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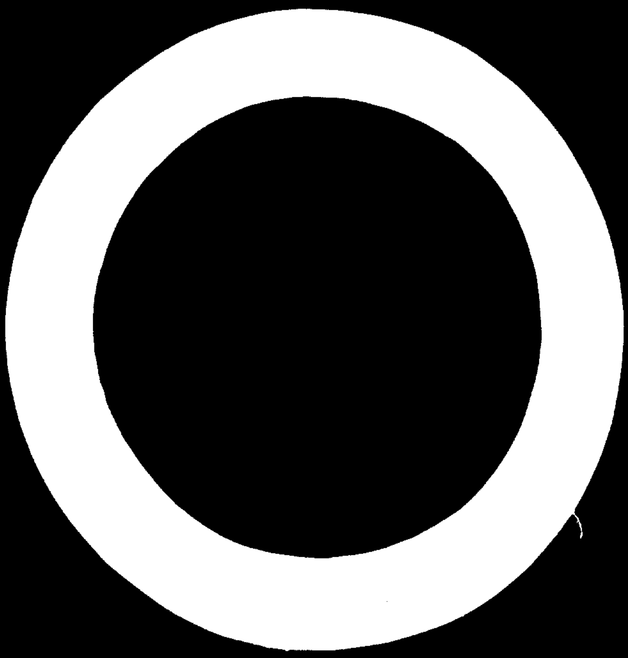
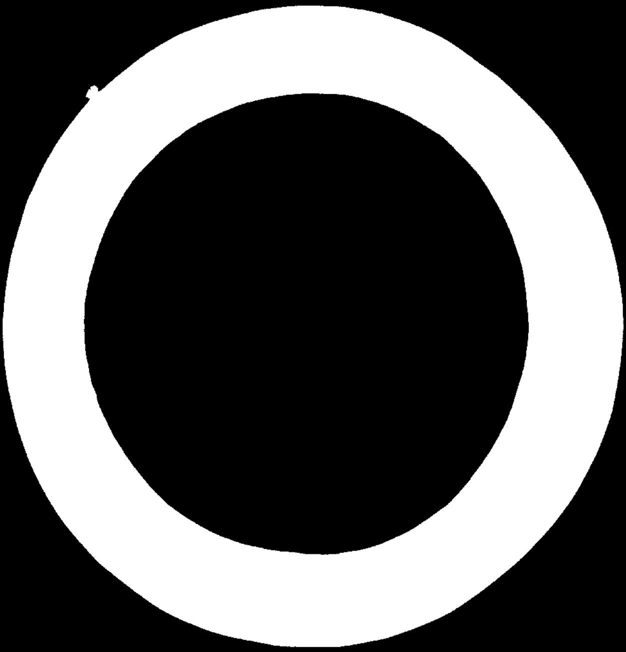
RECENT DEVELOPMENTS IN THE FERTILIZER INDUSTRY

UNITED NATIONS





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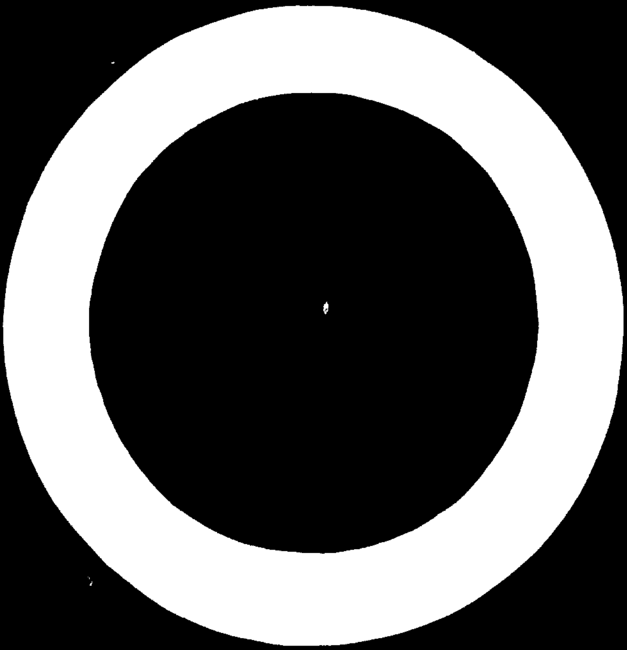

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
VIENNA

RECENT DEVELOPMENTS IN THE FERTILIZER INDUSTRY

Report of the Second Interregional Fertilizer Symposium
held at Kiev and New Delhi,
21 September to 13 October 1971

UNITED NATIONS
New York, 1972

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EXPLANATORY NOTES

Reference to tons is to metric tons.

Reference to dollars ($) is to United States dollars.

A slash indicates a one-year period encompassing two calendar years, as in a crop year or a financial year, thus: 1965/1966.

Use of a hyphen (–) between years signifies the full period involved, including the beginning and end years, thus: 1965–1966, 1965–1968.

The following abbreviations are used in this publication:

United Nations and specialized agencies

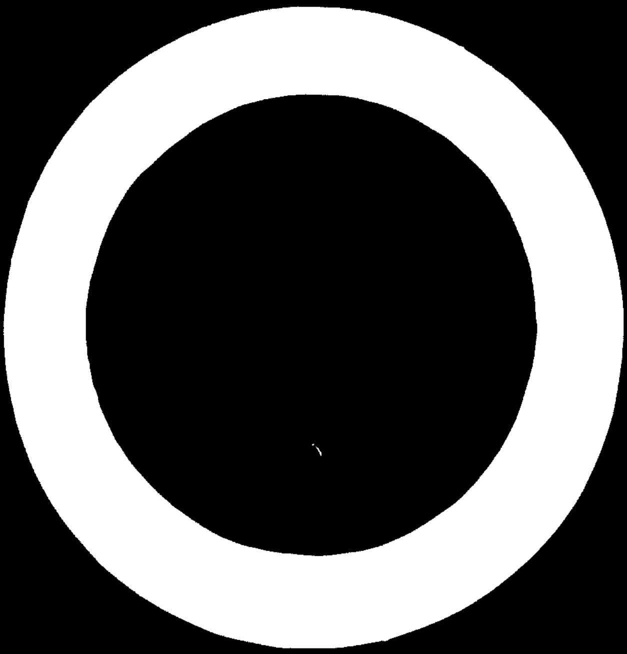
ECA	Economic Commission for Africa
ECAFE	Economic Commission for Asia and the Far East
ECE	Economic Commission for Europe
ECLA	Economic Commission for Latin America
FAO	Food and Agriculture Organization of the United Nations
IBRD	International Bank for Reconstruction and Development
IDA	International Development Association
IFC	International Finance Corporation
UNDP	United Nations Development Programme
UNESOB	United Nations Social and Economic Office in Beirut

Other organizations

ADB	Asian Development Bank
API	American Petroleum Institute
ASA	American Standards Association
CMEA	Council for Mutual Economic Assistance
EEC	European Economic Community
FIAC	Fertilizer Industry Advisory Committee
IDBI	Industrial Development Bank of India
IRRI	International Rice Research Institute
OAS	Organization of American States
OECD	Organisation of Economic Co-operation and Development
SIDA	Swedish International Development Authority
USAID	United States Agency for International Development

Economic, technical and scientific abbreviations

atm	atmosphere
DAP	diammonium phosphate
DEA	diethanolamine
DCF	Discounted cash flow
DIN	Deutsche Industrie Norm (German industrial standards)
FEC	Foreign exchange component
f.o.b.	free on board
GDP	Gross domestic product
GNP	Gross national product
ha	hectare (10,000 m^2)
HYV	High-yielding varieties
IAAP	Intensive Agricultural Areas Programme
IADP	Intensive Agricultural Development Programme
kcal	kilocalorie
kVA	kilovolt-ampere
LNG	Liquid natural gas
LPG	Low pressure gas
MAP	monoammonium phosphate
MEA	mono-ethanolamine
µm	micron (particle size measurement)
MW	Megawatt
ppm	parts per million
SSP	single superphosphate
TSP	triple superphosphate
VCR	Value-cost ratio



INTRODUCTION

The First United Nations Interregional Seminar on the Production of Fertilizers was held in Kiev, Ukrainian SSR, from 24 August to 11 September 1965.

The Second Interregional Fertilizer Symposium, organized by UNIDO in co-operation with the Governments of the Union of Soviet Socialist Republics and India, was held partly in Kiev, Ukrainian SSR, from 21 September to 1 October 1971 and partly in New Delhi, India, from 2 to 13 October 1971. The main objectives of the Symposium were:

To review and bring up to date the technological developments in the fertilizer industry during the past five years, with the aim of the transfer of technology to developing countries;

To make projections for production and consumption until 1980 and to discuss means of bridging the gap between the two;

To discuss possibilities for the design and construction of plants in developing countries;

To review the use of fertilizers in agriculture, their role in the "Green Revolution", and problems connected with their marketing and distribution;

To help resolve the problems facing the fertilizer industry in developing countries;

To forecast financing requirements of new projects during the Second United Nations Development Decade and to suggest ways to meet them;

To discuss the role of bilateral and international organizations in the development of the fertilizer industry.

This report follows the order of the presentation and discussion of papers at the Symposium. The conclusions and recommendations, which were discussed on the closing day (13 October 1971), form the last chapter.

The Symposium emphasized identifying the problems facing the fertilizer industry in developing countries and proposing solutions to these problems. The procedure of holding part of the Symposium in a developed country and part in a developing country allowed the participants to observe and study the evolution of the industry. Included in the programme were visits to a fertilizer complex in Cherkassy, Ukrainian SSR, and to a number of fertilizer plants in the north, east, south and west of India. The names and locations of plants visited are given in annex 3.

The Symposium held 24 meetings, of which 18 were in Kiev and 6 in New Delhi. The presentation and discussion of 108 technical papers made up the agenda. A list of papers circulated at the Symposium is given in annex 2.

Attending the Symposium were 247 participants from 40 countries and five international organizations: 32 participants from 22 developing countries; 10 UNIDO consultants from nine countries; 64 speaker participants from 13 countries and five international organizations; and 151 observers from 22 countries. The geographical distribution of the participants from developing countries is given below:

Region	*Number of countries*	*Number of participants*
Africa	5	5
Asia and Far East	4	9
Europe	6	9
Latin America	4	6
Middle East	3	3

The UNIDO secretariat and members of the organizing committees of the Second Interregional Fertilizer Symposium for the USSR and India provided the supporting services for the Symposium. Leading fertilizer experts from both developing and developed countries served as chairmen and rapporteurs of the various sections.

The Symposium was opened in Kiev by Mr. P. A. Rozenko, Deputy Chairman of the Supreme Soviet of the Ukrainian SSR and Chairman of the State Planning Committee of the Ukrainian SSR. In New Delhi, the Symposium was opened by Mr. P. C. Sethi, Minister of Petroleum and Chemicals. Mr. K. K. Cherednichenko, Deputy Minister, Ministry of Chemical Industries of the USSR, welcomed the participants in an opening speech. Mr. A. A. Zhukov, Director of the Organizing Committee of the USSR, was unanimously elected Chairman of the Kiev part of the Symposium, and Mr. B. Mukerji, Secretary to the Government of India, Ministry of Petroleum and Chemicals, was unanimously elected Chairman of the New Delhi part of the Symposium. Mr. M. C. Verghese, Chief of the Fertilizers, Pesticides and Petrochemicals Industries Section, UNIDO, was appointed Director of the Symposium. Mr. V. V. Kostenko of the State Planning Committee of the Ukrainian SSR was appointed Co-Director of the Kiev part of the Symposium, and Mr. I. G. Jhingran, Deputy Secretary to the Government of India, Ministry of Petroleum and Chemicals, was appointed Co-Director of the New Delhi part of the Symposium. Mr. Raymond Ewell, Vice-President for Research, State University of New York at Buffalo and UNIDO consultant, was appointed Technical Director of the Symposium. Section chairmen and technical rapporteurs were appointed in order to facilitate the presentation and discussion of papers.

