67	3.25	89.36	4.95	75.61	5.05	78.44	7.87	80.92	9.19
Asian centrally planned economies	10.00	0.22	8.33	0.24	10.64	0.59	24.39	1.63	21.56	2.16	19.08	2.16
Total developing countries	100	2.17	100	3.54	100	5.54	100	6.68	100	10.03	100	11.35
World total		100		100		100		100		100		100

Source: Calculated from the data in Annexes B-1, B-2, B-3.

Annex B-9 - Countries that accounted for approx. 80 per cent of the world consumption, by nutrient
(percentage)

NITROGENOUS				P_2O_5				K_2O			
1965/1966		1975/1976		1965/1966		1975/1976		1965/1966		1975/1976	
Country	%	Country	%	Country	%	Country	%	Country	%	Country	%
USA	25.7	USA	21.8	USA	23.6	USA	19.7	USA	20.9	USSR	24.2
USSR	12.1	USSR	16.9	USSR	10.6	USSR	15.9	USSR	15.7	USA	20.6
China	7.8	China	10.1	France	8.4	France	6.9	Germany FR	9.7	France	6.2
Germany FR	4.6	India	4.9	Australia	6.4	China	5.2	France	7.9	Poland	6.2
France	4.6	France	3.9	Germany FR	5.5	Brazil	3.7	UK	7.6	Germany FR	5.2
Japan	4.2	Germany FR	2.8	Japan	3.7	Germany FR	3.2	Japan	4.9	Germany DR	2.7
UK	3.7	Poland	2.8	China	3.5	Japan	2.6	Germany DR	4.7	Czechoslovak.	2.7
India	2.9	UK	2.4	Italy	3.0	Canada	2.2	Poland	4.2	Japan	2.5
Italy	2.5	Mexico	1.9	UK	2.8	Australia	2.0	Czechoslovakia	3.2	Brazil	2.2
Poland	2.3	Italy	1.8	Poland	2.4	India	2.0	Belgium	1.4	Hungary	2.1
Spain	2.0	Romania	1.8	Canada	2.2	Czechoslovakia	2.0	Oceania	1.4	China	1.8
Germany DR	1.8	Italy	1.7	New Zealand	2.3	Italy	2.0	Italy	1.4	UK	1.8
Netherlands	1.7	Germany DR	1.6	Germany DR	2.1	Hungary	1.8	Yugoslavia	0.1	Spain	1.3
Egypt	1.4	Japan	1.5	Spain	2.0	Romania	1.7	Netherlands	1.1		
Mexico	1.4	Canada	1.3	Czechoslovakia	1.7	Turkey	1.6				
Canada	1.2	Hungary	1.2	South Africa	1.3	New Zealand	1.6				
Korea Rep.	1.1	Czechoslovakia	1.2			UK	1.5				
		Korea Rep.	1.1			South Africa	1.4				
						Guatemala	1.2				
						Bulgaria	1.1				

Source: FAO Annual Fertilizer Review, 1977

Annex B-10 - Gross domestic product, by region

Region	GDP (millions of constant US dollars)				Growth rate (percentage)			
	1960	1965	1970	1975	1960-65	1965-70	1970-75	Average 1960-75
Developed countries								
Market economies	1,311,264	1,686,345	2,103,109	2,418,658	5.2	4.5	2.8	4.2
Centrally planned economies	238,133	298,527	428,188	574,216	4.6	7.5	6.0	6.0
Total developed countries	1,549,397	1,984,872	2,531,297	2,992,874	5.1	5.0	3.4	4.5
Developing countries								
Africa	29,123	34,439	44,485	53,869	3.4	5.3	3.9	4.2
Latin America	94,429	122,846	164,391	220,778	5.4	6.0	6.1	5.8
Near East	28,306	39,361	54,755	87,377	6.8	6.8	9.8	7.8
Far East	70,977	88,760	116,231	141,926	4.3	5.5	4.1	4.6
Others	589	654	917	1,267	2.1	7.0	6.7	5.3
Total market economies	224,424	286,060	380,779	505,217	5.0	5.9	5.8	5.6
Asian centrally planned economies	109,683	139,298	181,137	253,701	4.9	5.4	7.0	5.8
Total developing countries	334,107	425,358	561,916	758,918	4.9	5.7	6.2	5.6
World total	1,883,504	2,410,230	3,093,213	3,751,792	5.1	5.1	3.9	4.7

Source: UN Office of Statistics, New York.
Missing information was obtained from sources in the countries concerned.

Annex B-11 - World population, by region

Region	Population (millions)				Growth rate (percentage)			
	1960	1965	1970	1975	1960/65	1965/70	1970/75	Average 1960/75
Developed countries								
Market economies	650	691	724	757	1.2	0.9	0.9	1.0
Centrally planned economies	313	333	348	364	1.2	0.9	0.9	1.0
Total developed countries	963	1024	1072	1121	1.2	0.9	0.9	1.0
Developing countries								
Africa	215	246	279	319	2.7	2.5	2.7	2.7
Latin America	213	247	283	324	3.0	2.8	2.7	2.8
Near East	130	148	169	195	2.6	2.7	2.9	2.7
Far East	754	877	994	1125	3.1	2.5	2.5	2.7
Others	3	3	4	4	-	5.9	-	1.9
Total developed countries	1315	1521	1729	1967	3.0	3.0	2.6	2.7
Asian centrally planned ec.	706	742	808	880	1.0	1.7	1.7	1.5
Total developing countries	2021	2263	2537	2847	2.3	2.3	2.3	2.3
World total	2984	3287	3609	3968	2.0	1.9	1.9	1.9

Source: FAO Production Yearbook, Vol.29

Annex B-12 - Coefficient of elasticity, by nutrient and region

Region	Nitrogenous			P_2O_5			K_2O		
	1960/65	1965/70	1970/75	1960/65	1965/70	1970/75	1960/65	1965/70	1970/75
Developed countries									
Market economies	1.29	1.21	1.12	1.12	0.99	0.90	1.07	1.04	0.96
Centrally planned ec.	2.03	1.40	1.20	1.51	1.09	1.25	1.63	1.07	1.34
Total developed countries	1.43	1.29	1.17	1.18	1.02	1.01	1.19	1.07	1.14
Developing countries									
Africa	1.81	1.58	1.54	1.06	1.83	1.43	1.28	1.54	1.28
Latin America	1.64	1.59	1.24	1.62	1.71	1.45	1.25	1.91	1.15
Near East	1.39	1.43	1.24	1.64	1.59	1.62	1.64	1.23	0.96
Far East	1.47	2.08	1.34	1.81	1.94	1.33	1.79	1.85	1.33
Total market economies	1.48	1.78	1.28	1.54	1.77	1.33	1.35	1.80	1.18
Asian centrally planned economies	1.50	1.84	1.07	4.07	1.28	1.19	3.31	1.51	1.05
Total developing countries	1.49	1.80	1.20	1.96	1.58	1.34	1.53	1.73	1.14
World total	1.48	1.44	1.23	1.28	1.13	1.10	1.25	1.16	1.16

Source: Calculated from the data in Annexes B-1, B-2, B-3.

Annex C-1 - World demand/supply balance of nitrogenous fertilizers, by region

(thousands of MT)

Region	1955/1956			1965/1966			1976/1977		
	Consumption	Production	Balance	Consumption	Production	Balance	Consumption	Production	Balance
Developed countries									
Market economies	4706	5739	+ 1033	10850	13649	+ 2799	19999	22093	+ 2094
Centrally planned ec.	1006	1168	+ 162	3921	4250	+ 329	11284	13949	+ 2665
Total developed countries	5712	6907	+ 1195	14771	17899	+ 3128	31283	36042	+ 4759
Developing countries									
Africa	45	-	- 45	151	-	- 151	520	155	- 365
Latin America	271	237	- 34	728	511	- 217	2275	1315	- 960
Near East	158	31	- 127	440	197	- 243	1640	1045	- 595
Far East	375	88	- 287	1135	458	- 677	4356	3205	- 1151
Total market economies	849	356	- 493	2454	1166	- 1288	8791	5720	- 3071
Asian centrally planned economies	317	102	- 215	1603	942	- 661	5013	4122	- 891
Total developing countr.	1166	458	- 708	4057	2108	- 1949	13804	9842	- 3962
World total	6878	7365	+ 487	18828	20007	+ 1179	45087	45884	797

Source: **FAO Monthly Bulletin of Statistics, Vol. 1, January and March 1978**

Annex C-2 - **World demand/supply balance of phosphate (P_2O_5) fertilizers, by region**

(thousands of MT)

Region	1955/1956			1965/1966			1976/1977		
	Consumption	Production	Balance	Consumption	Production	Balance	Consumption	Production	Balance
Developed countries									
Market economies	6335	6780	+ 445	10431	11743	+ 1312	13364	15613	+ 2249
Centrally planned ec.	1103	1050	- 53	2797	2759	- 38	7001	7085	+ 84
Total developed countries	7438	7830	+ 392	13228	14502	+ 1274	20365	22698	+ 2333
Developing countries									
Africa	74	77	+ 3	112	224	+ 112	415	430	+ 15
Latin America	170	77	- 93	457	192	- 265	1886	1159	- 727
Near East	44	30	- 14	160	90	- 70	934	585	- 349
Far East	62	12	- 50	352	115	- 237	1243	776	- 467
Total market economies	350	196	- 154	1081	621	- 460	4478	2950	- 1528
Asian centrally planned economies	52	23	- 29	640	555	- 85	1650	1637	- 13
Total developing countr.	402	219	- 183	1721	1176	- 545	6128	4587	- 1541
World total	7840	8049	+ 209	14949	15678	+ 729	26493	27285	+ 792

Source: **FAO Monthly Bulletin of Statistics**, Vol.1, January and March 1978.

Annex C-3 - World demand/supply balance of potash (K_2O) fertilizers, by region

(thousands of MT)

Region	1955/1956			1965/1966			1976/1977		
	Consumption	Production	Balance	Consumption	Production	Balance	Consumption	Production	Balance
Developed countries									
Market economies	4950	4842	- 108	7997	9482	+ 1485	11543	13188	+ 1645
Centrally planned ec.	1594	2342	+ 748	3463	4294	+ 831	8908	11471	+ 2563
Total developed countries	6544	7184	+ 640	11460	13776	+ 2316	20451	24659	+ 4208
Developing countries									
Africa	35	-	- 35	81	-	- 81	212	267	+ 55
Latin America	120	16	- 104	293	56	- 237	1097	16	- 1081
Near East	9	-	- 9	16	-	- 16	49	-	- 49
Far East	51	-	- 51	234	-	- 234	759	-	- 759
Total market economies	251	16	- 199	624	56	- 568	2117	283	- 1834
Asian centrally planned economies	19	-	- 19	200	133	- 67	496	320	- 176
Total developing countr.	234	16	- 218	824	189	- 635	2613	603	- 2010
World total	6778	7200	+ 422	12284	13965	+ 1681	23064	25262	+ 2198

Source: FAO Monthly Bulletin of Statistics, Vol.1, January and March 1978.

Annex C-4 - Tonnages of nitrogenous fertilizers exchanged, by region

(thousands of MT)

Region	1965/1966			1970/1971			1975/1976		
	Export	Import	Balance	Export	Import	Balance	Export	Import	Balance
Developed countries									
Market economies	3633	1415	+ 2218	5544	2034	+ 3510	5548	3853	+ 1695
Centrally planned ec.	214	326	- 112	782	367	+ 415	2014	167	+ 1847
Total developed countries	3847	1741	+ 2106	6326	2401	+ 3925	7562	4020	+ 3542
Developing countries									
Africa	-	157	- 157	6	184	- 178	8	391	- 383
Latin America	223	451	- 228	245	862	- 617	187	1121	- 934
Near East	-	247	- 247	112	456	- 344	427	1094	- 667
Far East	-	744	- 744	67	1046	- 979	52	1231	- 1179
Total market economies	223	1599	- 1376	430	2549	- 2119	674	3837	- 3163
Asian centrally planned economies	15	701	- 686	18	1745	1727	2	968	- 966
Total developing countr.	238	2300	- 2062	448	4294	- 3846	676	4805	- 4129
World total	4085	4041	+ 44	6774	6695	+ 79	8238	8825	- 587

Source: FAO Annual Fertilizer Review, 1976, 1976 going to be distributed including amounts to be transported, state of the road network, storage facilities, packaging requirements; the cost of establishing a network of buffer point etc. The organization of a suitable fertilizer distribution network requires substantial capital outlays. Table 32 presents estimated fertilizer distribution, capital investment and costs for three alternatives.

Table Estimated fertilizer distribution
(prices in 1975)

	A_1[a]	A_2[b]	A_3[c]
(a) Total capital costs (millions of $)	50.2	46.8	40.7
Capital cost per ton of annual sales	62	151	131
(b) Total working capital (millions of $)	29.8	29.8	12.3
(c) Total annual operating cost (millions of $)	18.5	17.4	11.3
Operating cost per ton of annual sales	59.7	56.1	36.5

a/ Prilling of 170,000 t/y included
b/ Bagged fertilizers
c/ Bulk fertilizers

Note: The distribution alternatives are based on the following: area covered 80 Km^2, amount 310,000 MT/y, initial consumption 20 Kg/ha, consumption increase 10 per cent per annum, 8 satellite storages.

(iii) The financial services relate to the granting of credits to farmers for crop inputs purchasing for use as working capital to be repaid by crop revenues. In other cases, credits are granted to the fertilizer industry for financing the working capital needs of its fertilizer distribution activities. Adequate credit availability both for fertilizer distribution and for farmers, is a basic pre-requisite to stimulating fertilizer consumption. This credit should command a preferential interest rate.

(iv) Selling concerns the marketing efforts to expand the farmer's consumption by a number of means, such as timely availability of fertilizers, technical services to farmers, diffusion of relevant information, collaboration with farmers in order to accommodate study fertilizer output with seasonal demand etc.

Annex C-5 - Tonnages of phosphate fertilizers (P_2O_5) exchanged, by region
(thousands of MT)

Region	1965/1966			1970/1971			1975/1976		
	Export	Import	Balance	Export	Import	Balance	Export	Import	Balance
Developed countries									
Market economies	1574	948	+ 626	2414	1284	+ 1130	3840	1874	+ 1966
Centrally planned econ.	65	154	- 89	166	256	- 90	181	317	- 136
Total developed countries	1639	1102	+ 537	2580	1540	+ 1040	4021	2191	+ 1830
Developing countries									
Africa	156	51	+ 105	247	120	+ 127	237	198	+ 39
Latin America	-	273	- 273	10	563	- 553	44	750	- 706
Near East	6	94	- 88	21	161	- 140	25	467	- 442
Far East	-	252	- 252	8	242	- 234	6	287	- 281
Total market economies	162	670	- 508	286	1086	- 800	312	1702	- 1390
Asian centrally planned ec.	-	-	-	1	4	- 3	3	12	- 9
Total developing countries	162	670	- 508	287	1090	- 803	315	1714	- 1399
World total	1801	1772	+ 29	2867	2630	+ 237	4336	3905	+ 431

Source: FAO Annual Fertilizer Review, 1976, 1976

Annex C-6 - **Tonnages of potash fertilizers (K_2O) exchanged, by region**

(thousands of MT)

Region	1965/1966			1970/1971			1975/1976		
	Export	Import	Balance	Export	Import	Balance	Export	Import	Balance
Developed countries									
Market economies	4328	4126	202	6392	5951	+ 441	8990	8438	+ 552
Centrally planned econ.	1634	1041	593	3048	1964	+ 1084	4743	2898	+ 1845
Total developed countries	5962	5167	795	9440	7915	+ 1525	13733	11336	+ 2397
Developing countries									
Africa	NA	88	- 88	NA	143	- 143	11	212	- 201
Latin America	14	289	- 275	11	656	- 645	11	1174	- 1163
Near East	NA	14	- 14	NA	29	- 29	NA	56	- 56
Far East	NA	276	- 276	NA	363	- 363	NA	709	- 709
Total market economies	14	667	- 653	11	1191	- 1180	22	2151	- 2129
Asian centrally planned economies	NA	67	- 67	NA	121	- 121	NA	177	- 177
Total developing countries	14	734	- 720	11	1312	- 1301	22	2328	- 2306
World total	5976	5901	+ 75	9451	9227	+ 224	13755	13664	+ 91

Source: **FAO Annual Fertilizer Review**, 1975, 1976

Annex C-7 - Weight of fertilizers international trade over world production
(percentage)

Region	Nitrogenous			P_2O_5			K_2O		
	1965/66	1970/71	1975/76	1965/66	1970/71	1975/76	1965/66	1970/71	1975/76
Developed countries									
Market economies	18.16	16.81	12.66	10.04	11.68	15.50	30.99	35.85	38.29
Centrally planned ec.	1.06	2.37	4.60	0.41	0.80	0.73	11.70	17.10	20.20
Total developed countries	19.22	19.18	17.26	10.45	12.48	16.23	42.69	52.95	58.49
Developing countries									
Africa	NA	0.02	0.01	0.99	1.19	0.96	NA	NA	0.05
Latin America	1.11	0.74	0.43	NA	0.05	0.18	0.10	0.06	0.05
Near East	NA	0.34	0.97	0.04	0.10	0.10	NA	NA	NA
Far East	NA	0.20	0.12	NA	0.04	0.02	NA	NA	NA
Total market economies	1.11	1.30	1.53	1.03	1.38	1.26	0.10	0.06	0.10
Asian centrally planned economies	0.08	0.05	-	NA	NA	0.01	NA	NA	NA
Total developing countr.	1.19	1.35	1.54	1.03	1.38	1.27	0.10	0.06	0.10
World total	20.41	20.54	18.80	11.48	13.86	17.50	42.79	53.01	58.59

Source: Calculated from data in Annexes A-1, A-2, A-3 and C-4, C-5 and C-6.

Annex C-8 - Countries that accounted for approx. 80% of the world export and import in 1975/1976, by nutrient

Nitrogenous				P_2O_5				K_2O			
Export		Import		Export		Import		Export		Import	
Country	%	Country	%	Country	%	Country	%	Country	%	Country	%
USA	13.35	China	16.42	USA	48.55	France	13.62	Canada	35.86	USA	29.14
Japan	12.13	India	12.44	Belgium	13.48	Brazil	10.78	USSR	20.95	Poland	13.04
Netherlands	11.79	USA	8.40	Canada	4.69	Italy	8.87	German DR	18.94	Czechoslovak.	5.67
Belgium	7.40	France	6.24	Netherlands	4.59	India	8.67	USA	6.95	Hungary	4.91
Romania	6.88	Turkey	4.18	France	3.19	Germany FR	4.67			Brazil	4.82
USSR	5.90	Germany FR	4.00	USSR	2.86	USA	4.52			Japan	4.48
Poland	5.15	Brazil	3.27	UK	2.82	Hungary	3.99			UK	3.37
Canada	5.03	Mexico	3.25	Romania	1.99	Bangladesh	2.67			Belgium	2.32
Germany FR	4.25	Egypt	2.89	Germany FR	1.66	Canada	2.57			France	2.22
Italy	3.69	Indonesia	2.08			Pakistan	2.57			India	2.17
Norway	3.69	Italy	1.76			Korea Rep.	2.34			Italy	1.82
Bulgaria	3.52	Cuba	1.75			Indonesia	2.18			Oceania	1.54
		Belgium	1.71			Belgium	1.72			Netherlands	1.53
		Denmark	1.53			Cuba	1.66			Korea Rep.	1.35
		UK	1.57			Thailand	1.65			Finland	1.34
		Sweden	1.48			Chile	1.50			Denmark	1.30
		Germany DR	1.46			UK	1.28				
		Hungary	1.44			Denmark	1.22				
		Sudan	1.32			Japan	1.08				
		Philippines	1.15								
		Pakistan	1.00								
		Thailand	1.00								

Source: FAO Annual Fertilizer Review, 1976.

Annex D-1 - **Fertilizer demand forecast, by region**
(millions of MT)

Region	1978/79			1982/83			1987/88			2000/01		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Developed countries												
Market economies	21.05	13.82	12.24	24.19	15.34	14.22	28.28	16.69	16.85	40.60	21.03	25.28
Centrally planned economies	13.32	8.30	9.70	17.47	11.90	12.05	23.00	14.00	16.40	41.41	27.26	29.28
Total developed countries	34.37	22.12	21.94	41.66	27.24	26.27	51.28	30.69	33.25	82.01	48.29	54.56
Developing countries												
Africa	0.61	0.48	0.27	0.77	0.65	0.38	1.20	0.88	0.54	2.31	1.71	1.01
Latin America	2.98	2.21	1.37	4.09	3.13	1.89	5.80	4.46	2.90	11.20	8.82	5.47
Near East	1.93	1.01	0.06	2.72	1.38	0.08	4.17	1.94	0.11	8.06	4.05	0.23
Far East	5.57	1.73	1.10	7.80	2.42	1.47	11.53	3.45	2.08	23.97	6.47	3.92
Total market ec.	11.09	5.43	2.80	15.38	7.58	3.82	22.70	10.73	5.63	45.54	21.05	10.63
Asian centrally planned economies	5.88	1.94	0.60	7.42	2.67	0.80	10.00	3.75	1.01	17.91	6.88	1.72
Total developing countries	16.97	7.37	3.40	22.80	10.25	4.62	32.70	14.48	6.64	63.45	27.93	12.35
Total world	51.34	29.49	25.34	64.46	37.49	30.89	83.98	45.17	39.89	145.46	76.22	66.91

Source: For the period up to 1987/88, FAO/UNIDO/World Bank Working Group on Fertilizers, Paris meeting of June 19-23, 1978.
For the period 1987/88 to 2000/2001, calculated as discussed in section 4.2.1 and 4.2.2 of this study.

Annex D-1(a) - Fertilizer demand forecast, by region

Developed countries	**Trend function**
Market economies	$N \rightarrow y = 2.3777 + 0.54417\ t + 0.0044\ t^2$
	$P_2O_5 \rightarrow y = 11.01129 + 0.19972\ t + 0.00247\ t^2$
	$K_2O \rightarrow y = 8.33026 + 0.208243\ t + 0.0078856\ t^2$
Centrally planned economies	$N \rightarrow y = 0.41061 + 0.021308\ t + 0.015975\ t^2$
	$P_2O_5 \rightarrow y = 0.92414 - 0.06694\ t + 0.0118739\ t^2$
	$K_2O \rightarrow y = 1.1336 - 0.02727\ t + 0.011805\ t^2$
Developing countries	
Africa	$N \rightarrow y = 0.155457 + 0.0182775\ t + 0.001233\ t^2$
	$P_2O_5 \rightarrow y = 0.070654 - 0.008778\ t + 0.0008327\ t^2$
	$K_2O \rightarrow y = 0.042176 - 0.005059\ t + 0.0004853\ t^2$
Latin America	$N \rightarrow y = 0.343776 - 0.06480\ t + 0.0056397\ t^2$
	$P_2O_5 \rightarrow y = 0.23449 - 0.55276\ t + 0.004541\ t^2$
	$K_2O \rightarrow y = 0.173878 - 0.0356388\ t + 0.0028327\ t^2$
Near East	$N \rightarrow y = 0.2558 - 0.06044\ t + 0.004330\ t^2$
	$P_2O_5 \rightarrow y = 0.082513 - 0.028758\ t + 0.0021599\ t^2$
	$K_2O \rightarrow y = 0.009758 - 0.00059596\ t + 0.0001164\ t^2$
Far East	$N \rightarrow y = 1.5406165 + 0.1157649\ t + 0.0150063\ t^2$
	$P_2O_5 \rightarrow y = 0.09312 - 0.025676\ t + 0.00306298\ t^2$
	$K_2O \rightarrow y = 0.056356 - 0.014693\ t + 0.001839\ t^2$
Asian centrally planned economies	$N \rightarrow y = 0.02038489 + 0.0210506\ t + 0.0067365\ t^2$
	$P_2O_5 \rightarrow y = 0.03954 - 0.014539\ t + 0.0030259\ t^2$
	$K_2O \rightarrow y = 0.0294687 + 0.00937916\ t + 0.000513735\ t^2$

Annex D-2 - Fertilizer demand forecast, share by region (world level)

(percentage)

Region	1978/79			1982/83			1987/88			2000/01		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Developed countries												
Market economies	41.00	46.86	48.30	37.53	40.92	46.03	33.67	36.95	42.24	27.91	27.60	37.78
Centrally planned economies	25.95	28.15	38.28	27.10	31.74	39.01	27.39	30.99	41.11	28.47	35.76	43.76
Total developed countries	66.95	75.01	86.58	64.63	72.66	85.04	61.06	67.94	83.35	56.38	63.36	81.54
Developing countries												
Africa	1.19	1.63	1.06	1.19	1.73	1.23	1.43	1.95	1.35	1.59	2.24	1.51
Latin America	5.80	7.49	5.41	6.35	8.35	6.12	6.91	9.87	7.28	7.70	11.57	8.18
Near East	3.76	3.42	0.24	4.22	3.68	0.26	4.96	4.29	0.28	5.54	5.31	0.34
Far East	10.85	5.87	4.34	12.10	6.46	4.76	13.73	7.64	5.21	16.48	8.49	5.86
Total market ec.	21.60	18.41	11.05	23.86	20.22	12.37	27.03	23.75	14.12	31.31	27.61	15.89
Asian centrally planned economies	11.45	6.58	2.37	11.51	7.12	2.59	11.91	8.31	2.53	12.31	9.03	2.57
Total developing countries	33.05	24.99	13.42	35.37	27.34	14.96	38.94	32.06	16.65	43.62	36.64	18.46
Total world	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Source: Calculated from data in Annex D-1