I. WORLD FERTILIZER PRODUCTION AND CONSUMPTION AND INTERNATIONAL TRADE IN FERTILIZERS

The fertilizer industry is one of the major industries of the world with a total output in 1969/1970 of 200 million tons gross weight of products (containing 66 million tons of plant nutrients) and a total ex-factory sale value of approximately $7 billion. Among the world's industrial products, fertilizer is exceeded in gross weight of product only by steel, petroleum refinery products, cement and sawn lumber. By comparison with agricultural products, fertilizer is exceeded in tonnage only by wheat, maize, milk and rice.

Fertilizer is one of the largest commodities in international trade; approximately 50 million tons (gross weight) moved across international borders in 1969/1970. In addition to finished fertilizers, large tonnages of fertilizer raw materials (such as phosphate rock and sulphur) and fertilizer intermediates (such as ammonia and phosphoric acid) are traded on the world market.

World fertilizer consumption has increased steadily and at a high rate. In the 64 years after consumption statistics for fertilizer first became available in 1906, consumption grew as follows:

	Tons NPK
1905/1906	1,928,000
1913/1914	3,861,000
1919/1920	3,556,000
1938/1939	9,211,000
1945/1946	7,500,000
1947/1948	11,230,000
1959/1960	27,855,000
1969/1970	62,780,000

The rate of growth of fertilizer consumption over the decade of the 1960s averaged 8.5 per cent per year, which is the highest rate of growth since the years prior to 1913/1914 (see table 1 and bar chart for additional data).

Over the decade of the 1960s the developed countries experienced a growth rate for fertilizer consumption of 7.5 per cent per year, while the developing countries had a growth rate of 14 per cent per year, giving a world average of 8.5 per cent.

TABLE 1. PROJECTIONS OF WORLD PRODUCTION AND CONSUMPTION OF NITROGEN, PHOSPHATE AND POTASH FERTILIZERS FOR 1975/1976 and 1980/1981

	Nitrogen fertilizer (1,000 tons N)					
	Production			*Consumption*		
	1969/1970	*1975/1976*	*1980/1981*	*1969/1970*	*1975/1976*	*1980/1981*
Developed countries	26,200	41,500	57,200	20,810	34,500	48,500
Developing countries	4,135	9,500	14,800	7,675	14,200	19,900
Total	30,335	51,000	72,000	28,485	48,700	68,400

	Phosphate fertilizer (1,000 tons P_2O_5)					
	Production			*Consumption*		
	1969/1970	*1975/1976*	*1980/1981*	*1969/1970*	*1975/1976*	*1980/1981*
Developed countries	16,625	25,100	31,600	15,560	22,500	28,500
Developing countries	2,170	4,700	7,200	2,965	5,900	8,500
Total	18,795	29,800	38,800	18,525	23,400	37,000

	Potash fertilizer (1,000 tons of K_2O)					
	Production			*Consumption*		
	1969/1970	*1975/1976*	*1980/1981*	*1969/1970*	*1975/1976*	*1980/1981*
Developed countries	16,225	21,900	27,300	14,100	18,900	23,200
Developing countries	670	1,500	2,200	1,695	3,400	4,900
Total	16,895	23,400	29,500	15,795	22,300	28,100

	Total fertilizer (1,000 tons N + P_2O_5 + K_2O)					
	Production			*Consumption*		
	1969/1970	*1975/1976*	*1980/1981*	*1969/1970*	*1975/1976*	*1980/1981*
Developed countries	59,050	88,500	116,100	50,470	75,900	100,200
Developing countries	6,975	15,700	24,200	12,335	23,500	33,300
Total	66,025	104,200	140,300	62,805	99,400	133,500

Note: "Developing countries" include all countries of Asia, Africa and Latin America, except Japan. "Developed countries" include all the rest of the world. The bar chart (page 6) illustrates consumption data for four key years.

With regard to growth in the production of fertilizers, the developed countries evidenced a growth rate of 8 per cent per year in the 1960s, while the developing countries had a growth rate of 14.8 per cent, giving a world average of 8.6 per cent.

In 1969/1970 the developing countries produced 7 million tons of fertilizers (nutrient basis) and consumed 12.3 million tons, indicating an apparent deficit of 5.3 million tons. The developing countries showing the largest apparent deficits in 1969/1970 were: China[1] 1.6 million tons, India 0.8 million tons, Brazil 0.5 million tons, Cuba 0.5 million tons, and Turkey 0.4 million tons; and Egypt, Indonesia, Pakistan and the Republic of Viet-Nam 0.2 million tons each. These nine countries accounted for 85 per cent of the total apparent deficits for the developing countries in 1969/1970.

Projections of fertilizer production and consumption have been made for all countries in the world for 1975/1976 and 1980/1981, based on the historical data from 1959/1960 to 1969/1970. The projection method used was a graphical adaptation of the Gompertz growth curve.

The projections are summarized in table 1.

An increase in apparent deficits of the developing countries as a whole is predicted as follows: from 5.3 million tons in 1969/1970 to 7.8 million tons in 1975/1976, and 9.1 million tons in 1980/1981. The two largest deficits indicated by the projections for 1980/1981 are for China,[2] 3.1 million tons NPK, and India, 2.65 million tons NPK.

The projections for 1975/1976 and 1980/1981 agree closely with projections for these years made by the Tennessee Valley Authority and the Sulphur Institute (United States), and FAO. Estimates of fertilizer requirements to improve nutrition in the developing countries are somewhat higher than projected consumption. (For the actual and projected world consumption of fertilizers in four key years, see bar chart, page 6.)

Effective planning and large amounts of capital will be required to increase fertilizer production in the developing countries, from 7 million tons in 1969/1970 to 24.2 million tons in 1980/1981. Even larger amounts of capital will be required to make the developing countries self-sufficient in fertilizers by 1980/1981, i.e. production of 33.3 million tons.

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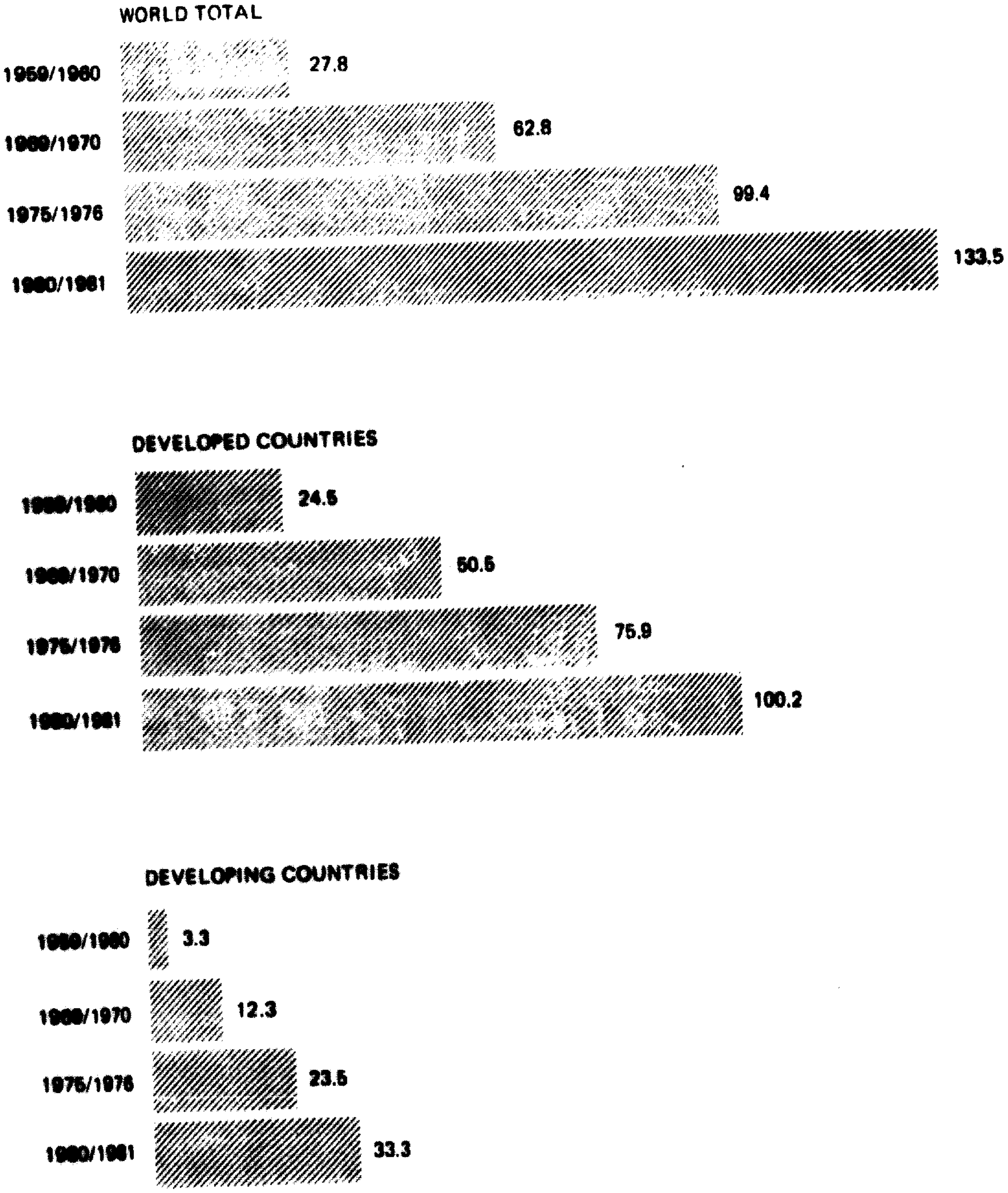
[1] In the present publication, references to "China" and to the "representative(s) of China" are to be understood in the light of General Assembly resolution 2758 (XXVI) of 25 October 1971. By that resolution, the General Assembly *inter alia* decided:

> "to restore all its rights to the People's Republic of China and to recognize the representatives of its Government as the only legitimate representatives of China to the United Nations, and to expel forthwith the representatives of Chiang Kai-shek from the place which they unlawfully occupy at the United Nations and in all the organizations related to it."

[2] See foot-note 1.

Actual and projected world consumption of fertilizers

(Million tons NPK)



II. PRODUCTION AND CONSUMPTION OF FERTILIZERS IN THE COUNTRIES REPRESENTED AT THE SYMPOSIUM

A summary of fertilizer output and use introduces the following sections on individual countries.

Brazil

Fertilizer consumption in Brazil has increased steadily since 1966. About 998,000 tons of nutrients were consumed in 1970 (275,900 tons of N, about 416,900 tons of P_2O_5 and 306,600 tons of K_2O). The forecast for the consumption of total nutrients by 1975 is 1.33 million tons, and by 1980, 2.39 million tons; by the latter date the consumption of N is expected to become the same as that of P_2O_5. This represents an increase in total nutrient consumption of 35 per cent by 1975 and of 136 per cent by 1980. Measures for subsidies (FUNDAG[3]) and promotion (ANDA[4]) are expected to contribute considerably to increased and more efficient use of fertilizers in Brazil.

It is estimated that national production [illegible] 1970 provided only 8.7 per cent of the country's nitrogen fertilizer consumption and 44.5 per cent of P_2O_5. No potash fertilizers are being produced in Brazil. However, potassium reserves have been discovered in the north-east region.

There were 17 fertilizer production plants in Brazil in 1971, with a total installed capacity of 189,300 tons per year of N nutrient and 245,000 tons per year of P_2O_5 nutrient. In addition to these production units a network of mixing and blending units (about 89) is spread out over various regions of the country.

Seven new fertilizer production projects are reported either to have been approved by the Government or to be at advanced stages of study and implementation. These seven plants are expected to come into operation during the period 1972–1975, and to have a total production capacity of 246,060 tons per day of ammonia.

Egypt

Egypt erected its first fertilizer plant for the production of superphosphates in 1937. The first nitrogen fertilizer plant started production in 1951. A total of three nitrogen fertilizer plants and three phosphate plants have been established so far in

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[3] Fundo Especial de Desenvolvimento Agrícola.

[4] Associação Nacional para Difusão de Adubos.

the country. A fourth nitrogen fertilizer plant is expected to start production in 1973. At present a project for the erection of a plant to produce 1,000 tons per day ammonia, for conversion into urea, is under consideration. Another project being studied at present is the production of elemental phosphorus by the electro-thermal process. No potash fertilizers are being produced in Egypt, and the country's annual requirements of about 6,000 tons are imported.

The consumption of nitrogen fertilizers in Egypt is expected to increase from 310,000 tons of nutrient in 1971 to 387,500 tons by 1975. Production is expected to increase from 186,000 tons of nutrient in 1971 to 511,500 tons by 1975, leaving about 124,000 tons available for export.

The consumption of phosphate fertilizers is expected to increase from about 85,000 tons of nutrient in 1971 to 180,000 tons in 1975. Production estimates for 1975 are for 225,000 tons, leaving about 45,000 tons nutrient available for export.

Ethiopia

Soil tests in the highlands of Ethiopia have revealed that the soil is generally deficient in nitrogen and phosphate and that a few locations are deficient in potash. In the majority of cases the soil is responsive to both single and combined applications of nitrogen and phosphate fertilizers.

Although fertilizer consumption in Ethiopia has been growing rapidly since 1969, it is at a very low level. The average national consumption of nutrients per hectare increased from 0.28 kg in 1969 to 0.44 kg in 1970. The transport and handling costs together with the present distribution and sales system may be partly responsible for the limited fertilizer use in the country. On the basis of conservative estimates of the additional acreage to be fertilized over the next five years, it is probable that requirements will amount to 24,500 tons per year of urea or 11,700 tons per year of nitrogen and 20,[illegible]00 tons per year of superphosphate or P_2O_5. Diammonium phosphate (DAP) is the least expensive high-grade fertilizer, and it is expected to become the most popular fertilizer in Ethiopia.

Ethiopia has no fertilizer production capacity at present, but the Government is planning to commission a feasibility study for the establishment of a fertilizer and pesticide industry in the country. UNIDO has been requested to assist in this study.

India.

In 1969–1970 the consumption of fertilizer nutrients in India amounted to 1.04 million tons of nitrogen, 0.234 million tons of P_2O_5 and 0.15 million tons of K_2O. India still imports large quantities of fertilizers, which costs the country an annual foreign-exchange outlay of $1,200 million.

Fourteen plants now produce synthetic ammonia and convert it to urea, ammonium sulphate, ammonium nitrate, double salt (sulphate-nitrate), ammonium phosphate, nitrophosphate and various NPK complex fertilizers. In addition, 30 factories produce single and triple superphosphate (TSP). The feed-stocks already in use comprise lignite and coke as well as liquid and gaseous feed-stocks, e.g. naphtha, coke-oven gas, refinery gas, associated and natural gas. Electrolytic hydrogen is also used. Substantial progress has also been made in the local fabrication of several items of equipment used in the fertilizer plant (70 per cent of total plant equipment).

Much attention is paid to the proper maintenance of plant and machinery, with emphasis on preventive maintenance. Some 20 projects to expand production capacity by establishing new factories and extending existing ones are in hand and others are in the planning stage. When these go on-stream, the domestic production capacity (annual) will exceed 5 million tons of nitrogen and 1.6 million tons of P_2O_5. India hopes to attain self-sufficiency in fertilizer production before the end of this decade.

Indonesia

In 1970 the importation of fertilizers for the food crops and estate sectors amounted to 76,000 tons of ammonium sulphate, 49,900 tons of compound fertilizers, 12,300 tons of potassium chloride, and smaller quantities of TSP, ammonium phosphate, single superphosphate (SSP) and potassium sulphate. The fertilizer requirements by the years 1973/1974 are estimated in the development plan to be 571,000 tons N, 284,000 tons P_2O_5 and 20,000 tons K_2O. In June 1970 the Government initiated a national study on fertilizers to obtain more accurate information and to devise a plan for the development of the fertilizer industry within the next decade.

In 1963 the first chemical fertilizer plant was inaugurated at PUSRI, Palembang. It was designed with a capacity to produce 100,000 tons per year of urea, and its capacity is being expanded by 380,000 tons per year. The plant utilizes natural gas from the surrounding oil and gas fields, both as feed-stock and plant fuel. The expansion facilities are expected to start operating in 1974. In 1963 construction was started on an SSP plant at Tjilatjap, producing 100,000 tons per year, and in 1966 on an ammonium sulphate plant at Gresik, producing the equivalent of 56,500 tons per year N nutrient. Neither of these two plants are in operation as yet, although the Gresik plant is expected to be on-stream by 1972. Two fertilizer bulk-handling units with unloading and bagging facilities were recently established at Tandjung Priok and Tjilatjap harbours with bagging capacities of 300,000 and 60,000 tons per year respectively. The Government is considering proposals for the establishment of fertilizer bulk-blending plants. The current development plan of Indonesia also envisages the construction of a urea and complex fertilizer plant based on an ammonia production capacity of 1,000 tons per day, and using imported phosphoric acid, but a detailed feasibility study is still required.

Iran

The fertilizer industry in Iran got off to a good start in 1960, and the country is consequently now self-sufficient in plant nutrients.

The domestic fertilizer demand is still modest, but it is increasing at a rate of 15 per cent per annum and is expected to surpass 550,000 tons per year of nutrients by 1975.

The industry enjoys a low-priced natural gas supply, making the production of ammonia competitive.

Three major fertilizer complexes are situated in Iran, namely, the Shiraz Fertilizer Factory, the Shahpur Chemical Co. and Kharg Chemical Co. The Shahpur Company rates as the biggest complex of its kind in Asia, with facilities for producing daily 1,000 tons of ammonia, 1,300 tons of sulphuric acid and 450 tons of P_2O_5 as phosphoric acid. The marketable end-product, fertilizer-plant capacities provide for the production at 500 tons per day of urea, 300 of DAP and 430 of TSP. A plan for doubling the plant capacities is being considered, providing favourable projections can be made for a future market.

Iraq

The use of fertilizers began only recently in Iraq. In 1969–1970 total fertilizer consumption amounted to 65,000 tons, of which 50,000 tons were ammonium sulphate.

Construction of the first fertilizer-production plant in Iraq has just been completed. The plant is based on the abundant supply of sweet natural gas from nearby oilfields, and on locally produced sulphur. Plant capacity is designed for 420 tons of ammonium sulphate and 160 tons of urea per day. Sulphuric acid is also produced with a capacity of 325 tons per day.

Investigations are in process with a view to expanding the nitrogenous fertilizer industries to take advantage of Iraq's favourable geographic location and natural resources of raw materials for producing fertilizers for export.

With regard to phosphate fertilizers, Iraq has promising deposits of good quality phosphate rock. An investigation to determine the extent of the deposits has been entrusted to a USSR organization. Depending on the outcome of these studies, superphosphate production facilities may eventually be built.

Israel

Israel possesses all the raw materials on which to base a modern fertilizer industry.

The first stage in the development of fertilizers was completed in 1956 with the establishment of production facilities for ammonia, nitric acid and ammonium sulphate. The phosphate mines at Oron, after raising the P_2O_5 content by enrichment to 29–30 per cent P_2O_5, were producing 400,000 tons of rock per year. The potash plants were also expanded to produce an additional 200,000 tons per year of KCl.

The second stage of development was concerned mainly with upgrading and expanding the production facilities for basic raw materials, not only to satisfy the domestic requirements but also to produce for export.

In 1969/1970 the production of nitrogenous fertilizers increased to 28,000 tons per year of N. The phosphate production rose to 1,02 million tons per year of P_2O_5, and the potassium production increased to 437,000 tons per year of K_2O.

In 1969/70 the domestic consumption was 51,500 tons per year of total nutrients, and the remainder was exported. Since 1954 the domestic consumption has been growing at an average annual rate of 9.5 per cent.

Mexico

Chemical fertilizers were first produced in Mexico in 1948. At present there are 17 production units in the country, whose total output in 1970 was:

497,800 tons of ammonia;
207,500 tons of nitrogenous (as N) fertilizers;
165,700 tons of complex NPK fertilizers;
130,500 tons of P_2O_5 in phosphate fertilizers.

Mexico has been exporting fertilizers since 1962. In 1970 the country exported about 17,000 tons of urea, 145,700 tons of TSP and 9,700 tons of complex fertilizers.

Fertilizer imports into Mexico in 1970 included 74,200 tons of anhydrous ammonia, 13,000 tons of complex fertilizers, 7,800 tons of urea and 5,000 tons of ammonium nitrate.

Consumption of fertilizers in Mexico has increased considerably over the past two decades. The largest nutrient consumed in the country has been nitrogen with consumption in 1970 amounting to about 391,000 tons, followed by phosphate fertilizers, 112,800 tons of nutrient, and, finally, potash fertilizers amounting to 20,200 tons of nutrient.

Nigeria

Fertilizer consumption increased steadily over the period 1964–1967 but decreased thereafter as a result of the civil war. Consumption figures in 1970 were about one half of those for 1967. About 14,000 tons of phosphate fertilizers, 7,000 tons of ammonium sulphate, 1,300 tons of potash fertilizers, and about 5,300 tons of other fertilizers were consumed in Nigeria in this year.

If available present acreage were utilized to grow the five main crops–sorghum, millet, maize, cotton and ground-nuts–potential consumption of N and P_2O_5 would be 191,000 tons and 159,000 tons respectively.

No fertilizers are presently being produced in Nigeria, but a number of feasibility studies for fertilizer production have been completed.

The Federal Government has decided to establish a phosphate fertilizer plant at Kaduna with a capacity of 100,000 tons per year. A contract has been awarded for a detailed project study. No decision has been taken so far with regard to the development of the nitrogen fertilizer industry, mainly because of the relatively small demand and the large capital requirements for minimum-size, economic production units. Although Nigeria has more potential demand for nitrogenous than for phosphate fertilizers, the country actually consumes more phosphate fertilizers.

Peru

In 1970 Peru consumed the following quantities of fertilizers expressed in nutrients: 70,629 tons N, 8,500 tons P_2O_5 and 3,960 tons K_2O in the form of ammonium sulphate, urea, calcium, nitrate etc. Peru has sufficient natural gas in the north for fertilizer production. In the Sechura desert, which is nearby this natural gas area, are phosphate and potassium deposits. Sulphur is also available as a by-product of the mining industry.

The soil in the agriculturally important Sierra region, at altitudes varying from 1,800 to 3,600 metres above sea level, usually contains less than 2 per cent of organic matter and is very insufficient in nitrogen. Phosphates are also frequently lacking.

There are three fertilizer production units in Peru:

FERTISA,[5] with a rated capacity of 18,000 tons per year of nitrogen in the form of ammonium nitrate and ammonium sulphate.

INDUS,[6] with a plant capacity of about 33,000 tons per year of superphosphate, 20 per cent P_2O_5, and 79,000 tons per year of granular mixed fertilizers. This plant utilizes imported phosphate rock and potassium chloride. However, its production is well below rated capacity.

CACHIMAYO,[7] with a rated capacity of 13,000 tons per year of nitrogen in the form of ammonium nitrate. This plant has also been facing difficulties and has been operating below its rated capacity.

The erection of a plant for the production of urea to be undertaken in 1974 in Talara, in the north, is under consideration by the Government.

Philippines

The present consumption of fertilizers in the Philippines is low, owing to several factors. Aside from transportation difficulties, little research has been undertaken to identify the fertilizer needs of specific crops. To this end, legislation for the establishment of a fertilizer research and development centre has been proposed and is now under consideration.

The Philippines imported about 250,000 tons of various types of fertilizers in 1970. Of this quantity, 98,000 tons were urea, about 88,000 tons potash fertilizers and 33,800 tons ammonium sulphate. Local fertilizer production in 1970 amounted to 255,000 tons, of which 141,000 tons were complex fertilizers, 77,000 tons ammonium sulphate, and 21,600 tons urea. There are four fertilizer plants in the country. However, the over-all capacity utilization of these plants has been below 50 per cent. The main factors contributing to this underutilization of capacity have been unfair competition from imported fertilizers, the inadequacy of the supply of imported raw materials (rock phosphate and sulphur) and lack of spare parts. Therefore, the Government has not been eager to encourage the establishment of new fertilizer-production facilities until full utilization of existing installed capacity has been realized.

Poland

Fertilizer consumption in Poland increased considerably between 1965 and 1970. The consumption of nitrogenous fertilizers has more than doubled, that of

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[5] Fertilizantes Sintéticos S.A.