Annex D-3 - **Fertiliser demand forecast - Growth rate, by nutrient and region**

Region	1976/1982			1982/1987			1987/2000		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Developed countries									
Market economies	3.2	2.3	3.5	3.2	1.7	3.5	2.8	1.8	3.2
Centrally planned economies	7.6	9.2	5.2	5.7	3.30	6.4	4.6	5.3	4.6
Total developed countries	4.9	4.9	4.3	4.2	5.6	4.8	3.7	2.4	3.9
Developing countries									
Africa	6.8	7.6	10.3	9.3	6.2	7.3	5.2	5.3	4.9
Latin America	10.3	8.8	9.4	7.3	7.3	8.9	5.2	5.4	5.0
Near East	8.8	6.8	8.1	8.9	7.0	6.6	5.2	5.8	5.8
Far East	10.2	11.8	11.6	9.1	7.3	7.2	5.8	4.9	5.0
Total market economies	9.8	9.2	10.0	8.1	7.2	8.0	5.5	5.3	5.0
Asian centrally planned ec.	6.8	8.3	8.1	6.1	7.0	4.8	4.6	4.8	8.1
Total developing countries	8.7	8.9	9.9	7.5	7.2	7.5	5.2	5.2	4.9
Total world	6.2	5.9	5.0	5.4	6.0	5.2	4.3	3.2	4.1

Source: Calculated from data in Annex D-1

Annex D-4 - Fertiliser demand forecast - Nutrient ratio, by region

Region	1982/83			1987/88			2000/01		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Developed countries									
Market economies	1.70 1.57	1.08 1	1	1.68 1.69	0.99 1	1	1.61 1.93	0.83 1	1
Centrally planned economies	1.45 1.47	0.99 1	1	1.40 1.64	0.85 1	1	1.41 1.52	0.93 1	1
Total developed countries	1.59 1.53	1.04 1	1	1.54 1.44	1.07 1	1	1.50 1.70	0.89 1	1
Developing countries									
Africa	2.03 1.18	1.71 1	1	2.22 1.36	1.63 1	1	2.30 1.34	1.71 1	1
Latin America	2.16 1.31	1.66 1	1	2.00 1.30	1.54 1	1	2.05 1.27	1.61 1	1
Near East	34.00 1.97	17.25 1	1	37.91 2.15	17.64 1	1	35.18 2.60	17.66 1	1
Far East	5.31 3.22	1.65 1	1	5.54 3.34	1.66 1	1	6.12 3.71	1.65 1	1
Asian centrally planned ec.	9.28 2.78	3.34 1	1	9.90 2.67	3.71 1	1	10.39 2.60	3.98 1	1
Total developing countries	4.93 2.22	2.21 1	1	4.92 2.26	2.18 1	1	5.14 2.27	2.26 1	1
Total world	2.09 1.72	1.21 1	1	2.11 1.67	1.26 1	1	2.17 1.91	1.14 1	1

Source: Calculated from data in Annex D-1.

Annex D-5(a) - Forecast of nitrogenous and potash production capacity
(millions of MT)

Region	N			K_2O		
	1978	1982	2000	1978	1982	2000
Developed countries						
Market economies	40.36	41.55	68.41	18.05	19.13	36.94
Centrally planned economies	27.59	36.47	69.78	14.10	17.15	41.90
Total developed countries	67.95	78.02	138.19	32.15	36.28	78.84
Developing countries						
Africa	0.55	1.09	3.51	-	-	0.28
Latin America	3.89	7.20	17.02	0.03	0.03	0.60
Near East	3.41	6.46	12.25	-	0.72	1.44
Far East	7.54	11.66	36.43	-	-	-
Total market economies	15.39	26.41	69.21	0.03	0.75	2.32
Asian centrally planned economies	11.13	11.13	27.22	0.36	0.50	2.35
Total developing countries	26.52	37.54	96.43	0.39	1.25	4.67
Total world	94.47	115.56	234.62	32.54	37.53	83.51

Source: For the period up to 1982, FAO/UNIDO/World Bank Working Group on Fertilizers, Paris meeting of June 19-23, 1978. For the period 1982-2000 calculated as discussed in section 4.3.1 and 4.3.2 of this study.

5.3.4 Plant construction

In the preceding chapters a number of matters relevant to the construction of plants have arisen, specially in chapters 5.1 and 5.2. This section gathers these together and lists other factors involved.

1. If the prospective fertilizer organization lacks specialist staff, the first essential is to engage a reputable independent consultant who will act on his behalf or support him with technical advice and assistance in the initial feasibility studies, in preparing the invitation to bid, in selecting a contractor and negotiating a contract with him, and in monitoring the progress of construction.

2. The invitation to bid should be comprehensive and detailed and the form and scope of the bids required should be clearly stated so that comparable tenders are received. Any alterations or additions must be passed on to all tenderers.

3. Under normal circumstances the client should insist on proven processes, should keep the plant as simple as practicable, should choose standard plant sizes and should be generous in his allowance of spares.

4. Competitive tenders should be obtained from experienced and reputable contractors.

5. The subject of types and conditions of contract is too specialised for detailed discussion here. The First Fertilizer Consultation Meeting in January 1977 asked that the drawing up of model forms of contract and the possibility of insurance against consequential losses caused by faulty process design or faulty equipment should be investigated. Reports on these issues will be presented to the Second Consultation Meeting on Fertilizers to be held in November 1978. However, the more frequent types of contract are the following:

(a) "turn-key" contract;

(b) complete supply contract except the civil engineering that is implemented by the buyer, but for which the contractor provides designs

Annex D-5(b) - Forecast of phosphate production capacity
(millions of MT of P_2O_5)

Region	1978/79			1982/83			2000/01		
	Phosphoric acid	Supply non-acid sources	Total	Phosphoric acid	Supply non-acid sources	Total	Phosphoric acid	Supply non-acid sources	Total
Developed countries									
Market economies	17.19	5.81	23.00	17.65	5.85	23.50	24.48	5.76	30.24
Centrally planned economies	5.74	4.26	10.00	7.49	4.70	12.19	25.81	6.10	31.91
Total developed countries	22.93	10.07	33.00	25.14	10.55	35.69	50.29	11.86	62.15
Developing countries									
Africa	1.55	0.24	1.79	2.51	0.28	2.79	7.48	0.45	7.93
Latin America	0.99	0.58	1.57	2.08	0.67	2.75	3.58	0.95	4.53
Near East	1.18	0.22	1.40	2.41	0.39	2.80	4.17	0.82	4.99
Far East	1.26	0.30	1.56	1.64	0.47	2.11	2.64	1.07	3.71
Total market economies	4.98	1.34	6.32	8.64	1.81	10.45	17.87	3.29	21.16
Asian centrally planned economies	0.07	2.04	2.11	0.18	2.79	2.97	1.50	5.10	6.60
Total developing countries	5.05	3.38	8.43	8.82	4.60	13.42	19.37	8.39	27.76
Total world	27.98	13.45	41.43	33.96	15.15	49.11	69.66	20.25	89.91

Source: For the period up to 1982/83, FAO UNIDO/World Bank Working Group on Fertilizers, Paris meeting of June 19-23, 1978.
For the period 1982/83 to 2000/01, calculated as discussed in section 4.3.1 and 4.3.2 of this study.

Annex D-6 - Fertiliser forecast - production capacity share

Region	1978/79			1982/83			2000/01		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Developed countries									
Market economies	42.72	55.51	55.47	35.96	47.85	50.97	29.16	33.63	44.23
Centrally planned economies	29.21	24.14	43.33	31.56	24.82	45.70	29.74	35.49	50.17
Total developed c.	71.93	79.65	98.80	67.52	72.67	96.67	58.90	69.12	94.40
Developing countries									
Africa	0.58	4.32	-	0.94	5.68	-	1.50	8.82	0.34
Latin America	4.12	7.79	0.09	6.23	5.60	0.08	7.25	5.04	0.72
Near East	3.61	3.38	-	5.59	5.70	1.92	5.22	5.55	1.72
Far East	7.98	3.77	-	10.09	4.30	-	15.53	4.13	-
Total market econom.	16.29	15.26	0.09	22.85	21.28	2.00	29.50	23.54	2.78
Asian centrally planned economies	11.78	5.09	1.11	9.63	6.05	1.33	11.60	7.34	2.82
Total developing c.	28.07	20.35	1.20	32.48	27.33	3.33	41.10	30.88	5.60
Total world	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Source: Calculated from data in Annexes D-5(a) and D-5(b)

Annex D-7 - Fertiliser production capacity growth rate

Region	1978/1982			1982/2000		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Developed countries						
Market economies	0.7	0.54	1.46	2.81	1.40	3.72
Centrally planned economies	7.2	5.07	5.02	3.67	5.49	5.09
Total developed countries	3.5	1.98	3.07	3.23	3.13	4.41
Developing countries						
Africa	18.65	11.73	-	6.71	5.97	-
Latin America	16.64	15.04	-	4.89	2.81	18.11
Near East	17.32	18.92	-	3.62	3.26	3.93
Far East	11.51	7.84	-	6.53	3.18	-
Total market economies	14.45	13.40	124.00	5.50	4.00	6.47
Asian centrally planned economies	-	8.92	8.56	5.09	4.54	8.98
Total developing countries	9.07	12.33	33.80	5.38	4.12	7.60
Total world	5.17	4.34	3.63	4.01	3.42	4.54

Source: Calculated from data in Annexes D-5(a) and D-5(b)

Annex D-8 (a) - **Fertilizer production requirements to the year 2000: investments and raw materials**

Region	No. of plants 1982/2000		Capital investments (billions of $,1977) 1982/2000		Raw materials requirements in 2000 (millions of MT)						
	N	P_2O_5	N	P_2O_5	Nat. gas ($10^9 m^3$)	Naphtha	Fuel oil	Coal	Phosphate rock	Sulphur	K_2O
Developed countries											
Market economies	78	36	11.62	3.24	35.42	2.77	3.87	11.08	74.91	20.71	32.14
Centrally planned econom.	97	95	14.45	8.55	36.11	2.82	3.95	11.29	78.98	21.84	36.45
Total developed countries	175	131	26.07	11.79	71.53	5.59	7.82	22.37	153.89	42.55	68.59
Developing countries											
Africa	8	27	1.53	3.11	1.98	0.16	0.22	0.62	21.62	5.98	0.22
Latin America	33	8	6.32	0.92	9.56	0.74	1.05	2.99	10.35	2.86	0.46
Near East	20	9	3.83	1.04	6.89	0.54	0.76	2.15	12.05	3.34	1.11
Far East	83	6	15.90	0.69	20.47	1.60	2.84	6.41	7.63	2.11	-
Total market economies	144	50	27.58	5.76	38.90	3.04	4.27	12.17	51.65	14.29	1.79
Asian centrally planned economies	57	7	10.92	0.81	15.30	1.20	1.67	4.78	4.34	1.20	1.81
Total developing countries	201	57	38.50	6.57	54.20	4.24	5.94	16.95	55.99	15.49	3.60
Total world	376	188	64.57	18.36	125.73	9.83	13.76	39.32	209.88	58.04	72.19

Source: Calculated from data in Annexes D-5(a) and D-5(b) as discussed in sections 4.3.3 and 4.3.4 of this study.

Annex D-8 (b) - Fertilizer production requirements to the year 2000: manpower needs for 1982/2000
(in thousands)

Region	Nitrogen complex			Phosphate complex			Total N-P manpower
	Technical	Non-technical	Total	Technical	Non-technical	Total	
Developed countries							
Market economies	17.94	5.46	23.4	5.65	1.23	6.88	30.28
Centrally planned econom.	22.31	6.79	29.1	14.92	3.23	18.15	47 5
Total developed countries	40.25	12.25	52.50	20.57	4.46	25.03	77.53
Developing countries							
Africa	3.71	1.42	5.13	10.26	2.03	12.29	17.42
Latin **America**	15.28	5.84	21.12	3.04	0.60	3.64	24.76
Near **East**	9.26	3.54	12.80	3.42	0.68	4.10	16.90
Far East	38.43	14.69	53.12	2.28	0.45	2.73	55.85
Total **market economies**	66.68	25.49	92.17	19.00	3.76	22.76	114.93
Asian centrally planned economies	26.39	10.09	36.48	2.66	0.53	3.19	39.67
Total developing countries	93.07	35.58	128.65	21.66	4.29	25.95	154.60
Total world	133.32	47.83	181.15	42.23	8.75	50.98	232.13

Source: Calculated from data in Annexes D-5(a) and D-5(b) as discussed in section 4.3.5 of this study.

Annex E - Case study on plant capacity utilization in the Far East region

In 1975 the Economic and Social Commission for Asia and the Pacific produced a "Report of the Expert Group on Regional Co-operation in Chemical Fertilizer Production and Distribution" which gives the following data on the utilization of capacity in the region in 1974.