[6] Industrias Químicas S.A.

[7] Fábrica de Fertilizantes Nitrogenados del Cuzco.

phosphate fertilizers has doubled, and that of potash fertilizers has tripled. By 1980, consumption is expected to reach 1.5 million tons of N, 1.25 million tons of P and 1.75 million tons of K.

Poland has the raw materials and energy resources required for the production of nitrogenous fertilizers. There are at present four large nitrogen plants and a fifth is under construction. Three of these plants are of Polish design and their equipment was manufactured mostly in Poland. The nitrogenous fertilizers produced include ammonium nitrate, lime ammonium nitrate, urea, ammonium sulphate and aqueous ammonia. In 1970 fertilizers equivalent to about 1 million tons of nitrogen were produced. Production is expected to reach 1.55 million tons of N by 1975.

Ten plants produce phosphate fertilizers such as SSP, TSP and ammonium phosphate. In 1970 phosphate fertilizers equivalent to about 600,000 tons P_2O_5 were produced. This figure is expected to reach about 1 million tons in 1975. Most operating phosphate-fertilizer plants are based on Polish designs. Phosphate rock is imported from North Africa and the USSR, but sulphur is available locally.

Poland's requirements for potash fertilizers are being met and will continue to be met by imports from the German Democratic Republic and the USSR.

Romania

Plants in operation in Romania are producing 1.4 million tons per year of ammonia, 1.3 million tons of ammonium nitrate, 1.2 million tons of urea and 400,000 tons of phosphate fertilizers. Plants under construction will increase these yearly production figures by 900,000 tons of ammonia, 600,000 tons of ammonium nitrate, 900,000 tons of urea and 200,000 tons of phosphate fertilizers.

The present high level of fertilizer production in Romania has led to remarkable progress in the development of fertilizer machinery and equipment manufacture in the country.

The phosphate fertilizers produced in Romania are TSP and NPK compound fertilizers. Romanian processes are used for the production of phosphoric acid and TSP. The future trend is expected to be towards the production of NPK compound fertilizers.

Studies have shown that the most suitable process for the production of compound NPK fertilizers in Romania is one based on the nitric phosphate process. Several processes, Romanian and foreign, are used for the production of ammonia, nitric acid and ammonium nitrate. The method adopted for the new NPK plants is the Norsk Hydro process.

Sudan

No fertilizers are being produced in Sudan. Nitrogenous fertilizers make up more than 97 per cent of the country's total imports of artificial fertilizers. Urea is the fertilizer most widely used and mainly on irrigated areas. New areas are being brought under cultivation and the fertilizer application rates are being increased. The estimated yearly requirements of fertilizers, which were about 100,000 tons of urea in 1969, are expected to reach about 200,000 tons by the late 1970s.

The response of crops to the application of fertilizers has been studied extensively in Sudan. Most of the country's soil has long been known to be inherently low in nitrogen. The main crop, cotton, has responded significantly and fairly consistently to N. However, this crop's response to P has been erratic and to K, negligible.

The establishment of a urea plant with a capacity of 200,000 tons per year of urea, using naphtha, has been under study for the past five years. Because of the small production capacity envisaged and the need to use reciprocating compressors, however, the project may prove uneconomical. The total recycle process has been recommended for urea synthesis by the reaction of ammonia and its by-product, carbon dioxide. As regards the location of the proposed plant, a railway junction on the Blue Nile, at Sennar, has been recommended because it is situated at the centre of the main agricultural area of the country. Adequate supplies of fresh water and relatively cheap hydroelectric power are available nearby.

Syrian Arab Republic

It has been estimated that Syria could utilize at present about 1 million tons of fertilizers, and 1.3 million tons by 1975. Syria's actual present consumption is about 150,000 tons of different types of fertilizer, mainly nitrogen.

Construction has just been completed of a nitrogenous fertilizer plant in Homs with a capacity of 148,000 tons per year of calcium ammonium nitrate containing 26 per cent N. The ammonia unit of the plant has a capacity of 150 tons daily and is based on the catalytic reforming of naphtha. The nitric-acid unit has a capacity of ,87,000 tons per year (based on 100 per cent nitric acid). Another small plant has been producing 3,000 tons per year of superphosphate by treating Jordanian-Syrian phosphate rock with sulphuric acid obtained as a by-product in detergent manufacturing. The capacity of this plant is limited by the unavailability of sulphur.

Contracts are being negotiated for the construction of a 100,000 tons-per-year TSP plant. This plant will use sulphur produced in the Homs refinery, and local phosphate deposits. It is also probable that plants for the production of urea and DAP could utilize locally available raw materials. The future development of the industry will depend on how effectively some of the problems, such as marketing and the shortage of investment capital, can be solved.

Thailand

The consumption of fertilizer in Thailand in 1970 was roughly 30 times as much as it was in 1950. Average fertilizer consumption per hectare is about 10 kg of plant nutrient. The share of N fertilizers is only about 15 per cent of the total. Mixed fertilizers have become more popular and presently account for 85 per cent of the market. About 60 per cent of the mixed fertilizers used is composed of ammonium phosphate.

In 1970 over 200,000 tons of fertilizer were imported. The Chemical Fertilizer Company produces ammonium sulphate and urea, using lignite from local deposits and imported sulphur. The designed capacity of the plant is 200 tons daily of ammonium sulphate and 100 tons of urea. The plant is reported to be facing serious difficulties, however, and it is operating at only 65 per cent of designed capacity.

Turkey

A considerable effort is being made in Turkey to increase the domestic production as well as the consumption of fertilizers.

In the 1960s fertilizer production increased by 8 to 10 per cent; nevertheless, imported fertilizers will be required for some time to meet the country's various requirements in consumption.

The consumption of fertilizers during the last 10 years increased from about 100,000 tons in 1960 to 1.9 million tons in 1970. To meet this demand, Turkey had to import about 1.2 million tons of fertilizers in 1969.

The consumption of fertilizers varies regionally. By far the greatest is in the Mediterranean region. The lack of communication between the consumer (farmer) and the supplier has been a major problem.

Several projects to increase the domestic production of fertilizers are under consideration, such as the plant at Gemlik on the Marmara seacoast and another near Izmir next to the Ali Aga refinery.

Union of Soviet Socialist Republics

In 1970 fertilizer production in the USSR amounted to 55.4 million tons (based on N, P_2O_5 and K_2O) or about 13 million tons of nutrients. The average annual rate of increase in production was 11.7 per cent over the period 1965–1970. The *per capita* production of nutrients in 1970 was 58 kg. Planned fertilizer production for 1975 is 22.19 million tons of nutrients (about 20 per cent of the world's total nutrient production). Plans for 1980 envisage the production of about 38 million tons of nutrients.

In future the share of complex and concentrated fertilizers in gross fertilizer production is expected to increase, reaching about 80 per cent in 1975. The production of phosphate and potash fertilizers will also increase in comparison with nitrogenous fertilizer production.

Fertilizers are being produced in large plants situated near the raw material sources or in areas where intensive agriculture is practical. There has been a trend towards larger single production-line capacities in all branches of the fertilizer industry. The maximum plant capacity for the production of phosphate fertilizers increased by 339 per cent between 1950 and 1970.

Nitrogenous fertilizers

During the past ten years the production of nitrogenous fertilizers in the USSR increased by 600 per cent. The raw material used for ammonia production has changed in that natural gas has become the principal material used (70.1 per cent in 1969) and the use of coke-oven gas, coke and coal has decreased correspondingly.

One of the most important developments has been an increase in the capacity of production equipment. Plants have been built with a capacity of 109,000 tons per year of ammonia based on natural gas and catalytic steam-oxygen conversion at a pressure of 20 atm. As of 1973, the production of ammonia is planned to be developed solely in larger-capacity production lines, which make it possible to approach self-sufficiency in electricity and steam.

The present capacity of a single-stream ammonium-nitrate line is 150,000 200,000 tons per year, which permits a reduction of 10 per cent in the prime cost and of 25 per cent in capital investment. Considerable attention is being paid to the problem of improving the quality of ammonium nitrate by increasing granular stability; this is being done by controlling granular formation in the towers and by the use of highly efficient conditioning additives making it possible to store and transport ammonium nitrate without caking. Together with liquid ammonia, urea is considered to be the most promising nitrogenous fertilizer in the USSR. Between 1961 and 1970 the production of urea increased by 480 per cent. During the past five years urea has been produced in liquid recycle units with an annual capacity of 90,000 tons. Production units with a capacity of 180,000 tons per year are envisaged in the future, and they are expected to reduce production cost by 33 per cent and capital cost by 34 per cent.

Phosphate fertilizers

Phosphate fertilizers produced in the USSR are SSP and TSP, and a small quantity of basic phosphate slag. Fertilizers containing water-soluble forms of P_2O_5 are preferred. SSP is still the major phosphate fertilizer, but its importance is steadily declining. It is predicted that the share of SSP in the production of phosphate fertilizers will drop from 80 to 35–40 per cent by 1975.

Two methods are used for the production of TSP, namely, the chamber method and the continuous-line method. In the future, preference will be given to the continuous-line method for planned TSP production units.

Potash fertilizers

The USSR is rich in deposits of natural potassium salts. Potassium chloride is obtained by extraction and by flotation enrichment. It contains 60 per cent of nutrient (K_2O) and does not cake in storage. By 1975, the demand for potash fertilizers in the USSR is expected to amount to 5.5 million tons of K_2O, with chlorine-free potash fertilizers accounting for 10 per cent of this total.

Phosphoric acid

Two methods are used to produce phosphoric acid in the USSR: decomposition of phosphate rock with sulphuric acid (wet process), and the electro-thermal process making yellow phosphorus. It is expected that production in the USSR will be tripled during the next five years with annual production at 3 million tons P_2O_5. Almost all the wet-process phosphoric acid is produced using the dihydrate method, which results in an acid concentration of 29–30 per cent P_2O_5. Research work is being conducted to produce wet-process phosphoric acid using the hemihydrate process. The further perfection and development of phosphoric-acid production by the wet process will be connected with the introduction of more efficient large-capacity production lines (up to 200,000 tons per year), based on the hemihydrate method and making it possible not only to increase the P_2O_5 yield per extractor-volume unit and filter-area unit, but also to obtain highly concentrated acid. New materials for the construction of the equipment required are being developed.

The USSR has also achieved considerable success in the field of electro-thermal phosphoric-acid production. Research and design work is in progress for the purpose of reducing the cost of electro-thermal production.

Two basic methods are used in the USSR for the production of compound fertilizers. The first is based on the application of sulphuric acid and the second on the decomposition of phosphate rock by nitric acid. In 1970 about 57 per cent of compound fertilizers produced in the USSR were based on the use of ammonium phosphates. This percentage is expected to increase to 76 per cent by 1975.

Extensive research is being undertaken in the USSR to develop local methods and equipment for processing phosphate rock with nitric acid.

The main types of compound fertilizers used in the USSR are monoammonium phosphates (MAP), diammonium phosphates (DAP), nitrophosphates, and formulations of the NP complex group, NPK and PK fertilizers.

Yugoslavia

Major developments have taken place in the fertilizer industry of Yugoslavia in the last five years. Large single-train plants for ammonia and nitric acid have been built, urea production has started, and the rate of NPK fertilizer production has increased. Large sulphuric-acid plants now produce phosphate fertilizers, using off-gases from existing plants, and new copper, zinc and lead smelting plants. A start has also been made in the production of phosphoric acid.

Natural gas is the main raw material used. Rock phosphate has been imported up to now, but the exploitation of domestic deposits is under consideration.

Two ammonia plants with a capacity of 650 tons per day are in operation and urea is being produced in two plants, each with a capacity of 100,000 tons per year. Several large units are producing NPK fertilizers with a total capacity of 1.4 million tons per year.

The present annual production capacity of the country is about 500,000 tons of nitrogen and about 300,000 tons of P_2O_5. Total domestic consumption in 1971 was expected to reach about 350,000 tons N and 220,000 tons P_2O_5. Yugoslavia's exportable excess production in 1971 was expected to reach about 500,000 tons of fertilizer.

Zambia

Fertilizers are absolutely necessary for agricultural production in Zambia. Soil deficiencies have been identified in nitrogen, phosphates, potassium, sulphur and boron.

In 1970–1971 about 65,900 tons of fertilizers were imported into the country. It was estimated that in 1971–1972 about 61,200 tons would be imported, consisting mainly of compound fertilizers, urea and ammonium sulphate. In addition about 34,000 tons of ammonium nitrate were expected to be produced locally by the Nitrogen Chemical Company of Zambia (NCZ). NCZ is the only Zambian fertilizer-producing operation. Ammonium nitrate is produced from hydrogen, which is made from locally mined coal with nitrogen fixed from the atmosphere. However, the ammonium nitrate produced by NCZ is not a balanced fertilizer. It is estimated that by 1977/1978 some 148,000 tons of fertilizers will have to be imported.

Planning for fertilizer imports is complicated by uncertainties in transportation. Therefore, mixing imported concentrated fertilizers locally has been recommended. A mixing plant is planned for 1972 as an extension of the existing fertilizer plant.

III. TECHNOLOGY OF THE PRODUCTION OF AMMONIA AND NITROGEN FERTILIZERS

In developing countries indigenous raw materials for ammonia manufacture must be evaluated in consideration of the over-all potential saving in critical foreign exchange. While this approach usually leads to higher initial plant-investment costs and more complex operations, these can be offset by conserving foreign exchange.

In India, for example, the greatest ammonia production capacity, 3.15 million tons of ammonia per year (over 60 per cent), is achieved *via* the simplest synthesis-gas production process, i.e. steam-reforming of natural gas and naphtha. Owing to the limited natural gas resources in India, plus the world-wide shortage of naphtha and associated premium prices (crude oil at $1.28/barrel in 1971 to $2.05/barrel by 1975), alternative raw materials have been investigated for use in the proposed large-capacity (600–910 tons-per-day) ammonia plants with end-products of urea or urea and NPK fertilizers. It is planned to use single-stream design with centrifugal compressors.

The cost of production of ammonia (compared to naphtha-based plant), after depreciation and interest, was estimated in 1971 to be 5 per cent higher in the case of plant based on heavy-oil feed-stock and about 20 per cent in the case of coal-based plant. By 1975 these figures are estimated to become 5 per cent (same) and 10 per cent respectively. These higher investments are offset by an important saving in foreign exchange for production costs. The initial investment compared to naphtha-based plant is 24–30 per cent more for heavy oil feed-stock or heavy residue-based plant, and about 88 per cent more for coal-based plant.

The possibility of substituting Indian coal for world naphtha is remote, because the deposits are generally far inland and contain high ash. Since liquid natural gas/low pressure gas (LNG/LPG) is becoming a world-wide commodity and is highly desirable as a feed-stock for ammonia plants, it has been suggested that this be investigated in detail for future potential use in India and other developing countries.

Improvements in the technology for the production of ammonia

Advances in the technology for ammonia production in the last five to six years have contributed significantly towards smoother, less time-consuming initial commissioning operations, and faster on-stream availability of ammonia plants. These improvements apply primarily to the large-scale (600 tons-per-day or over) single-train, centrifugal compressor-type plant, and to catalysts, materials of construction, thermal and mechanical energy self-sufficiencies. This improved technology is now being applied, based on the experience gained, with plants having capacities of 1,500 tons or more per day of ammonia.

Large-capacity plants for the production of granulated ammonium nitrate

The process and equipment for the manufacture of prilled ammonium nitrate in a large-capacity plant (1,400 tons per day) have been further developed. They differ from the conventional processes and equipment, and are claimed to have the following advantages:

The process does not create air or water pollution;

Losses of raw materials and finished products are kept to a minimum;

Specific size of the prilling tower is reduced, thus lowering construction cost;

Depending on the market conditions, screening of the product is not required since 96 per cent of the product has a size of 1–3 mm;

The product has good storage properties;

The adoption of specially developed, reliable equipment in the plant reduces investment and operating costs;

Fewer operating personnel are required owing to automation and appropriate layout of the plant.

The product, ammonium nitrate, has 34.8 per cent N and the moisture content is less than 0.2 per cent.

The plant uses 58–60 per cent nitric acid and gaseous ammonia, and the neutralization is carried out at close to atmospheric pressure. The nitrate solution is further concentrated in a falling-film type evaporator to 95–96 per cent. The ammonium-nitrate melt is then prilled. The prills are cooled in a fluidized bed-coller, located under the tower, before being sent to the bagging plant.

The hot-air exhaust from the prilling tower and evaporator is admitted to a scrubber to remove traces of ammonium-nitrate dust. Consumption of raw materials and utilities per ton of finished product are as follows:

Ammonia vapour (100 per cent) at 3 atm	213 kg
Nitric acid (as 100 per cent HNO_3), 58–60 per cent	794 kg
Saturated steam at 14 atm	180 kg
Power	28 kWh

The increase in sulphur compounds present in many natural gas feed-stocks at the well-head necessitated an improvement in the existing technology for desulphurization. The classical, activated carbon-bed absorption, which was adequate for processing pipeline natural gas containing relatively low sulphur concentration of less than 10 ppm, was satisfactory for the removal of hydrogen sulphides and mercaptans. The increase in heavy hydrocarbons such as butane reduced the effectiveness even for short periods of the activated carbon. More sophisticated processes, using hot zinc-oxide bed as a back-up desulphurizer with natural gas feed at about 400°C, or with more complex feed-stocks using a bed of hot cobalt-molybdate catalyst ahead of the zinc oxide, have been found more effective for desulphurization and the removal of carbonyl sulphide.

Improvements in the steam/natural gas primary reformer construction include welding techniques, field erection with tube-support springs, fabrication procedures, quality control in manufacturing the 25Cr/20Ni tubes, and special monitoring for operating conditions. The improved strength of catalysts and the employment of small-size catalyst at the reformer tube inlet for increased heat exchange, with larger-size catalyst at the outlet for decreased pressure drop, have resulted in better control of so-called hot spots on the tubes, improved heat distribution and an improvement in the heat-exchange characteristics of the reformers.

With the increase in energy costs, more efficient hot potassium-carbonate systems are replacing the amine systems (MEA etc.). New and improved corrosion inhibitors for hot potassium carbonate leads to less costly alloy steel construction. There is little capital cost difference now between the two different processes. Other refinements are new and improved packing materials for carbonate service, and the identification and elimination of the causes of sludge formation. The foaming tendencies have been reduced, with better operating techniques.

First- and second-generation large-scale ammonia plants utilized two-case centrifugal compressors, resulting in a synthesis pressure of about 150 atm for plants producing 600–1,000 tons per day. With increased plant size, and improved compressor technology, synthesis pressures have risen to the 200–240 atmosphere level for new plant designs above the range of 1,300 tons per day. It is now possible, utilizing three cases of centrifugal compression, to operate the synthesis pressure up to 300–320 atm.

There are now several approaches to new ammonia-synthesis reactor designs, since the size of a single-train plant has become a limiting factor for capacity, and the pressure drop is increasingly important. Proprietary types of radial-flow reactors of smaller size and lower pressure drop, and also horizontal reactors, are being used. A horizontal reactor is now in operation in a 1,700 tons-per-day ammonia plant and designs are projected for plants with 2,000–3,000 tons-per-day capacities.

There is little incentive for savings in capital cost by increasing the size of ammonia plants to the range of 1,500 or more tons per day, since the progressive increase in cost is almost directly proportional to the size.

The development of modern technology for the production of ammonia, nitric acid, methyl alcohol etc. in large-capacity plants has been made possible by exhaustive research, which first established the physical-chemical basis. Pilot-plant tests for the scope of this work then led to the discovery of new catalysts for:

The hydrogenation and absorption of sulphur compounds contained in natural gas;

A nickel-containing catalyst conversion of hydrocarbons (reforming);

The wide-temperature-range catalyst for conversion of carbon monozide;

Methanation;

Ammonia synthesis, using a granular catalyst, which reduces the pressure drop in the absorption columns, thus providing higher capacity;

The oxidation of ammonia with catalysts of reduced platinum content;

The decomposition (reduction) of nitrogen oxides contained in nitric-acid plant exhaust gases;

A two-stage system using non-platinum catalyst for the oxidation of ammonia to nitric oxides.

Most of the above newly developed catalysts are produced on an industrial or semi-industrial basis in the USSR and many other countries to supply the growing demand.

The following techniques are used for studying and testing the catalysts:

Differential thermal analysis together with measurement in change of weight;

Thermo-magnetic analysis;

Infra-red spectroscopy;

X-ray structural analysis of phase composition.

Electron-defraction and electron-microscopy methods are used to study the catalyst surface microstructure. The local X-ray spectral-analysis method is used to determine the small concentration of chemical elements of the basic component and of micro-additives along the phases.

Both static and dynamic methods are used for proper testing. Thermographic, chromatographic, mass-spectrum and thermo-magnetic analyses of catalysts are carried out with the samples being heated in a gas stream. A wide variety of new physical-chemical testing methods have been developed and were used in the course of this catalyst investigation and development programme. A new trend in the field of heterogeneous catalyst studies is the application of local X-ray spectral analysis. So far, this is the only direct method of observation for the distribution of the elements along the phases. This method, combined with petrographic analysis, is a useful tool for further detailed studies of catalyst-phase composition and element redistribution along the phases.

On the basis of this extensive catalyst research and development programme, the USSR can now design and engineer large catalyst factories producing a wide range of catalysts.

Ammonia production based on coal and lignite—technical and economic aspects

The processes for the production of synthesis gas from coal or lignite that have been used are:

The Winkler gasifier with fluidized bed;

The Lurgi pressure-gasifier, which gasifies the coal in a fixed bed;

The Koppers-Totzek gasifier, which gasifies coal in suspension at high temperatures.

A brief description of an existing plant using the Koppers-Totzek process follows:

Lignite from storage is crushed to 30 mm and sent to the lignite drying and pulverization unit. The dryer reduces the moisture content from 45 per cent to

8 per cent, and the lignite is then pulverized in a tube mill to +20 per cent (0.09 mm DIN 70 screen) residue. The pulverized lignite is fed to the gasification plant pneumatically.

Oxygen and nitrogen are obtained from an air-separation plant. The degree of gasification is about 99 per cent, although the ash content of the lignite is in the range of 35–40 per cent. The ash flowing from the gasifier is granulated in a water bath to 3–5 mm and is suitable for paving and road-making.

Fine dust is removed in water scrubbers and mechanical washers. The entire low-pressure section is monitored and serviced from a central control station. Raw gas is stored in a gas holder. The raw gas is compressed in turbo-compressors to 10 atm, and desulphurization follows in a sulfinol unit. The gases are then compressed in reciprocating compressors. CO conversion is carried out at about 25 atm, after which the CO_2 is removed in a cold methanol-wash unit followed by liquid nitrogen wash. The synthesis of ammonia takes place at about 500 atm. The control of the operation for the entire pressure section, including air plant, is centralized.

An economical comparison has been made of the use of feed-stocks such as lignite, coal, fuel oil and naphtha for the production of ammonia in a 1,000 tons-per-day plant. The erected plant costs are estimated to be:

	Million dollars
Lignite feed-stock	40
Coal feed-stock	39
Fuel-oil feed-stock	30
Naphtha feed-stock	25

The plant is assumed to operate for 8,000 hours per year (or 333 operating days/year at capacity). Interest is assumed at 7 per cent, and the amortization period is calculated to be 12 years.

A graph has been plotted for the cost of production of ammonia at different feed-stock prices. With favourable coal prices the production of ammonia is quite competitive with fuel oil or naphtha.

For the 1,000 tons-per-day ammonia plant the requirement for foreign currency has been calculated for the use of various feed-stocks, assuming that coal is available indigenously and that fuel oil and naphtha are imported. The foreign-exchange component has been assumed as 50 per cent of the total investment.

The foreign-exchange requirement is lower for coal and lignite compared with that for fuel oil and naphtha.

	Foreign-exchange requirement per year (Million dollars)
Lignite	5.04
Coal	4.91
Fuel oil	7.53
Naphtha	10.14

Some doubts were expressed about the on-stream efficiencies of solid fuel-based plants compared with liquid and gas feed-based plants.