ESCAP REGION: CAPACITY UTILIZATION 1974

	NITROGEN ('000 tons N)			PHOSPHATE ('000 tons P_2O_5)		
	Capacity end-1974	Production calendar-1974	Output (%)	Capacity end-1974	Production calendar-1974	Output (%)
Bangladesh	212.0	75.0	35.4	49.5	0 b/	0 b/
India	2,153.0	1,115.0	51.8	655.5	316.0	48.2
Indonesia	273.0	141.0	51.7	-	-	-
Iran	157.0	141.9	90.3	102.0	88.3	86.6
Korea, Rep.of	543.0	512.0	94.3	147.0	162.0	110.3
Malaysia	44.0	42.0	95.4	-	-	-
Pakistan	313.0	300.0	95.9	9.6	4.2	54.0
Philippines	114.5	59.0	51.5	78.0	45.3	76.8
Thailand	26.0	6.3	24.2	-	-	-
	3,835.5	2,392.2	62.4	1,041.6	615.8	59.1

b/ Up to September 1974.

The Bangladesh output was low because the larger of the two nitrogen factories was closed for half the year after an explosion. A fuller account of plant utilization in India is given below. In Indonesia the largest plant only began operations in August 1974. The low utilization in Thailand is due to operational difficulties with a lignite gasification plant.

One of the most interesting and comprehensive papers on this subject is a survey entitled "Productivity in the Indian Fertilizer Industry" by the Fertilizer Association of India in Fertilizer News, March 1975. The survey covers the period 1969-70 to 1973-74 for twelve nitrogen fertilizer factories, six nitrogen and phosphate factories and an unspecified but presumably much larger number of superphosphate factories. In 1969)70 the total installed capacity was 1.33 million tons of N and 0.43 million tons of P_2O_5, and this had increased by 1973-74 to 1.95 million tons N and 0.58 million tons of P_2O_5, so that during the period N capacity increased by 50 per cent and P_2O_5 capacity by 35 per cent. The effect of this increase is seen in the summmary below which sets out the overall capacity utilization for each year in the first line, and in the second removes fertilizers which started up in the year in question. Only a partial correction is possible for P_2O_5 factories.

		1969-70	1970-71	1971-72	1972-73	1973-74
Original%	N	53	63	62	70	54
Utilization	P_2O_5	52	53	56	66	56
New						
Factories	N	61	63	67	70	66
Eliminated	P_2O_5	52	53	57	66	56

The corrected figures are much more consistent and suggest an improvement in utilization from 60 per cent to 65-70 per cent over the five years. The nitrogen fertilizer plants perform better than the phosphate fertilizer plants, though they also show an improvement. The poorer performance of the phosphate plants is probably due to the large number of old and relatively small single superphosphate plants included. The analysis does not give the losses caused by external factors, such as the supply of raw materials, power or spare parts. If these losses were excluded there is no doubt that the percentage utilization figures would be significantly higher.

An analysis according to plant age showed that plants set up prior to 1960 had much lower utilization, and thereafter that,in general, the newer a plant the better its performance. A classification of N plants according to size showed no marked differences, though there were indications that the larger plants were marginally better. Nitrogen plants using naphtha as a feedstock did much better than plants using coal, though the comparison was heavily weighted by difficulties in the Neyveli plant which uses lignite. In 1972-73 the seven major naphtha-based plants averaged 86 per cent utilization. A survey according to processes showed that steam-reforming plants gave very good results (91 per cent for 1972-73) and partial oxidation

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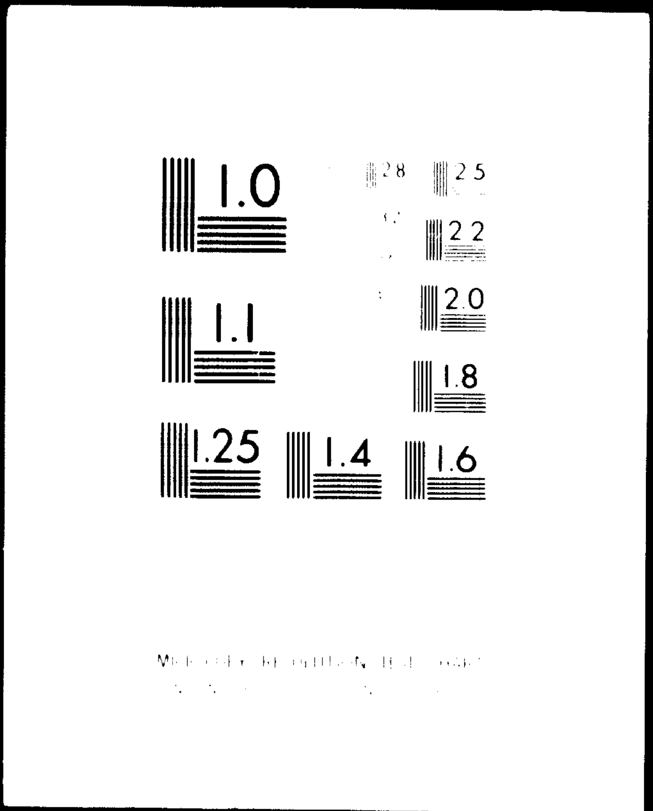

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J. Supply of goods, intermediates, spare parts, component and raw materials

(1) definition of equipment

(2) lease or sale of equipment

(3) source of procurement

(4) supply of drawings and other constructional data of equipment

(5) "Tied" provisions and clauses

K. The production phase

(1) subcontracting

(2) source and quality of raw materials etc.

(3) schedule of production

(4) testing procedures

(5) supply of technical information to meet standards of quality

L. Special aspects concerning trade marks

(1) registration of trade marks of the licensor

(2) assignment or transfer application for registration of trade marks to licencee

(3) registration of the licencee

(4) description of the trade marks to be used

(5) agreed products and sources concerning which trade marks may be used

(6) methods of use

(7) exclusivity or non-exclusivity

(8) termination of use of trade marks

(9) duration

(10) quality control of the product

(11) use of other control

(12) sale or produce of products under different trade marks

(13) price of products for which trade marks has been granted

(14) suspension or termination of use of trade marks

(15) assignement of licence and grant of sub-licence

(16) infrigements

(17) non-use of trade marks

(18) price and payment

M. Other aspects concerning marketing

(1) products labeling; advertising or publicity and other promotion activities

(2) channels of distribution

(3) sales prices of the product

(4) import of the product manufactured by licensor or third person

(5) export of products manufactured by licencee

(6) sale of same or similar products by the licencee

N. **Management services**

(1) budget and work programme

(2) appointment by licencee/licensor of personnel for the operation

O. **Compensation consideration; price, remuneration; royalties; fees**

(1) terminology

(2) varietes

- initial payment
- lump-sum payment
- series of lump-sum payment
- royalties
- computed royalties
- special aspects of net selling price
- maximum royalties
- minimum royalties
- plan and drawing fees
- consulting fee
- separate pricing or valuation of each element of the technology
- maximum amount of price or cost of industrial property rights or the technology
- indirect non-monetary compensation
  (a) cost shifting or sharing
  (b) feed-back of information
  (c) acquisition of market and patent data
  (d) supply of parts and components
  (e) dividends and value increase of financial participations; capitalization of lump-sum payments or royalties

P. **Settlement of payments**

(1) reports

(2) books of account; files etc.

(3) designation of currency, remittance and exchange rate

(4) tax treatment of amounts payable by licencee

(5) credit terms and guarantees of payment

Q. **Most favourable terms and conditions**

(1) as to royalties only

(2) as to other terms and conditions

(3) specification of the countries in respect which the term and condition of concluded agreements are to be compared with existing licence

R. Rights of related enterprises; transfer and assignment; sublicencing; sub-contracting

(1) exercise or use by related enterprise
(2) right to grant sub-licence
(3) transfer ability and assignability
(4) sub-contracting
(5) disclosure of confidential information
(6) approval of government authorities

S. Injury or damage to third person or third property; insurance

(1) responsibility of the licensor arising out of the licence
(2) responsibility of the licensor out of performance of its obligations under licence towards licencee
(3) Insurance

T. Default; changed conditions or events; waiver; remedies

(1) delay or non-performance by the licensor
(2) delay or non-performance by the licencee
(3) change in conditions or accurence of events interferring with performance
(4) waiver

U. Entry into force; duration; term; termination; expiration; extension

(1) entry into force
(2) term of licence
(3) termination
(4) expiration and extension of the term
(5) renewal; negotiation of new terms
(6) effect of termination or expiration

V. Approval of government authorities

(1) approval of government authorities of the country of the licencee
(2) approval of government authorities of the country of the licensor

W. Settlement of disputes

(1) text controlling interpretation of the licence
(2) other rules of interpretation
(3) applicable law
(4) means of settlement of disputes

X. **Modification or amendments**

(1) procedure

(2) approval of government authorities

Y. **Notices, appendices, annexes**

(1) designation of addressee

(2) place of address of addressee

(3) language of notice

(4) means of communication

(5) effective date of notice

(6) content of appendices, annexes etc.

(7) conflict in wording

Z. **Execution**

(1) authorized officers

(2) place(s)

(3) date(s)

(4) witness

(5) certification or legalisation

(6) locations of execution in the licence

Annex H: Training Schemes

Pakistan: Fauji Agrico Fertilizer Project[a]
Operational manpower needed and training (1,000 NH_3 + 1,725 Urea)

1. When in full operation, the project will employ about 660 people including some 200 contract workers for product handling, loading and general labor. About 100 of these will be production and enginneering personnel ranging from senior managers to shift supervisors and chief operators. A few experienced key people may possibly be recruited from the other fertilizer producers in Pakistan plus, perhaps, several Pakistanis now working overseas. However, the majority of the skilled work force needed will have to be hired and trained in Pakistan, as it is the intention of the sponsors and GOP to use Pakistan staff and labor to the fullest extent and as soon as possible. Accordingly, arrangements have already been made with Dawood Hercules Ltd. (which operates a Kellogg ammonia plant and a Toyo urea plant) to train key supervisory, operating and engineering personnel on behalf of FAFCO, for a suitable fee and expenses. This is expected to cost the equivalent of about US $ 800,000 in local currency and will be undertaken as follows.

Training Program for FAFCO Technical Personnel

General

2. FAFCO has prepared a program to cover the pre-startup training of technical personnel. The program, of 36 to 40 weeks' duration, is aimed at preparing a team of personnel capable of carrying out successfully the task of commissioning, and subsequently of efficient operation and maintenance, of the fertilizer complex.

3. The program will consist of the training of three batches in succession, comprising of Senior Engineers, Unit Engineers, and Plant Operators, respectively. Each batch will undergo a combination of classroom and in-plant training, with the course content and duration specified in accordance with the technical level of the trainees, as well as their future job requirements in the organization.

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a/ World Bank Report No. 1392-PAK, 1976. Vol. II Annex 4-5

4. Once the first batch of Senior Engineers has gone through the training program, they will participate in the training of subsequent batches as instructors together with the DH personnel.

5. The performance of each trainee will be determined on the basis of weekly tests as well as their general participation in the training program and the results will be sent to the FAFCO management.

6. The outstanding feature of the program is the exposure of all levels of personnel to an operating plant, in which the training can be immediately and directly related to plant experience.

Scope of program

7. In view of the complexity of the tasks associated with the commissioning and operation of a modern fertilizer complex, the training will include a study of the relevant chemical and mechanical engineering principles. However, the main part of the program will be devoted toward equipping trainees with a knowledge of process principles, operating procedures and equipment and mechanical details of their respective areas. In particular, all trainees will be taught the essentials of modern plant practices regarding safety, good housekeeping, handling of various toxic chemicals, plant upsets and emergency shutdown procedures.

8. The practical part of the program will begin with training on a Carmody simulator[b], which will help in familiarizing the trainees with the control panel and associated plant operations. The main practical training will be carried out on the Dawood Hercules plant, in keeping with the specific job requirements of the different batches.

Program structure and content

9. The training period of the Senior Engineers will be 16 weeks, with 10 weeks devoted to classroom training and the remainder to in-plant training. The training will be conducted by DH engineers, who will also have overall management responsibility for the program. The batch of 15 trainees will have the following composition:

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[b] This device is analogous to the Link trainer used for instructing aircraft pilots via simulated flight while on the ground.

4 Plant Incharges
4 Shift Incharges
2 Process Engineers
4 Maintenance Engineers
1 Chief Chemist
15

10. Since a knowledge of the entire complex is considered necessary at this level, during the class training the batch will be kept in a single group, and will follow a common syllabus. Training on a Carmody simulator will also be done. During in-plant training, the batch will be assigned to the respective plant incharges at the DH plant in the general shift, although some flexibility will be maintained in the schedule to enable the technical and engineering staff to keep in tough with their counterparts at the DH plant. With the completion of their training, the plant incharges will stay on at the DH plant to conduct and supervise the training of their respective batches of Unit Engineers, while the remainder will move on to the FAFCO site.

11. The Unit Engineers' training will cover a period of 12 weeks with 8 devoted to classroom training. The batch will have the following composition:

12 Unit Shift Engineers
4 Process Engineers
4 Maintenance Engineers
1 Chemist
12 Boardmen
33

12. The batch will be divided into three groups, i.e., ammonia, urea and utilities, in keeping with the future job assignments of the trainees. During the classroom training the group will be required to study the manuals and other materials relating to their respective plants. The general chemical and mechanical engineering training will be common to all groups, as will the training regarding general plant practices. Training on a Carmody simulator will also be performed. During in-plant training the trainees will be attached to the Shift Engineers in charge of the respective units at the DH plant, and will be required to be on shift duty.