Urea synthesis–Montedison urea process

In the new Montedison process, decomposition of the unconverted ammonium carbamate is done by heating at a pressure of about 80 atm, followed by condensation at the same pressure. Owing to the high temperatures at which condensation takes place, the heat is recovered as steam and re-used in the plant, both directly and after the turbo-compressor. This new process first became operational in an industrial-scale plant in 1968–the CNA[8] plant in Sluiskil, Holland, which has a capacity of 700 tons per day.

The improvements claimed by Montedison may be summarized as follows:

High-efficiency, high-pressure (200 atm) synthesis essentially unchanged, except for smaller reactor sizes, maintaining a molar ratio of NH_3/CO_2 at 3.6 and a conversion efficiency of 0.63;

A reduction in operating pressure and temperature for the ammonium-carbamate decomposition cycle to 80 atm and 190°C, with condensation performed at the same pressure and at temperatures ranging from 145° to 135°C (in spite of the low water content and high ammonia concentration in the recycle composition). The low recycle uses a molar ratio of H_2O/CO_2 at 0.50;

A portion of the carbon dioxide, about 25 per cent, is admitted to the stream in the condenser, operating at 80 atm (where most of the aqueous ammonia and ammonium-carbamate solution is between 140° and 135°C);

There is a modest claim for reduction in power consumption as a result of lowering the pressure requirement in compressed CO_2 (about 25 per cent of the total) for the recycle system;

The steam consumption is equal to or lower than that of other systems. It is claimed that the net consumption level of 850 kg/ton of urea at 20 kg/cm^2 is attained;

Equipment for heat recovery operates under less severe conditions, resulting in considerably lower pressures and temperatures, economy in operating costs and less exposure to damaging corrosive conditions.

The re-use of steam recovered from the waste-heat boilers in steam turbines or pumps previously driven by electric motors saves electric power.

Stamicarbon urea-stripping process

The urea-synthesis reactor operates at a pressure of 125–140 kg/cm^2; the resulting carbamate solution is then stripped at the same pressure with carbon dioxide. The NH_3-CO_2 gas mixture issuing from the stripper is condensed at the reaction pressure and this heat is used for producing low-pressure steam, which can be returned in the process.

A considerable saving in power cost may be achieved by driving the CO_2 compressor wholly or partly with a steam turbine, in which case steam at 40–60

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[8] Compagnie Néerlandaise de l'Azote S.A.

kg/cm^2 is expanded to the desired pressure of 20 25 kg/cm^2. The steam turbine can also be driven with low-pressure steam.

Typical features of the process are the adjustment and control of the process conditions in the carbamate condenser and the reactor, and, particularly, the stripping operation with carbon dioxide. The stripping operation is carried out counter-currently in a falling-film evaporator, to ensure short contact time and thereby prevent hydrolysis of urea and the formation of biuret. Uniform distribution of liquid and gas in the stripper tubes is essential and is achieved by suitable design of the liquid and gas distributors.

The construction material used is stainless steel 316 L, and for protection against corrosion, air or oxygen is added to the fresh CO_2.

Thirteen urea plants using this process have so far been built.

Mavrovic "heat-recycle" urea process (TECHNIP)[9]

The "heat-recycle" urea process is claimed to provide improved conversion efficiency in the urea-synthesis reactor, resulting in a reduction of the carbamate recycle and in the size of the equipment handling the carbamate recycle.

Reduction in steam consumption is obtained by recovering internally the heat of reaction of NH_3 and CO_2 to carbamate. The feed to the reactor is at a higher temperature level compared with conventional urea processes. This is accomplished by transferring heat from the reaction of NH_3 and CO_2 to carbamate to the reactor feed-streams. Consequently, the urea-synthesis reaction becomes strongly exothermic, in contrast to the adiabatic reactor of a conventional urea process. This excess heat added to the reactor is utilized for the production of steam in the reactor coil. Such steam produced is at a pressure level required for the decomposition of the carbamate for the reactor effluent. The heat recovery is approximately 85 per cent of the heat released by reacting the NH_3 and CO_2 gas in the recovery and absorption section. This heat is recovered by heat exchange with the reactor feed-stream and recycled to the reactor. The steam production is sufficient to cover 55 per cent of the steam required in the carbamate decomposition system.

The reactor operates at a temperature of 190°C and at a pressure of 225 atm. The molar ratio of ammonia to carbon dioxide is about 4.2, and the H_2O to CO_2 molar ratio is 0.6. The over-all conversion efficiency is rated at 72 per cent.

Stability of the process is attained by controlling the synthesis loop, particularly with respect to the solution concentration of the carbamate recycle, thus eliminating the possibility of solution crystallization and the consequent mechanical failure of the equipment. The water-vapour content in the NH_3 and CO_2 produced in the carbamate decomposers is reduced by a novel method and is also maintained in a predetermined range by a continuous concentration-analyser, installed on the carbamate recycle-solution feed-line. The concentration-analyser is directly calibrated in terms of the crystallization temperature.

The equipment design is simplified and consists of simple and conventional shell and tube exchangers.

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[9] Institut français du Pétrole, Compagnie Française d'Etudes et de Construction.

The raw materials and utilities per ton of urea are as follows.

Ammonia	0.58 tons
CO_2	0.75 tons
Steam	0.50 tons (calculated at absolute pressure)
Power	135 kWh
Cooling water	42 m^3 at 12°C

Mitsui Toatsu process

Mitsui Toatsu have now developed the TR–C–Improved and Total Recycle D(TR–D) process, based on the company's commercially proved Total Recycle C(TR–C) process. In comparison with the TR–C process, the TR–C–Improved process achieves higher conversion in the reactor by reducing the amount of water recycled back to the reactor. This improvement is achieved by a higher operating temperature and higher pressure in the reactor, greater decomposition in the high-pressure decomposer (fitted with a specially designed heater) and CO_2 stripping in the low-pressure decomposer, by maintaining a lower-equilibrium pressure in the low-pressure absorber.

The special feature of the TR-D process consists in the recovery of excess ammonia, without losing its heat content, by the addition of a separation unit operating at 60–80 kg/cm^2, thereby saving in the consumption of utilities (steam and cooling water). Other advantages claimed for the TR-D process are higher on-stream factor cost and lower investment cost.

The consumption of utilities for various processes is shown below:

	TR-C low biuret	*TR-C low biuret*	*Improved high biuret*	*TR-D low biuret*
Power (kWh)	160	160	145	155
Steam (tons)	1.10	1.90	1.10	0.85

The Mitsui Toatsu process is used by 58 plants in 21 countries. Three plants, all in Japan, are using the TR-C-Improved process; the one with the largest capacity, of 1,500 tons daily, has been in operation since July 1969. The TR-D process has not been proven on a commercial basis.

Recent innovations include computer-controlled operation and testing of two Japanese-fabricated centrifugal pumps and one US pump for carbamate-recycle service. Computer-fed information used for measuring exhaust fumes containing entrained dust from the prilling tower resulted in the control of pollution.

The cost of computer-control installation was stated to be about $30,000. The total cost of a plant based on direct prilling was reported to be about the same as that for crystallization and prilling.

The SNAM urea-stripping process

The urea-synthesis reactor operates at 150 kg/cm^2 and 185°C. The stripping medium employed in this process is ammonia. The process achieves almost total conversion of carbamate in urea in one system, consisting of the reactor-stripper-carbamate condenser. The condensed carbamate solution is sent to the reactor by an ejector using liquid ammonia. The water content of the carbamate solution is kept to a minimum.

Plant performance data are given for steam, electric power, product quality and operability. All the heat used for decomposing the carbamate in the reactor effluent is recovered at a high level and directly used in subsequent urea concentration steps. With steam supply to the battery limits of the plant at 40 kg/ton and with the use of the by-product steam produced in the plant, the utilities requirement would be:

Steam	1,100 kg/ton urea
Power	15 kWh/ton urea

Less corrosion of the plant equipment is claimed owing to the use of lower operating temperature and pressure in the reactor, the use of ammonia as a stripping agent where ammonia acts as a corrosion inhibitor, and the elimination of critical items such as carbamate pumps. The stripper is a falling-film evaporator.

It is claimed that this process enables the construction of single-line plants with a capacity up to 2,000 tons per day. SNAM has used a centrifugal compressor for CO_2 compression up to the synthesis pressure. Four plants are on-stream, the largest of which has a capacity of 750 tons per day. The synthesis loop equipment is all located on the ground floor owing to the use of the ejector device.

Chemico-thermo-urea process

This process derived its name from the fact that it is based on the principle of heat recovery. Production economics are reported to be attractive, especially for large tonnage plants in the 1,000–2,000 tons-per-day range. A continuous semi-commercial test is being projected by Chemico.

One important feature will be that conventional urea-process equipment such as absorbers, ammonia condensers, circulating pumps and coolers, as well as carbamate recycle pumps, are no longer required. Part of the heat of compression is recovered by feeding the gases to the decomposers (CO_2 to the second decomposer and low-pressure recycle gas to the first decomposer). Make-up CO_2 gas is mixed with the decomposition gases. Reportedly, the process will not require steam in the pressure range of 17 to 25 kg/cm^2 absolute, because the first decomposer uses reaction heat. Steam at 10 kg/cm^2 absolute will not be required for the urea-crystal method, when the compressors have turbine drives and the CO_2 compressor has a partial extraction turbine. Each of the centrifugal compressors has two cases and is provided with suction separators, inter-case coolers with separators and by-pass coolers. The compressors can be driven by steam turbines (preferred) or electric motors (plus speed-reducer gears).

Utilities (steam and power) required per ton of urea are shown below:

Electric power	32 kWh
Import steam (42 atm superheated)	1.347
Export steam (3 atm saturated)	0.21 tons

Although no commercial plant operates by this process, the method is regarded as a pathfinder, since it incorporates significant departures from conventional technology and offers potential savings in investment and operating cost.

The Symposium took note of the improvements already achieved in the processing technology and of the continuous efforts of the companies involved to improve urea processes and equipment. The participants felt that greater attention should be paid to producing urea with better product quality, such as hardness, and to streamline bulk transportation since this would contribute greatly to reducing the cost for the consumer. It was also contended that product-size range should be widened to avoid problems of separation upon bulk-blending of urea with other granular materials.

IV. TECHNOLOGY OF THE PRODUCTION OF PHOSPHATE AND POTASH FERTILIZERS, INCLUDING MIXED, COMPLEX AND LIQUID FERTILIZERS

Phosphoric-acid wet-process

The Symposium reviewed the technology used in the production of phosphoric acid in the USSR, with special reference to optimizing process yield using apatite concentrates from Kolskij and phosphate rock from Kara Tau.

The majority of the phosphoric-acid plants in the USSR use the classical dihydrate wet phosphoric-acid process. The capacity of standard production units varies from 55 to 110 tons per day of P_2O_5. As a rule, 30–32 per cent P_2O_5 phosphoric acid is obtained from the reactors after filtration. The filtration of calcium sulphate dihydrate (gypsum) is carried out by a horizontal tilting pan-type vacuum filter.

The design parameters of this unit operation are today well known, as adapted to the use of phosphate rock from Kolskij and Kara Tau. The recovery of 96 per cent of P_2O_5 is claimed for normal production.

Concentration of phosphoric acid from 30 per cent to 50–53 per cent P_2O_5 is accomplished by submerged combustion.

Recent efforts in the USSR have concentrated on obtaining a yield of 40–50 per cent P_2O_5 phosphoric acid from the wet phosphoric-acid process by crystallizing calcium sulphate in the hemihydrate form. The aim is to reduce the input of energy required for the evaporation step in the process.

Three approaches are known for the production of hemihydrate calcium sulphate (crystal).

The process whereby hemihydrate is precipitated and separated by filtration in the first step, after which the hemihydrate is re-crystallized to form dihydrate calcium sulphate;

The process whereby dihydrate crystals are formed first and then re-crystallized to calcium sulphate hemihydrate;

The "hemihydrative" process (USSR).