With the completion of their training, the unit shift engineers will stay on at the DH plant to conduct the training of the operators attached to their respective units, while the remainder of the batch, i.e., the process and maintenance engineers, and boardmen, will move on to the FAFCO site.

13. The training of the operators will cover 10 weeks, with 6 weeks allocated to classroom training, and the remainder to in-plant training. The composition of the batch will be as follows:

16	Ammonia
20	Urea
16	Utilities
4	Bagging & Shipping
56	

14. During classroom training the operators will be given a general idea of the complex and also of their respective plants, but the main stress will be on studying manuals and other materials relating to the specific areas to which they will be attached. General plant practices will also be discussed, as in the previous two batches, but an additional item will be the teaching of some basic topics of chemistry and chemical engineering. In-plant training of the operators will be carried out by conducting extended plant visits, under the supervision of the concerned unit shift engineer, which will enable the operating staff to observe at first hand the operation and maintenance of their respective areas of the units and complex.

Training materials and syllabus

15. The classroom training will centre around the operating manuals and equipment specifications to be provided by the suppliers of the ammonia and urea plants, and of the main items of the utility plant. In addition, operating and equipment manuals provided by the suppliers of special equipment such as major turbines, pumps, compressors, refrigeration equipment, will be studied. The breadth and depth of study of each batch will depend on the duties required. In the case of Senior Engineer, all the operating and equipment manuals will be studied, while for the Unit Engineers and Operators the respective units and areas will be covered.

16. Other materials will include operating and maintenance fundamentals, which will be studied by the trainees in their own time, through the method of programmed learning. Safety handbooks and chemical handling will be studied by all batches, while the operators will also study some basic aspects of chemistry and engineering.

17. A Carmody simulator will be used in the phase of classroom training for Senior and Unit Engineers. This will familiarise the trainees with the control panel, and will prepare them for upsets and emergencies faced during plant operation and start-up.

18. As requested by the Bank, further training opportunities will be provided for key Pakistani project and operating personnel by arranging for them to work in the office of Kellogg, USA and Toyo Engineering, Japan during the engineering and procurement phases of the project. Selected groups of Pakistani engineers and others will work side-by-side with their US and Japanese counterparts and will also be given appropriate experience in the workshops and offices of the major equipment vendors (especially makers of rotary machines). Most importantly, during the final stages of plant construction and subsequent commissioning, Pakistani administrative, supervisory and operating manpower will work closely with experienced field crews from the contractors, vendors and key Agrico operating personnel and put into practice their previously acquired learning. This supplemental experience plus the formal training program in the Dawood Hercules plant should provide FAFCO with a proficient, safety-conscious and reliable plant operating staff.

19. Training of senior designated Pakistani executives in project and operations administration, market research and marketing will also be undertaken on a side-by-side basis in conjunction with experienced Agrico personnel according to the corporate management structures shown in annex 2-2 and annex 4-6 and as part of the Technical Assistance and Know-how Agreement between Fauji and Agrico.

ANNEX I.

Fertilizer marketing systems in three selected countries

1. Thailand

1.1 Presentation

The chemical fertilizer consumption in Thailand is low, although during 10 years (1964-1974) it increased about five times:

in Kg/ha

	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
$N+P_2O_5+K_2O$	2.4	2.6	5.0	7.6	7.4	7.8	6	9.3	11.6	10.7	13.4

The area cultivated in 1973 was about 14,500 thousand ha., and in 1975 about 15,000 thousand ha.

Compound fertilizers are used to a great extent, the preferred formulae being: 16:20:0; 20:20:0; 18:24:0; 15:15:15; 13:13:21.

The mixed chemical fertilizer factory, having capacity of 100,000 - 120,000 t/y started its production in 1975 and manufactures about 17 types of NPK mixed fertilizers and some grades with microelements (mgO and Cu) using only imported basic fertilizers.

Another fertilizer factory is Mao Moh Lignite Factory, commissioned in 1966, having a design capacity of 60,000 t urea and 30,000 t ammonium sulphate, but operating considerably under its capacity (in 1976 only 19,000 t of ammonium sulphate and about 24,000 t of urea).

Approximately 80 per cent of the fertilizer demand is imported each year and 20 per cent at the most is produced in Thailand.

The consumption, production and import of fertilizers are shown by the following data, in thousands of metric tons:

	1970	1972	1974	1975	1976
Consumption of fertilizers (N-P-K)	268.3	283.3	434.3	386.6	552.8
out of which imported %	92.5	82.4	97.8	87.6	77.0

plants gave acceptable but distinctly lower results (76 per cent for 1972-73). There were also indications that plants making a single product, preferably urea, did rather better than plants producing two or more products.

The FAI report sums up the survey as follows:-

"The foregoing analysis does, however, point to the fact that by and large modern plants with a large capacity using naphtha feedstock and adopting steam reforming processes and producing a single product, preferably urea, and owning a power plant tend to turn out very well...... The lesson here is obvious. For a country like India with limited resources and which has rapidly to augment domestic production to meet the ever increasing demand, we must adopt proven, even though less sophisticate , technology and equipment..........despite the the handicaps and constraints under which we operate, the fertilizer industry in India compares favourably with its counterparts elsewhere........the plants can produce up to their maximum capacity if external constraints like power, raw materials and spare parts were removed. The direction in which action needs to be taken is thus clear."

The types of fertilizers imported in 1976 were the following: nitrogen fertilizers - 211,000 t; phosphorous fertilizers - 1,815 t; potassium fertilizers - 12,450 t; mixed fertilizers - 282,000 t; other types - 114,000 t. The ammonium sulphate (207,000 t) and potassium sulphate (12,900 t) represent an important share for the import.

An increase in the fertilizer consumption is foreseen for 1980 to about 536,000 t, for 1985 to about 710,000 t and for 1989 to about 845,000 t, out of which most part is compound fertilizers of various grades, containing MgO too.

1.2 Fertilizer Supply

About 28 per cent of the fertilizer used is produced domestically, the balance being imported. There are approximately 160 fertilizer importers, foreign and national.

1.3 Distribution Channels

Nearly all fertilizer sold in Thailand has its origin in Bangkok. Imported fertilizer is transported by truck and domestic production by trail. About 69 per cent of all fertilizer transport is by truck, 24 per cent by rail and 7 per cent by water.

All fertilizers are sold in bags either paper or plastic. Individual weights can vary from 50 Kg down to 3 Kg or even 0.5 Kg. The smaller bags require higher prices.

The government owns 25,000 metric tons of storage which is used primarily for fertilizers. Private dealers are responsible for providing their own, most of which is in Bangkok with little or no storage up country. Nearly 50 per cent of all fertilizers are sold in the period from May to August.

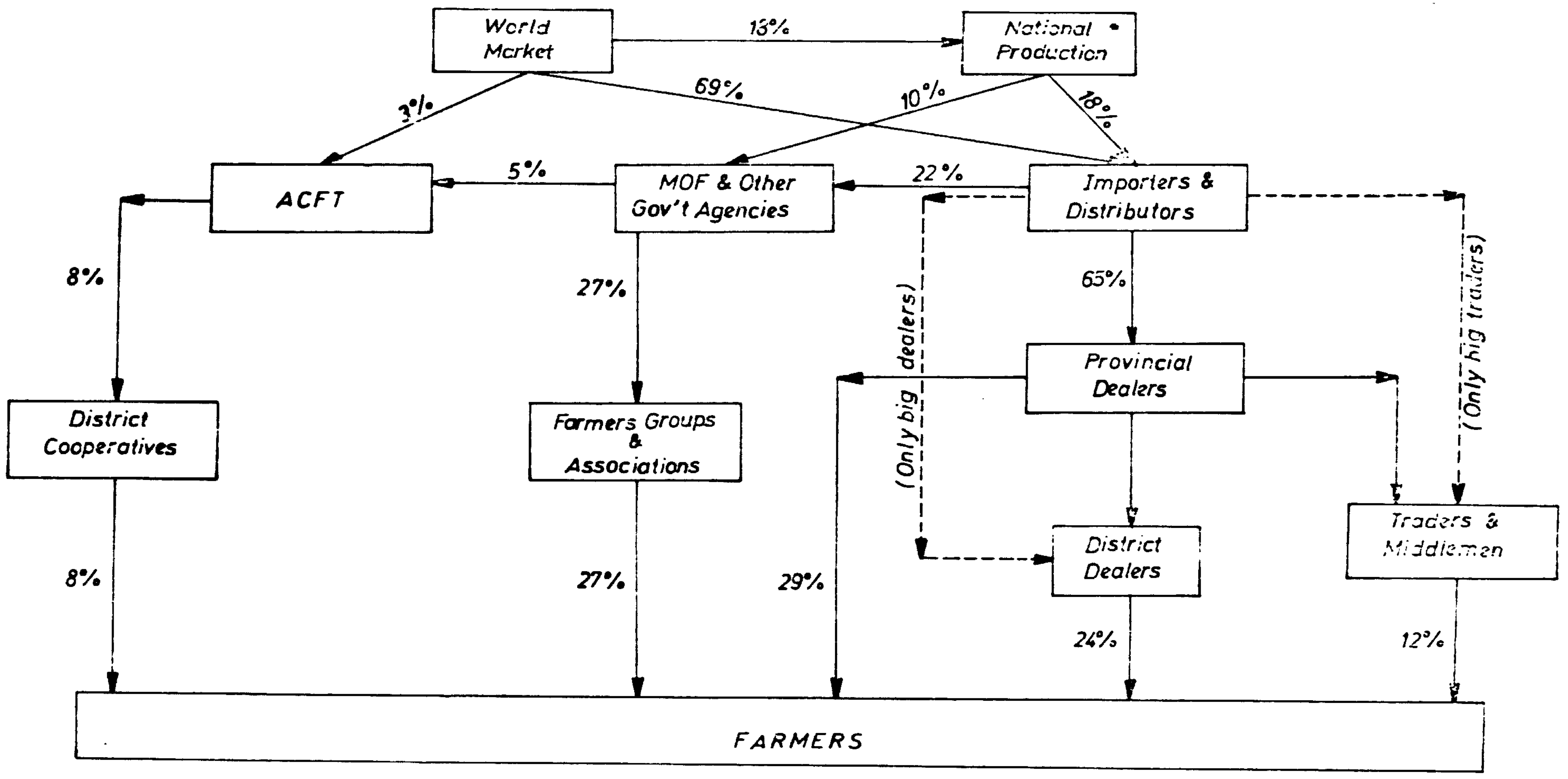
The pattern of distribution is shown on the following chart.

1.4 Marketing System

One third of domestic production goes to large wholesalers and two-thirds to dealers. Imports go to the large wholesalers and representatives of the foreign suppliers roughly in the ration of 1:2. These firms are the foundations of the marketing system.

Figure I.1

FERTILIZER DISTRIBUTION IN THAILAND 1975



NOTE: ACFT: Agricultural Cooperative Federation of Thailand Ltd.
MOF: Marketing Organization for Farmers.
* Including mixing plants.

They supply the dealers and sub-dealers. It is estimated that about 73 per cent of the total fertilizer is supplied to farmers through the private dealers. Sugar and rice mills also supply fertilizer particularly to their growers. There is also a small public sector which includes a co-operative organization. Various government bodies like the Rubber Estate Organization and the Tobacco Monopoly physically provide some fertilizers to farmers. The Irrigation Department makes credit arrangements and provides organizational help to farmers buying from big trading farms in Bangkok. Co-operatives who supply only about 8 per cent of the fertilizer get their supplies through government sources.

The distinction between the functions of wholesaling or retailing is not definite in Thailand, because many wholesalers do their own retailing. It is estimated that there are many thousands of retailers most of whom are multiproduct.

A typical pattern pf renumeration might be:

Importers margin	- 12 per cent of landed price
Wholesalers margin	- 17 per cent of wholesale price
Dealers margin	- 5 per cent of retail price
Sub-dealers margin	- 3 per cent of retail price

1.5 Credit

Nearly 70 per cent of farmers buy fertilizers on credit, of these just over half use institutional credit and the remainder "open market" credit from from dealers, money-lenders and friends. Not all dealers give credit and those that do, many are selective accommodating certain customers only or giving loans only on some fertilizers.

Wholesalers credit to dealers averages about 8 months. In turn dealers normally give farmers credit of from 6-8 months, the length of time it takes to plant and harvest the major crops. Dealers often make most of their profit from credit. While the interest rate for credit from wholesaler to dealer is about 12 per cent per annum, the dealers usually charge the farmer double this.

1.6 Price Structure

Prices are not controlled and can vary widely. Discounts are given at both dealer and farmer level for quantity and cash. Seasonal discounting is not usually practiced. Promotional work by wholesalers includes giving dealers bonuses per ton sold.

1.7 Extension Services

Technical advice is given by the government extension service, some private wholesalers offer limited assistance.

At dealer level some literature provided by the extension servise or major importers is distributed. Most dealers are not technically trained or knowledgeable and much of their effort goes into brand advocacy+).