The third process, which was developed in the USSR, is based on stabilizing the hemihydrate calcium sulphate. Over 50 per cent of fluorine (F) is said to be recovered from the phosphate-rock feed in the form of fluosilicic acid (H_2SiF_6). Larger active filter surface areas are required to separate the hemihydrate calcium sulphate from the phosphoric acid than those used for the dihydrate form. The concentration of phosphoric acid obtained was 43–48 per cent P_2O_5. In addition, an increase in productivity by 25–30 per cent and a reduction in capital investment are reported. Operating efficiencies have also increased by 13–15 per cent.

The isothermal-reactor process

The Gulf Design Company of Florida has developed the "isothermal reactor" for the decomposition of phosphate rock with sulphuric acid. The development of this reactor-crystallizer was accomplished jointly with the Swenson Division of the Whiting Corporation, an equipment manufacturer in the United States, and Farmland Industries Inc., a producing company. At the time of the Symposium, a full-scale production plant with a capacity of 640 tons per day of P_2O_5 was nearing completion in the United States.

The isothermal-reactor equipment employs a draft tube-type agitator system, which permits a high circulation rate for the slurry while operating under reduced pressure. The reduced-pressure operation enables uniform temperature and concentration control for the system. The limiting factor in the conventional reactors (whether multiple- or single-tank) is the quantity of slurry in circulation. In a classical reaction system the circulated slurry is seven to ten times that of the slurry fed to the filter. The heat removal from the reaction is a governing factor in establishing the circulation rates, besides retention time, which is nominal.

On the basis of the pilot-plant (22 tons per day of P_2O_5) test work, the following advantages are claimed for the isothermal system by comparison with the classical reactor systems:

Lower power requirements;

Elimination of sulphuric-acid dilution mixers;

Lower operating costs;

Reduction in capital investment;

Improved filter-cake washing;

Improved temperature control;

Improved mixing of reactants;

Elimination of mandatory rock-grinding as applied to Florida or western US phosphate rocks;

Increased recovery of P_2O_5 from the reaction system;

Reduction of in-plant pollutant fluorine emission;

Reduction of the residual fluorine in the gypsum from 1.0–0.8 per cent.

The adaptability of the reactor for the hemihydrate calcium-sulphate process is being investigated.

Electro-thermal phosphoric acid

Work on optimizing the operating conditions for phosphate-rock reduction furnaces brought to light that at least 25 per cent excess air has to be provided to maintain temperature within 600°C for the subsequent oxidation reaction; the contact time was 2–3 seconds.

The effects have been studied of partial pressures of water and temperature on the absorption of P_2O_5 in water for the production of phosphoric acid. The use of a recycled acid stream, with controlled concentration, spray density and temperature, gives an optimum set-up with the least volume of absorption and minimum entrainment in the effluent gases.

Electrostatic precipitators are used for the separation of entrained mist. A water curtain removes 40 per cent of the heat release in the furnace, built of alloy steel. The gas inlet temperatures are 900°C to the hydration tower and 200°C to the precipitator. Seventy-five per cent of the production is obtained from the tower and 25 per cent is drawn from the electrostatic precipitator.

Acid concentrations obtained vary between 10 and 35 per cent. The system is adaptable to polyphosphate production.

Liquid mixed fertilizers

The Symposium paid special attention to the growth in consumption of liquid fertilizers. A representative of the TVA emphasized the spectacular growth in the use of liquid fertilizers in the US, where 24 per cent of the total fertilizers were in liquid form. By 1969, 25 per cent of the gross tonnage was consumed in liquid form. Growth has been noteworthy, from 350 plants in 1959 to 2,700 in 1970.

The advantages of using liquid fertilizers are conveyance and ease of application, resulting in labour saving. Their extra flexibility allows the addition of many herbicides, micro-nutrients and insecticides. Liquid fertilizers may be spread combined with irrigation water.

TVA recommends that developing countries seriously examine their local needs and determine if these can be met by liquid fertilizers where simple production methods are used and problems of distribution are not insurmountable. By using suspensions, relatively high grades such as 12–24–12 and 15–15–15 can be made. Customary intermediates include urea, ammonium nitrate, wet-process and thermal phosphoric acids, ammonium polyphosphates and potash.

In some countries, urea ammonium nitrate (UAN) solutions containing 26 per cent N are marketed with a salting-out temperature of −25°C.

Mixed liquid fertilizers are produced in the US by small satellite plants with an annual production of less than 500 tons to 25,000 tons. These small plants are located in agricultural centres and their products are delivered directly to the farmer.

The producing plants fall into the following categories:

The "hot-mix" plants using phosphoric acid and ammonia with a typical grade of 10–34–0. This in turn is often shipped to a "cold-mix" plant;

The "cold-mix" plants using ammonium-phosphate solutions combined with other ingredients such as potash and a filler;

The "semi-hot-mix" plants deriving MAP from phosphoric acid and ammonia. Part of the MAP is purchased in solid form.

Investment costs may be $20,000 to $30,000 for "cold-mix" plants, $30,000 to $50,000 for "hot-mix" plants and about $25,000 for nurse-tanks and applicators.

An even simpler plant concept is the "fertilizer filling station", comprising a group of tanks containing various N, P and K base solutions. These are metered, mixed and pumped to the farmer's nurse-tank in prescribed quantities. Liquid fertilizers are becoming popular in the United Kingdom, France and Belgium. Although relatively new in the field, their advantages for and prospects in developing countries should not be underestimated.

The availability of superphosphoric acid (usually 40–80 per cent of P_2O_5) in the form of polyphosphoric acid gives extra flexibility to liquid fertilizer applications.

Additional advantages are:

Higher-analysis base solutions owing to the high solubility of ammonium polyphosphates.

The production of clear solutions, since impurities from the wet-acid process are sequestered before and during polymerization.

Micro-nutrient elements are easy to dissolve in ammonium polyphosphate solutions, whereas many of these elements are essentially insoluble in ammonium orthophosphate solutions.

The highly concentrated superphosphoric acid (over 70 per cent P_2O_5) economizes on shipping freight.

In 1959, TVA started manufacturing 11–33–0 base solution of about 76 per cent P_2O_5, later changing the grade to 11–37–0, which contained 27 per cent of P_2O_5 as orthophosphate, 42 per cent as pyrophosphates, 20 per cent as tripolyphosphate and 11 per cent as higher polyphosphates. The superphosphoric acid used for ammoniation was obtained from both electric furnace acid and the wet process as mixed acid. Usually 20–40 per cent of P_2O_5 comes from wet phosphoric acid.

Systems that have been operated as demonstration units by TVA were described. A typical sample is a standard 11–37–0 composition, containing 22 per cent P_2O_5 as "ortho", 42 per cent as "pyro" and 20 per cent as "tripoly", the balance being higher polyphosphates. The pH was between 5.8 to 6.2; viscosity was of 80 centipoises; specific gravity at 24°C was 1.4; and the crystallization point was below –20°C.

Polyphosphate solutions have the property of sequestering solid precipitates, which would otherwise separate out as suspensions in the mixtures. Compositions are usually made for instant use and hence the loss of polyphosphates by hydrolysis to orthophosphates is limited. But where solutions are to be stored, keeping the temperatures at 20°C (if necessary by cooling) is recommended.

Etablissements Gardinier of France constructed a pilot plant for producing 2.4 tons per hour of 10–34–0 ammonium-polyphosphate solutions based on the TVA system. They described the problems that arose in scaling-up operations and the solutions that were evolved.

The starting material is wet phosphoric acid fabricated either from Kola phosphate rock or from calcined Moroccan rock.

The phosphoric acid is heated to 135°C in a heat exchanger made of drilled graphite blocks. The reaction between ammonia and phosphoric acid is accomplished in three steps.

Ammoniation to MAP, which is an exothermic reaction carried out at temperatures up to 150°C in a scrubber.

Polymerization of ammonium phosphate, completed at temperatures of about 250°C.

Separation of vapour, coupled with recovery of ammonia, in a concentration step carried out at 255°C.

The equipment for this system is constructed from Hastelloy "C".

The product solution 13-60-0, drained from the scrubber, may be adjusted with ammonia and water to the standard concentration of 10-34-0. The formation of insoluble urea phosphates is prevented. The adjusting tank is constructed of stainless steel (18/10).

The scale formation in the graphite heat exchanger has been solved by keeping acid velocities in excess of 2 m/sec.

In the pilot plant, 52 per cent P_2O_5 phosphoric acid was used as long as its CaO content was less than 0.2 per cent and the organic impurities were virtually nil.

The stability of the polyphosphates in storage is further enhanced by adjusting the polyphosphate content of the solution to less than 50 per cent and refrigerating the storage at below 15°C.

Attempts to mix polyphosphates with ammonium nitrate to form melts appear to be promising. The resulting melts may be processed to yield prilled products with formulations 25–25–0 and 17–17–17. Etablissements Gardinier is piloting this process to diversify its commercial potential.

Projections for investment cost for a 200 tons-per-day plant, producing a 10-34-0 mixture with liquid ammonia supplied at 0°C and wet phosphoric acid, were in the order of 2 million French francs.

Granular mixed fertilizers

The potential of urea in compound fertilizer mixtures and granulates is of great interest, since urea promises to be the world's leading nitrogen fertilizer by 1975.

The commercial size (1.0–1.5 mm diameter) of urea granules, coupled with the relatively poor mechanical strength of its prilled grades, makes it incompatible with other granulated prime components for the production of bulk-blends. Cominco's (Consolidated Mining and Smelting Co., Ltd) spray-drum or pan granulation may improve sizing as well as strength to overcome these deficiencies. TVA's pan-granulating studies confirm that urea-superphosphate compound granulates may be produced with minimal fume and dust problems.

Recent tests for producing urea phosphates directly from wet phosphoric acid give a potential NP material which may either be used directly as a fertilizer, or be converted to ammonium "ortho" or polyphosphates by heating, without excess urea.

Urea has been granulated with ammonium phosphates and potash in India and Japan. The unit in India uses an ammoniator-granulator whereby urea prills are coated with ammonium-phosphate slurry, which is fixed as DAP by ammoniation.

The Japanese practice has included the use of rotary drums, pans and pug mills for granulations. Fisions Ltd. (United Kingdom) prefers to use non-granular MAP with crystal or prilled urea as feed to a rotary-drum granulator or pug mill.

The grades made by these several producers varied between 28-28-0, 24-30-0 and 19-19-19.

TVA studies concentrated on the production of NPK granulates starting from urea, ammonia, phosphoric acid and potash. Problems arose in drying the product to less than 1 per cent moisture content, since temperatures of the product had to be confined within 95°C to avoid urea hydrolysis. This resulted in uneconomic sizes for dryers.

Liquid and solid mixed fertilizers

Predominantly urea ammonium-nitrate mixtures (with or without free ammonia) are distributed as an aqueous solution for mixed fertilizers. These mixtures contain phosphoric acid, ammonium phosphates (including polyphosphates), "white" potassium chloride or ammonium sulphate or even sulphur suspensions. Micro-nutrients like zinc may also be incorporated with the pH adjustment by the addition of ammonia.

Although, intrinsically, total nutrient content of liquid fertilizers is low compared to some solid fertilizers, convenience of application, adaptability to precise uniform placement, elimination of the problems of caking, dusting, hygroscopicity and inhomogeneity, ease of manufacture and lower handling and storage costs are all advantages that make consumers prefer this type of product not only in the United States but also in the United Kingdom and France.

Potash refining

A review of extraction and refining of potash ores in the USSR indicates that a total volume of 33.48 million tons of potash ores from underground sources were utilized.

In the "room-and-pillar" method used, extraction efficiency achieved was only 50–60 per cent. Industrial-scale tests have been successfully carried out on supporting the roofs of the workings progressively on telescopic pillars, so that there are now prospects of improving the extraction efficiency to 75 per cent. Special combines for mineral extraction and self-propelled wagons and belt conveyors for transporting the ore have been introduced to economize operations.

Techniques for refining crude potash use flotation and hot-solution crystallization. In the flotation method, part of the clay is separated from a slurry of crushed ore. Potassium-chloride concentrate is added to the aerated product, which is then dried after thickening and filtration. The separated clay is subjected to hot counter-current leaching. The hot extract is evaporated and crystallized in vacuum crystallizers. Coarse-grained potassium chloride is produced by flotation at Berezniki and Soligorsk.