2. Brazil

2.1 Presentation

There are three important agricultural regions in Brazil where fertilizers are applied: north-eastern, central and southern areas, out of which the central one participates almost 2/3 of the total fertilizer consumption.

The main areas where a large amount of fertilizer is used are cultivated with: coffee, corn, maize, cotton, sugar cane, pea nuts.

The fertilizer consumption between 1973-1976 has developed as follows:

Thousands tons $N+P_2O_5+K_2O$

	Nitrogen			Phosphate			Potassium		
	1973/74	1974/75	1975/76	1973/74	1974/75	1975/76	1973/74	1974/75	1975/76
Consumption	346	395	410	724	806	915	529	521	588
Production	114	150	160	320	371	510	-	-	-

Source: FAO Commission on Fertilizer - Fourth Session - Sep. 1977.

Most of the fertilizer applied were NPK compounds as blends or granular blended materials.

Most of them are transported by lorries, a large amount being sent directly to the farmers. In the central area of Brazil, intermediate storages are experimented.

+) - Fertilizer Statistics 1976-77. The Fertilizer Association of India, New Delhi - Dec. 1977.
- FIA-FAO Seminar on Strategy for Stimulating Fertilizer Consumption, 1976. The Fertilizer Association of India - March 1977.
- Handbook on Fertilizer Marketing - The Fertilizer Association of India - New Delhi - Dec.1976

2.2 Marketing System

Between 80-90 per cent of fertilizers are sold through private dealers and the balance through co-operatives. Two methods of using private dealers are in operation.

2.2.1 where all sizes of farm are catered for through commission agents;

2.2.2 where salaried representatives handled large orders but prefer to have exclusive retail dealers as well as commission agents to handle orders up to 10 tons.

The principal contact with the farmer is the commission agent who usually sells one company's products only and receives a payment of between 3 and 8 per cent of the sales price. Typically he helps the farmer by a) arranging for bank financed fertilizer credit; b) arranging truck transport for the fertilizer prices are generally fob plant; c) sending soil samples to parent company for analysis and fertilizer recommendation; d) collection payment.

Between 10-20 agents respond to an area sales inspector who plants and monitors the sales campaign and, in turn, himself reports to one of a number of regional sales supervisors who are the key communication link between production and sales. They set sales targets and transmit company objectives to the sales force.

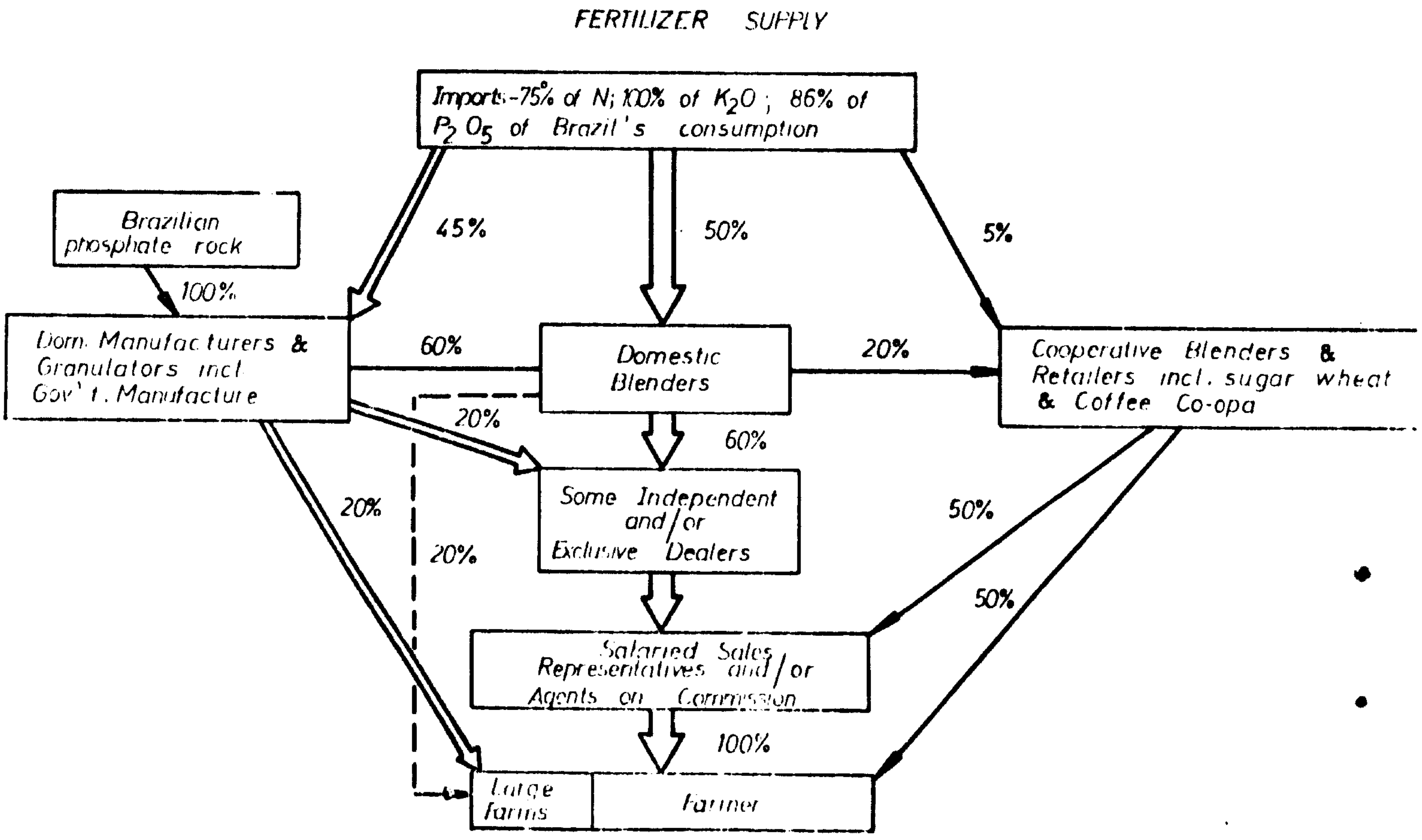
Sales targets are fixed by estimating local consumption and the amount which each agent ought to be able to sell based on his farmer contacts. His area is usually a radius of 5-10 km from a town. Efforts are made to avoid agents overlapping.

Companies using the method described in 2.2.2 have separate routes to reach the farmer: salaried retail salesmen, exclusive retail dealers and commission agents. Each sells direct of farmers but the salaried salesmen confine themselves to 10 ton loads or over, bearing the smaller orders for dealers and commission agents.

Dealer mark-up is usually 6 per cent plus early buying and quantity discounts. Although usually dealers sell only one brand of fertilizer, they do sell other inputs. Up to 60 per cent of the tonnage may follow this route.

The commission agent handles about 10-20 per cent of the tonnage but the quantity is declining. The tendency is use him in areas

Figure I.2
BRAZIL'S FERTILIZER DISTRIBUTION CHANNELS



(Percentages are in terms of the total tonnage at each market level. About 20%-30% of the material moves from domestic manufacturers and blenders through regional field storage.)

remuneration varies between 3 and 8 per cent of the retail price.

The manufacturer provides technical advice on cultural practices, runs farmer educational meetings, analyses soil samples and interprets the results for the farmer. There is also a tendency in these companies to move mixing and blending units into major consuming areas, supplying blending materials in bulk. They sell fob plants delivered on custom applied by the dealer.

2.2.3 The co-operatives are mainly retailers, but do some importing and mixing too.

They hold about 10-20 per cent of the market; half of their sales are made direct to farmers and the other half through commission agents.

Co-operatives usually get a 5 per cent discount, which for large tonnages may increase to 10 per cent. In turn, they give a 5 per cent discount for volume and 3 per cent discount for payment before the end of the fertilizer year. Most local co-operative customers rely on local bank credit and/or credit extended by the co-operative. Frequently if a grower uses co-operative credit, he must market his crop through the co-operative.

Usually negotiations with the fertilizer supplies can result in better prices for early delivery in which case the co-operative is prepared to provide credit for 6-9 months.

For the future, co-operatives recognize the need to provide storage facilities not only for most form inputs but also for grain.

2.3 Credit

Assistance to obtain bank loans is provided by 2/3 of the dealers and most provide credit, either directly or through an agent of their company. The quoted interest charges vary from 12 to 36 per cent per year. In addition, FUNDAG, created in July 1970, is a government supported credit programme which provides credit at 7 per cent for up to 5 years for all, modern inputs like fertilizers, pesticides, animal protein supplements, improved seed.

2.4 Price Structure

Fertilizer prices are determined by the individual companies for the following six-month period. The prices are usually for manufacturing and/or mixing plant. Some companies publish a retail list on a delivered basis; the list prices are basic and discounts are given for volume and cash payments. There are no fertilizer subsidies.

3. Federal Republic of Germany

3.1 Presentation

Between 1973-1976 the fertilizer consumption - which was very high-showed a slight increase in nitrogen fertilizers and a significant decrease in the phosphorous ones due to the considerable rise in phosphate prices.

Thousand tons ($N+P_2O_5+K_2O$)

	Nitrogen			Phosphate			Potassium		
	1973/74	1974/75	1975/76	1973/74	1974/75	1975/76	1973/74	1974/75	1975/76
Consumption	1,101	1,201	1,228	917	877	780	1,163	1,170	1,099
Production	1,473	1,774	1,259	962	911	649	2,539	2,659	1,848

Source: FAO Commission on Fertilizers, Fourth Session, Sep. 1977.

Over 30 per cent of them are applied as compound fertilizers and about 50 per cent as ammonium nitrate.

The phosphate consists of 60 per cent compound grades and 35 per cent basic slag. Potassium is incorporated in compound fertilizers in percentage of over 50 per cent.

3.2 Fertilizer Supply

In fertilizer industry which is privately owned, produced in 1969/70, 4.7 million tons NPK of which about 40 per cent was exported.

3.3 Distribution Channels

There are t distribution channels at both wholesale and retail level - private traders and co-operatives. So far as possible the wholesaler avoids involvement in the physical tasks of movement and storage. The aim is to have at the most only one storage point between manufacturer and farmer, at the retailer. About 55 per cent of the tonnage is handled by co-operatives and the balance by private retailers.

Rail movement is used extensively, particularly for the large journeys, for shorter trips trucks are employed. The manufacturer arranges this initial movement.

3.4 Marketing System

The diagram shows the marketing structure of the industry. Generally the minimum annual sales of a wholesaler are over 50,000 tons. The two largest each sell over 1 million tons per year.

The main functions of the wholesaler are to administer the collection of orders, and to organize credit on favourable terms for the retailer. He does not, as a rule, keep stock of fertilizer or become involved in transport.

The share of co-operatives has increased in recent years because they enjoy certain fiscal priviledges and have easier access to the capital market because they can more easily combine in a trade association. As modern marketing facilities demand increasing investment this is an important advantage. Access to capital is further facilitated by the very close links which exist between the rural co-operatives and the rural co-operative banks, which serve not only the farming sector, but also other business sectors and industrial workers living in rural areas.

At the retail level rather more than half the fertilizer tonnage is sold by local co-operatives, who are completely free in their choice of wholesaler. In addition to fertilizer a full range of other inputs is sold by the retailer, who also buys from the farmer his crops. Often fertilizer sales may be no more than 15 to 20 per cent of the total turnover.

The margins allowed to wholesalers and retailers are somewhat variable depending to a degree on the services they perform. In general, the wholesaler may receive 2 to 4 per cent of the retail list prices and the retailer about 7 per cent. Competition can force these rates down.

3.5 Credit

The provision of credit is one of the main functions of the wholesaler. Generally, the fertilizer manufacturer does not provide credit , he expects payment about 10 days after the customer receives his account.

Most fertilizers are sold to farmers on credit of between three and six months duration. A co-operative bank (they are widely spread) may offer a farmer personal credit. Private retailers make extensive use of bills of exchange which are discounted either by wholesalers or banks. The method of financing has the advantage of being simple and relatively cheap. There is no special government services for financing fertilizer sales. The Central Bank may well give some priority to discounting bills of exchange.

After more than 70 years trading in fertilizers, there are no major problems in financing fertilizer orders.

3.6 Price Structure

Prices are fixed by the manufacturers for the ensuring fertilizer year and are retail selling prices, franco buyer's nearest railway station. They include an average transport cost and are the same for the whole country. Discounts are allowed for quantity and cash. In addition there are rebates for early delivery to help the dispatch load on the factory. A further incentive for this purpose is an early ordering rebate which leaves the delivery date at manufacturer's option. For early delivery the discount is a maximum of 11 to 12 per cent, and for early ordering one to three per cent. There are no government subsidies.

3.7 Extension Services

The government supported farmer's extension service is well developed. In addition, each of the fertilizer manufacturers has his own specialized fertilizer advisory service, which advises in mainly retailers and farmers on the practical economic aspects of fertilizer marketing and application. The manufacturers have their own research stations and part of the research is subcontracted to specialized university research institutes. The co-operatives and private traders

Annex F - Main types of plant available

1. Bagging and blending plants

The simplest way of making a start in the fertilizer industry is to import solid fertilizers in bulk and to set up a plant which bags them and also blends nitrogen, phosphate and potash fertilizers to produce a range of mixtures for a local market. The plant is relatively cheap, it is labour intensive, and it requires very few skilled people. The plant itself would cost $0.5 to $1.0 million, but this would be increased to $3 to $5 million by working capital in stocks of imported materials and blended products, depending on the size of consignment in which the bulk fertilizers are received. There are no technical limits to plant size but a market for about 20,000 tons a year would be needed to justify a plant, and at 100,000 tons a year a plant with a higher added value should be considered. The plant is very flexible, both in its total output and in the range of mixtures that it can produce; it can produce mixtures to suit varying farming conditions, which it would probably be uneconomic to import.

Bulk blending plants can also be very useful, and present opportunities to small-scale entrepreneurs, in a country with a well established fertilizer industry. In this situation they would draw their bulk supplies of fertilizers from existing large plants, and supplement these with imported potash. With dependence on imports thus greatly reduced, there is much greater freedom in the choice of a location. Plants can, and should be, placed close to their markets; they also can develop a close and useful relationship with the local farming community. Because they draw most of their supplies from a local factory, they can operate with much lower stocks, and their working capital, which would otherwise comprise 50 to 70 per cent of their total capital, is greatly reduced.

2. Single superphosphate plants

Single superphosphate (SSP) is made by treating phosphate rock with sulphuric acid. An SSP plant comprises a sulphuric acid plant, rock treatment plant, granulation and bagging plant. The processes are relatively simple and require few technically trained or skilled people. The economies

FIGURE I.3

MARKETING CHANNELS FOR FERTILIZER: F. R. GERMANY, 1971

Manufacturer	Wholesaler	Retailer	Farmer
7 N	13 Central cooperatives	1600 Cooperatives for input and output marketing	672700 full time farmers part time farmers minor income outside agriculture
6 P_2O_5	9 Purchasing groups of retailers	8800 Cooperative rural banks (Raiffeisenkassen) with trading functions	
2 K_2O	30 Independent wholesalers	5600 Private	319600 part time farmers major income outside agriculture
Total 15	52	16000	992300

have their own training centres on business administration, marketing methods and financing. Their curriculum includes courses on economic aspects of fertilizer use.

The fertilizer industry provides mainly specialized advice on fertilizer application, but also advises retailers in the modernization and rationalization of marketing operations.

3.6 Government Regulations

Fertilizer legislation specifies quality standards and the appropriate inspection and control procedures.

Annex J FERTILIZER SUBSIDIES

Direct subsidies

Direct price subsidies for fertilizer are common in most developing countries. They are usually paid directly by the government (a) to the farmer; or (b) to the distribution outlet. If sufficient control is exercised to ensure that they are in fact being reflected in the price of fertilizer to the farmer, direct subsidies may be a very effective means of expanding fertilizer use. If, however, the subsidy is such that it has a really significant impact on use, the programme may tend to be very expensive. Furthermore, unless policies to expand fertilizer supplies simultaneously with subsidies are introduced, the subsidies will promote fertilizer scarcities and the potential increase in use due to the price subsidy will only be partly realized.

While a permanent price subsidy can lead to fertilizer shortages, temporary subsidy programmes can cause rapid expansion of fertilizer consumption in countries with excess productive capacity and resulting high domestic prices. As consumption increases, capacity utilization goes up and per unit costs are reduced. This, in turn, reduces the need to continue the subsidy programme. The problem with temporary subsidies, however, is that once introduced they tend to be difficult to phase out.

(a) Subsidy to the farmer. The dominant trend in most developing countries is to fix the retail price to the farmer at a maximum level above which it cannot lawfully be sold. For nitrogenous fertilizers, the price per unit of nitrogen is usually considered a base for the pricing of all types. This may not always be true of phosphate fertilizer, but it holds true for potash types. The fixed retail price to farmers is different from one country to another and may bear no relation to the world market price. It may also differ from one material to another. Annex table 1 below shows the variations in fertilizer retail prices and fertilizer subsidy in four selected developing countries in 1974, a year

Annex table 1. Retail prices (A) and subsidies (B), in selected developing countries, 1974 ($US/metric ton)

	Iran		Egypt		Bangladesh		Pakistan	
	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)
Urea	129.0	221.0	160.0	315.0	179.0	244.0	150.0	343.0
Am. nit 26%	107.0	198.0	85.0	192.0	-	-	87.0	250.0
Am. nit 35.5%	-	-	108.0	239.0	-	-	-	-
Am. sulphate	76.0	22.0	68.0	30.0	-	-	68.0	26.0
Single superphosphate	-	-	43.0	17.5	-	-	44.0	-
Triple superphosphate	119.0	231.0	-	-	143.0	290.0	110.0	298.0
DAP	178.0	272.0	-	-	-	-	150.0	282.0
Pot. sulphate	141.0	-	75.0	37.5	107.0	48.0	-	-

Sources: Worked calculated data from various different sources, and FAO Fertilizer Industry Advisory Committee and *ad hoc* Working Party on the Economics of Fertilizer Use 1975.

of unusually high prices. These data represent the highest degree to which the fertilizers had hitherto been subsidized. On the basis of unified fertilizer rate of application of urea nitrogen, the subsidy values per hectare for four crops - cotton, wheat, maize, and rice - in these countries are presented in Annex table 2, for the sake of comparison. It can be seen that, on the basis of the world market price for each of the four crops, and for effective subsidy, productivity of one of the four ought to be at the highest level in Pakistan, followed by Egypt, Bangladesh, and Iran. In fact, however, this is not true, which explains the quite different applicability of fertilizer subsidy as far as its economic efficiency is concerned in different developing countries. In other words, the benefits of fertilizer subsidy enjoyed by farmers in developing countries vary considerably.

Annex table 2. Calculated subsidy for four crops, selected developing countries, 1974
($US/ha)

Crops	Urea Rate of application (N kg/ha)	Iran	Egypt	Bangladesh	Pakistan
Cotton	170	82	117	91	127
Wheat	200	95	135	105	143
Maize	220	106	152	117	165
Rice	120	57	82	63	89

(b) Subsidy to distribution outlet. The general trend among governments in developing countries is to have all fertilizer activities carried out by the public sector. However, in many countries of Asia (Iran, Indonesia, India, Pakistan) and South America (Chile, Brazil, Colombia, and Argentina) fertilizer distribution and marketing are carried out by both government and private sector. Information regarding subsidies to private dealers in many of these countries is not sufficient to make a complete analysis; nevertheless, it is known that they are incorporated in transportation and other distribution costs.

Indirect subsidies

The real price of fertilizer may be reduced in a number of ways other than through direct subsidies. One of the most common means is to make credit available to farmers at subsidized interest rates. Where fertilizer acceptance is a consideration, supervised credit may be offered, i.e. credit contingent upon the supervision of new users by technicians. Permanent subsidizing of credit for fertilizer may prove to be costly, of course. Long-term solutions for the problem of agricultural access to financial markets may include the replacement of informed credit markets by other institutional forms.

Risk and uncertainity in agricultural production and lack of credit security are probably the major causes of high interest rates and reluctance among commercial banks to provide agricultural credit. Government policy aimed at reducing the risk and uncertainty and providing additional security for the moneylenders in a way acceptable to the farmer would be more likely to provide higher benefits than subsidized interest rates. However, it is difficult to guarantee in advance that subsidies earmarked for fertilizer purchases will in fact lead to an increase in the use of fertilizer. For this reason, the impact of such programmes may be much smaller than expected.

Indirect subsidies may also take the form of support to, inter alia, (a) local fertilizer manufacturers; (b) discharging operations; (c) transportation systems; (d) storage agencies; or (e) rebagging systems.

(a) Subsidy to local manufacturers. Domestic fertilizer production is strongly subsidized in most of the developing countries in order to keep local prices at or below the level of those of imported fertilizer. This was particularly true before the sharp increase in world fertilizer prices in 1973/74. The table below shows a wide variation in the subsidies given to domestic industrial production in Bangladesh, Pakistan, and Egypt in 1974. Before 1974, some countries imposed high taxes on imported fertilizers. This policy was considered to be a means, in a sense, of protecting local industry and to be a subsidy for local production. The practice of paying direct cash subsidies to manufacturers on ex-factory sales price, prevails in countries where the fertilizer industry is otherwise permitted to operate on a free enterprise basis. In countries where the industry is government-owned, the subsidy is usually paid at the end of the fiscal year as a penalty production cost in the case of budgetary deficit.

Subsidy for domestic production, selected developing countries, 1974
($US/metric ton)

Fertilizer	Bangladesh	Pakistan	Egypt
Urea	46.0	63.48	-
AN	-	28.15[a]	25.0[b]
AS	-	1.31	-
TSP	138.0	-	-
SSP	-	-	2.60

Sources: FAO Fertilizer Industry Advisory Committee on the Economics of Fertilizer Use, and National Statistics Data.

[a] For AN 26 per cent N.

[b] For AN 33.5 per cent N.

(b) Subsidy to discharging operations. Fertilizer imported by the public sector in the developing countries is usually bought on a "cost-including-freight" basis. Unloading costs are borne by the importer. These add considerably to the final costs. In addition, inefficient ship-to-shore handling is often a cause of serious losses. Sometimes, too, the cost of delays in unloading the transport ships has to be borne by the government. No detailed information is available at the present time regarding the real economic effects of such processes upon fertilizer costs in most developing countries. Whether all or part of them are paid by the governments or built into the wholesale fertilizer cost has to be clarified in the future for different countries. However, information available from Egypt reveals that discharging costs per metric ton in that country reached $13 million in 1974, the total sum of $1,350 million for fertilizer imports of about 100,000 metric tons of different types being carried entirely by the government.

(c) Subsidy to transportation systems. Costs of loading, transporting and unloading fertilizer tend to be higher in developing than in developed countries, thus adding to the retail prices. Where the government has set a ceiling for retail prices, the dealers are usually required to carry those additional costs. Where the government is the sole agency for fertilizer marketing, however, it absorbs the costs as a fertilizer subsidy.

(d) Subsidy to storage agencies. The repeated storing of fertilizers - first at factory warehouses, then at central warehouses and finally at co-operative societies or dealers' stores - results in relatively high costs. Local fertilizer producers in developing countries are responsible for the first type of storage and pay for it themselves as part of the over-all cost. The same principle is applicable to storage by dealers and traders. Storage in central warehouses or co-operative stores, which are usually government-owned, is often covered by the government and hence considered an additional subsidy.

(e) Subsidy to rebagging systems. Repeated moving and changes in the storage of fertilizers, even if they are stored and bagged for a long time or under pressure of high stacks, results in considerable damage because of the low durability of the bag material. The only solution to this problem is rebagging. In most cases, this takes place at the intermediate stage, at the centralized warehouses or co-operative stores. Rebagging costs are often borne by the government as part of an indirect cash subsidy.

The effects of fertilizer subsidy

Experience has shown that fertilizer subsidy has both advantages and disadvantages. Unless the subsidy is efficiently administered and implemented, its effect will not be wholly satisfactory. However, in general, subsidies have proven effective in the promotion and use of fertilizers. In Egypt, for example, in 1959/60, when no subsidy was allocated, nitrogen consumption was only 140,000 metric tons. With continued subsidy, however, it reached 410,000 metric tons in 1974/75, representing an increase of about 300 per cent of annual rate of growth of 20 per cent. There are many such reports of the success of fertilizer subsidy programmes in developing countries. The following table shows the dramatic effect of subsidy on fertilizer consumption in Brazil over a 20-year period.

Subsidy practices in Brazil, 1950-1970

	Subsidy	Consumption (thousands of metric tons)
1950	No	88.5
1958	Yes	249.7
1962	No	236.8
1966	Yes	281.1
1968	Yes	601.7
1970	Yes	820.0

Source: Fertilizer Use and Agricultural Development in Brazil. Economics and Sociology Occasional Paper No. 163 by W. C. Nelson and R. L. Meyer, Department of Agricultural Economics and Rural Sociology, Ohio State University, 1973.

The following table shows the effect on fertilizer consumption in Pakistan when the subsidy was changed from one year to another.

Effect on consumption in Pakistan of changes in subsidy

	Subsidy (mill. Rs)	Consumption (metric ton $N+P_2O_5+K_2O$)
1965/66	63	70,487
1966/67	124	111,834
1969/70	112	307,711
1972/73	199	436,495

Source: Study on Fertilizer Subsidies in Selected Countries, (FAO/FIAC, 1975).

On the other hand, the practice of providing subsidies is not necessarily to be intended for prolonged use. It should last only for the period needed to attain a margin of relief. An economically balanced agricultural structure is not necessarily an unsubsidized one, but for purposes of long-term policy planning, this may be the objective. The continuation of fertilizer subsidies over long periods has led, in many cases, to a dependent agricultural structure. Farmers in certain developing countries with stable subsidy systems are accepting the subsidies as their right, and figuring their returns accordingly. It should always be borne in mind that subsidies constitute a heavy drain on the budgets of developing countries.

Alternatives to subsidizing

As fertilizer subsidy programmes started only about 25 years ago, any verdict upon their effectiveness would still be premature, especially as full information regarding their use in developing countries is lacking. However, subsidies have proved successful in most of these countries. The degree of subsidy justification in one country may not necessarily match that of another. It is the farmers' standard of living, their actual need for subsidy, education level, and social status which create the personal attitude and eagerness to catch up with new technology and planning, their appreciation of the subsidy programmes, and their willingness to co-operate seriously.

Available indicators reveal that under certain conditions and specifications of agricultural structure, fertilizer subsidy is indispensable in developing countries. Where the agricultural sector is run completely by the government with emphasis on enforcing crop rotation and certain crop patterns with a view to marketing the great majority of farm products, fertilizer subsidy becomes an important component of the agricultural system. In countries where fertilizer use is something of a new trend in agriculture, a subsidy may be far more instrumental in promoting fertilizer use and crop production than any alternative system.

In Brazil and India, attempts were made to substitute fertilizer subsidy with crop price support. But as far as fertilizer use and consumption were concerned, it was found that they dropped sharply, along with crop production - and crop prices on the black market were enhanced considerably.

Finally, the two fertilizer subsidy systems mentioned earlier - direct and indirect - together with a moderately scaled crop price support policy, can work as a strong promotional tool for fertilizer use and crop production if the national budget has the financial resources required for a rather long period of time.

of scale are not large and a small plant producing 50 to 100 tons a day and costing $4 to $6 million, can be viable. The low concentration of the product (16-18% P_2O_5) limits the area that a plant can serve in competition with more concentrated products, e.g. triple superphosphate with 46 per cent P_2O_5, but it has the agronomic advantage of containing sulphur in appreciable quantities. It also has the considerable advantage that impurities in phosphate rock are much less troublesome than in the manufacture of the more concentrated fertilizers. It would be possible to make SSP from a locally available rock which would present problems as a raw material for phosphoric acid manufacture.

An SSP plant should be located close to its markets because the product weighs nearly twice as much as the raw materials used in its manufacture.

3. Satellite Plants

The next possibility after blending/bagging plants and SSP plants is the establishment of medium-sized fertilizer plants based upon the import of one or both of the fertilizer intermediates, ammonia and phosphoric acid. It involves a major step in terms of capital cost and complexity of operations, requires technically qualified people and makes heavier demands on the country's infrastructure. It is appropriate in countries which do not have the basic raw materials, but have built up a significant fertilizer demand, say 30,000 to 130,000 tons of nitrogen or phosphorus pentoxide a year. Fertilizer demand of this magnitude does not justify the establishment of a large plant based on imported raw materials, but a "satellite" plant using imported intermediates may be viable.

A satellite plant making about 250,000 tons of ammonium nitrate (80-85,000 t N) a year would cost about $45-50,000 million, and a plant making about 250,000 tons of AP (45,000 N and 115,000 t P_2O_5) a year would cost about $20-25 million. The considerable difference in cost arises from the fact that the manufacture of AP from phosphoric acid is a relatively simple operation involving the addition of ammonia to the acid, the evaporation of the AP solution and the granulation of the solid. In ammonium nitrate manufacture a similar series of operations is carried out, but it is preceded by the manufacture of nitric acid from imported ammonia.

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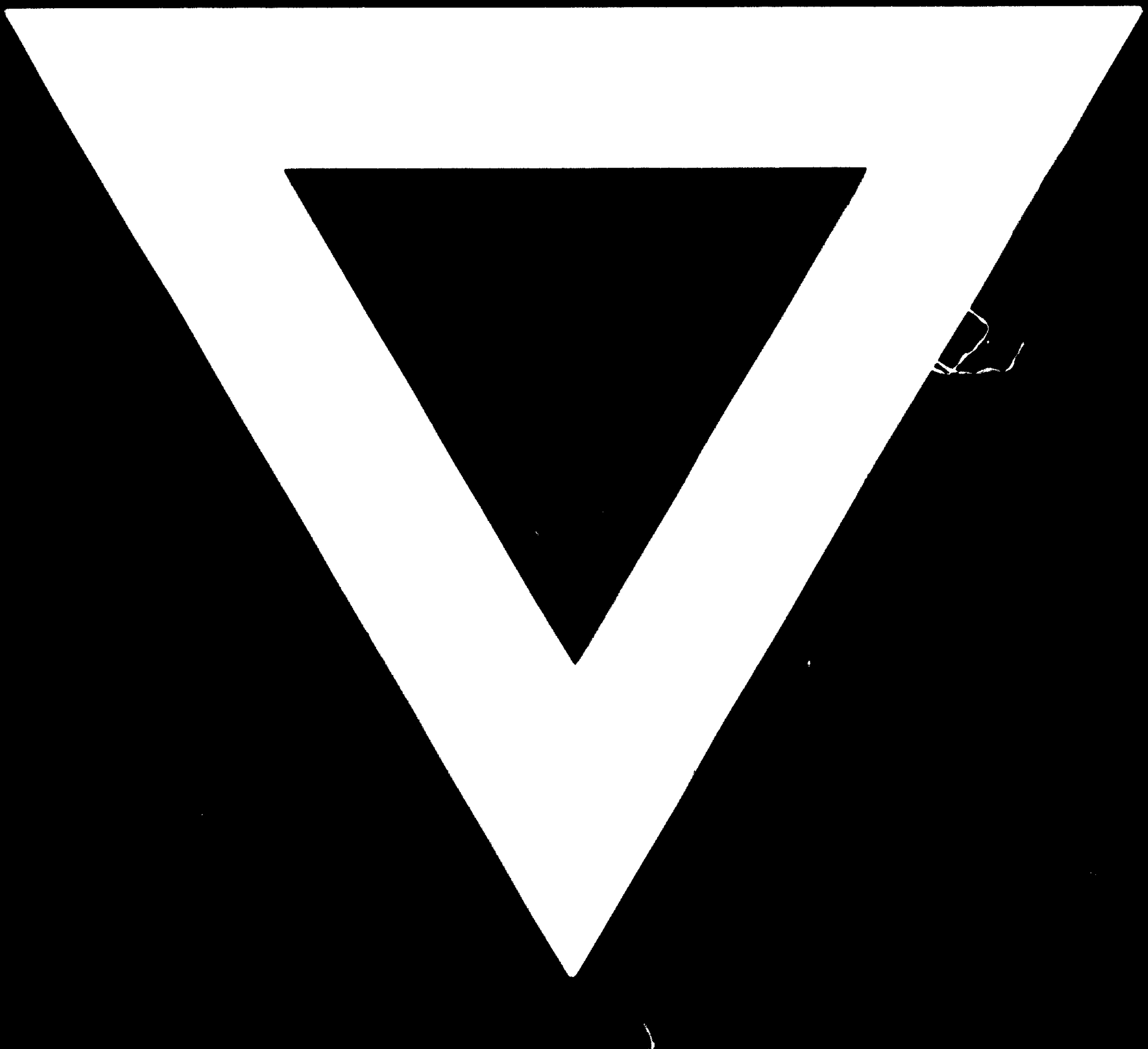

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Satellite plants have certain limitations. It is desirable to locate the plant within a few kilometers of the point at which the ammonia or phosphoric acid is off-loaded, so that it can be pumped directly from the ship to plant storage. If the plant is too far away for pumping and the ammonia or phosphoric acid has to be off-loaded into quayside storage porior to being transported to the plant, considerable additional costs are incurred. For ammonia, which requires refrigerated storage, these costs are particularly large, and the hazards of large scale storage may present problems.

A further limitation on nitrogen fertilizer plants is that, if they are to be profitable, ammonium nitrate, and not urea, must be made. The manufacture of urea requires supplies of both carbon dioxide and ammonia. Where ammonia is being produced, this is no disadvantage because carbon dioxide is a by-product of ammonia manufacture. However, if carbon dioxide has to be specially manufactured, the costs of its manufacture would make the urea prohibitively expensive. If urea is the predominant fertilizer in the market served by the plant, a market for ammonium nitrate should be developed before the plant starts up.

Phosphate fertilizer manufacture has no similar limitation. A satellite phosphate plant would make triple superphosphate (TSP) or ammonium phosphate (AP) and could also make NPK complexes. For TSP, it would be necessary to import some phosphate rock: for AP and NPK, some ammonia, potash and possibly ammonium nitrate or urea would have to be imported. If phosphate and nitrogen fertilizer plants were set up on the same site no imports, other than ammonia, phosphoric acid and potash, would be necessary and the range of products that could be manufactured economically would be greatly increased. In due course ammonia and phosphoric acid plants can be added, giving completely integrated fertilizer plants using locally available or imported raw materials.

4. Major fertilizer units

These are large-scale plants with fertilizer outputs of over a thousand tons a day, costing $150 to 350 million, which convert the basic raw materials into finished fertilizers. They comprise at least two separate chemical plants, one making an intermediate, such as ammonia or phosphoric acid, and another converting the intermediate into a finished product, e.g. urea or ammonium phosphate. They may have additional chemical plants, such as a sulphuric acid plant for phosphate fertilizers, a power station and extensive auxiliary facilities in the form of offices, workshops, stores, laboratories and so on. In some locations they may require housing estates and harbour facilities. They make heavy demands on the local infrastructure for water supplies, drainage, and for the transport of raw materials and products and also of equipment during construction.

They exist and multiply because, efficiently designed and operated, they make fertilizers more cheaply than any other type of plant, but they are not without their disadvantages. They are technologically complex and they require great technical skill and training, in both management and operation. Since single units of equipment are used, they are less reliable than the previous generation of multi-stream plants, as many operators have found to their cost. The older plants frequently operated at full output for 340 days a year; in the new plants 300 days is normally regarded as satisfactory. Furthermore, by virtue of its size, one single plant may supply a major part of a country's fertilizer requirements; thus any prolonged failure of the plant may lead to serious fertilizer supply problems. They also make very heavy demands on a country's industrial infrastructure. These disadvantages notwithstanding, major plants have gained almost universal favour since they produce fertilizers more cheaply than smaller or multi-stream plants.

Annex C - Basic elements of check-list to be used in activities evaluating the transfer of technology

A. Type of the agreement

1. Licence agreement
   - patent licence
   - industrial design licence
   - utility model licence
   - trade mark licence
   - plant variety licence
   - cross licence
2. Technology transfer agreement
   - technical information or technical know-how agreement
   - technical services and assistance agreement
     - (a) training services
     - (b) engineering services
     - (c) instalation services
     - (d) start-up services
     - (e) operation and maintenance services
     - (f) management services
     - (g) research and development services
     - (h) technical marketing and commercial information services
   - preliminary disclosure; maintenance of secrecy and option agreements
3. Franchise or distributionship agreements

B. Place, date and parties to the agreement

C. Preamble; whereas clauses; recitals

D. Definitions of key works and expressions

(a) rights granted and scope of the agreement
(b) product
(c) component parts, spare parts, repairs, etc.
(d) container and packaging material
(e) process
(f) licence, technology

  - invention
  - patent
  - trade-mark
  - know-how
  - technical information
  - technical data; operating and instruction materials
  - purchase and marketing information
  - basic detailed plant: layout
  - engineering, management, start-up, operations and maintenance services
  - improvements
  - developments

(g) plant and equipment

(h) measurements

(i) field of use

(j) royalties, remittance of funds and related terms

(k) territory

(l) legal entity

E. <u>Scope of licence options</u>

(1) identification of the availability of technology

(2) methods of acquisition
  - licence
  - trade mark
  - know-how
  - improvements

(3) utilisation of technology formula
  - field of use
  - exclusivity or non exclusivity
  - manufacture, use or sale
  - specification of the territory

(4) optional territory

(5) export of products

(6) extension, reduction or relinquishment of technology

(7) conditions under which licence may or may not use competitive technology

F. <u>Special aspects concerning patents</u>

(1) specification of the patents which are subject of the licence

(2) patent marketing and indication of manufacture under licence

(3) maintenance in force of the patent

(4) recognition of validity of rights and assurance of non-contest

(5) patent warranty and meazures to be taken upon the invalidation of the patent

(6) defense of the patent

(7) working of the patent invention

G. Technological advances: improvements and developments within the scope of the licence or the agreement

(1) improvements made by licensor

(2) improvements made by licence

(3) application for patent by one party

(4) transfer with or without the right to grant other a licence or sublicence

(5) reciprocity concerning improvements or inventions

(6) new products or processes

(7) research and development

H. Know-how; technical information

(1) scope in time of the know-how; developments in the know-how

(2) specification of know-how and the means for its transfer

(3) technical information

- content of technical information
- procedure of furnishing technical information

(4) disclosure of know-how

(5) guarantee of know-how

(6) guarantee offered for plant performance

(7) marketing of indication of manufacture of the products by virtue of know-how

I. Technical services and assistance

(1) training of licence personnel

(2) engineering services

(3) performance tests, start-ups and related services

(4) marketing and commercial information services

(5) management services

(6) research and development services