Hot-solution crystallization uses conventional routes with hot counter-current leaching and cooling of hot lye. The degree of extraction of potash attained in flotation plants is 80–85 per cent, and in the hot-solution plants, 90–92 per cent. Potassium-chloride purities obtained are 95 per cent in the former and 98 per cent in the latter.

As an extension to potash extraction, a by-product of various grades of common salt has also been planned. Kalusha and Stebnikovsk produce chlorine-free potash fertilizers (K_2SO_4) from polymineral ores. The natural ores contain about 9 per cent K_2O and 15 per cent clay. A hot extract is obtained by leaching, which is cooled and treated with 20–30 per cent by volume of liquor saturated with magnesium and potassium sulphates. Schoenite ($K_2SO_4 \cdot MgSO_4 \cdot 6H_2O$) is decomposed with limited quantities of water to separate K_2SO_4.

Research is being undertaken to try dry methods for clay separation. Interesting possibilities have opened up for the beneficiation of ores. When the heated ore is treated with benzene-sulphuric-acid reagents in the course of heating, and transported to an electrostatic separator, the mineral components require opposite electrical charges, and high-voltage separation takes place. Semi-industrial-scale beneficiation of silvinite ore, containing 27–19 per cent potassium chloride, produced a concentrate analysing 90–95 per cent potassium chloride.

V. TECHNOLOGY OF THE PRODUCTION OF NITROPHOSPHATE FERTILIZERS

While nitrophosphate processes have been known for the last 40 years or more, older processes using phosphate rock and nitric acid gave products with a P_2O_5 content that was only 30–50 per cent water-soluble. The participants at the Symposium noted with interest the commercialization of processes producing 75–80 per cent water-soluble products and, in some cases, over 90 per cent water-soluble phosphates.

The production of high water-soluble nitrophosphates involves a high degree of separation of the calcium nitrate from the phosphoric acid, produced by the acidulation of the phosphate rock with nitric acid. The following three different methods practised by industry were described:

Chilling to crystallize out the calcium nitrate, either directly or by the addition of super-saturating materials;

Adding ammonium sulphate to precipitate the calcium as calcium sulphate;

Solvent extraction to extract the phosphoric acid.

In general, the calcium nitrate is converted to ammonium nitrate. Four different processes were described. Among the processes in commercial operation using chilling to crystallize out calcium nitrate are the Norsk Hydro process (involving direct batch-type chilling) and the Chemoprojekt-Bamag process (involving chilling with white spirit). The Norsk Hydro process, a refinement of the classical "ODDA process", has been licensed on the world market for four years, and, apart from plants in Norway, one plant is in operation in the United States and others are under construction in Hungary and Romania. The process is capable of producing formulations with 80–85 per cent water-solubility. The Chemoprojekt-Bamag process has been in use at Lovosice, Czechoslovakia, since 1967 for the production of NPK fertilizers with 60 per cent P_2O_5 water-solubility, utilizing Kola phosphate as raw material. A new (60 per cent P_2O_5) plant is about to start commercial production in Spain, producing material with 80 per cent water-solubility based on calcined Moroccan phosphate.

Processes for the separation of calcium by the use of ammonium sulphate have been available for some time. The Stamicarbon (DSM) process was described. It was noted that these processes are of particular value where by-product ammonium sulphate (e.g. from Caprolactam production or coke-ovens) is available.

Recently, processes have been developed that use solvents to extract the phosphoric acid. The Typpi Oy process (Finland) was described and discussed. The process involves the use of tertiary amyl alcohol as the extraction solvent, and subsequent treatment with ammonia and ammonium nitrate. Pilot-plant data for consumption of raw materials and utilities were given. The process is said to produce a 99 per cent water-soluble product.

Various grades of compound fertilizers can be made from different processes. In the case of the ammonium-sulphate separation process, the ratio of N : P_2O_5 cannot be less than 1.4 : 1 (for Kola rock; higher for other rocks) without the use of additional phosphoric acid. In the calcium-nitrate separation processes, the main range is between 1 : 1 and 2 : 1 of N : P_2O_5 ratios, although 0.8 : 1 is possible. A standard 1 : 1 grade is 23–23–0. In the case of solvent-extraction processes, 0.5 : 1 ratios are possible and the 1 : 1 product is 28–28–0.

The capital costs for the various nitrophosphate processes were considered to be generally similar to those processes using sulphuric acid (to manufacture MAP or DAP). Including the cost of manufacture of nitric acid, the nitrophosphate plant capital costs are higher.

A preliminary examination of the cost of manufacture indicated that the cost of production of nitrophosphates for a 28–14–0 product is about the same as for DAP/MAP and ammonium nitrate, based upon a sulphur price of $10 per ton. In subsequent discussions, it was felt by the participants that this break-even price for sulphur is low. There was little doubt, however, that nitrophosphates are more economical with sulphur at over $20 per ton, as in most developing countries.

Economic plant sizes for nitrophosphate units were indicated for one of the processes discussed at 90–100 tons P_2O_5 per day. There was no significant reduction in costs of manufacture beyond 100–120 tons P_2O_5 per day.

Some other advantages for nitrophosphates, which were pointed out by the participants, were that in sulphur-short countries no foreign exchange would be required for the acid raw materials, and that in manufacturing nitrophosphates (except by solvent extraction) the secondary and trace elements contained in the rock remain in the fertilizer and are of value.

Disadvantages cited for nitrophosphate processes included lack of flexibility and higher maintenance costs. The danger of self-sustaining decomposition of nitrophosphate-based NPK compounds containing potassium chloride was briefly mentioned.

VI. FERTILIZER INTERMEDIATES AND THE CONCEPT OF SATELLITE PLANTS

Production of compound fertilizers from intermediates in satellite plants

Recent years have seen a spectacular growth in the construction of large ammonia, urea and other plants near suitable raw material sources. While this has enabled substantial economies of scale and has facilitated the logistics of production, less progress in meeting the individual needs of farmers has resulted owing to the inherent inflexibility of large plants. This problem has been largely solved in developed countries by resort to a system whereby concentrated intermediates are produced economically in large plants and shipped in bulk to market areas where they are mixed in granulated, bulk-blended or liquid form in small satellite plants, according to prescribed nutrient ratios. While this approach may not be universally applicable, it may undoubtedly be adopted with advantage in many developing countries.

Examples of main intermediates are ammonia, urea, TSP, DAP and potash. More recent ones are nitrogen solutions, phosphoric acid, ammonium polyphosphate and powdered MAP. These are relatively stable, high-analysis materials with high water-solubility and compatibility; moreover, they can be stored and shipped in bulk.

Granulated compounds

In the United States, use of intermediates was augmented by the introduction of the TVA ammoniator-granulator in about 1953. This has enabled building plants for simple batch-wise weighing and continuous granulation with capacities of 10 to 30 tons per hour at a cost of $250,000 and upwards. Subsequent availability of DAP, stricter environmental control and bulk-blending practices have diminished the popularity of such plants. However, their advantages are low cost, flexibility and the capability of producing homogeneous products. In 1954 some 70 per cent of all P_2O_5 used in granulation was based on SSP. Today, this proportion has declined to about 10 per cent, although the tonnage is about the same. This may not be the wisest course, since some higher-analysis intermediates may cost relatively more and do not furnish essential sulphur and calcium. A shift has occurred at the same time from locally owned plants to their acquisition by large chemical and oil companies, although more recently a reverse trend has been evident with the increase of co-operatives, which represent local interests.

Some granulation plants are locally owned in France, Germany and Spain. In Belgium, Italy, the Netherlands and Norway, production of nitrophosphate compounds in large plants is prevalent. In the United Kingdom, granulation is frequently undertaken locally, even by large producers. An interesting practice is the pre-granulation of intermediates for final compounding locally; this enables high production rates (30 to 50 tons per hour). Some small plants have been more successful than large ones. In Japan, 80 per cent of all fertilizers are granulated and high-analysis grades (over 35 per cent) predominate. Granulation is also undertaken in Central and South America.

Bulk-blended mixtures

In the United States, bulk-blending of solid intermediates by mechanical mixing has grown rapidly, from about 300 plants in 1959 to 5,000 in 1970. Advantages include low capital and operating costs, and great flexibility. Capacities average about 2,000 tons per year. Production is seasonal and spreading services are often supplied. Operation is simple: raw-material storing, batch-weighing, mixing and loading. A 10–20 per cent cost advantage is claimed for blended in preference to granulated fertilizers delivered to the farm. Undoubtedly, bulk-blending has been a major factor in greater fertilizer use during the last decade. Typical intermediates used are ammonium nitrate, DAP, TSP and potash. However, the incompatibility of urea with ammonium nitrate and with TSP must be remembered. Also, to avoid segregation, intermediates must be matched in particle size. A maximum distribution radius in the United States is about 25 miles.

Except for Canada, bulk-blending has so far been little used elsewhere. Undoubtedly, it has a good potential in other countries, since it does eliminate one step in the distribution system, and also bagging in most cases.

Satellite plants in developing countries

It must be remembered that establishing fertilizer plants in developing countries involves not only solving technical problems. Both natural and man-made barriers exist and must be overcome. These include: unequal distributions of primary raw materials – e.g. natural gas, phosphate rock, potash and sulphur–throughout the world in relation to market areas; political obstacles; and foreign-exchange limitations. Another frequent problem is the disparity between imminent fertilizer consumption in a specific country and the economic sizes of plants to produce the needed materials.

A successful way of overcoming the latter problem is to adopt a step-by-step approach whereby, according to needs, finished fertilizers are imported, first in bagged and then in bulk form; intermediates are imported and mixed or granulated in prescribed ratios; and large plants of minimum economic size are built to produce either NPK nitrophosphates or major intermediates for subsequent mixing or granulation according to circumstances. This approach also helps to keep investment needs in harmony with other priorities and may therefore be recommended.

To illustrate this principle, consider an ammonia plant of 150,000 tons per year of N capacity–the generally accepted minimum economic size. If an average application rate of 40 kg N per hectare annually (slightly less than the recent average of 43 kg N per hectare for Europe) is assumed, such a plant could supply enough N for 40,000 km^2 on a one-crop-per-year basis. Out of 15 developing countries in East

Africa, for example, only Ethiopia, Uganda and the United Republic of Tanzania have cultivated areas exceeding this figure, and a forecast by the Economic Commission for Africa (ECA) shows that even by 1980, respective annual consumptions are likely to be no more than 15,000, 21,000 and 27,000 tons of N. The importation of ammonia or equivalent solid intermediates thus appears to be the logical next step. After a fertilizer industry based on imported products has been soundly established in these countries, primary production may be envisaged. A similar situation exists regarding phosphoric acid: by 1975, in the 15 East African countries referred to, only Rhodesia will have a P_2O_5 consumption that will justify installing a phosphoric-acid plant of minimum economic size (180,000 tons per year of P_2O_5).

Imported phosphoric acid as a fertilizer intermediate

To reduce pressure on limited foreign exchange and other resources in a developing country, it is usually preferable to import N, P and K materials in certain circumstances rather than to establish domestic production, until increasing market needs justify this stage. Nevertheless, several developing countries have set up basic fertilizer plants in the hope that expanding markets will some day warrant full capacity. This could mean a long period of underutilization and over-supply. For example, if a 200 tons-per-day phosphoric-acid plant were built in a country having an annual consumption of 20,000 tons P_2O_5 per year and a growth rate of 10 per cent annually, it would take 14 years to catch up with plant capacity.

Demand-supply flexibility

It is estimated that about 30 countries are currently in a favourable position to import phosphoric acid as an intermediate, and that another 50 will be ready to import it in the future, when domestic markets justify progressing from imported fertilizers to domestic production. Imported phosphoric acid may thus be regarded as a fertilizer intermediate in two ways: first, as a convenient supply of concentrated P_2O_5 for further processing domestically; and second, as a means of supporting an intermediate period of growth between fertilizer imports and the domestic manufacture of fertilizer. The corresponding market growth pattern is an S-shaped curve: the base represents an initial starting rate (phase 1), followed by a period of rapid expansion (phase 2), which gradually diminishes as large market needs are increasingly met (phase 3).

Monoammonium phosphate (MAP) as a fertilizer intermediate

Diammonium phosphate (DAP) has been produced for some 20 years on a large scale by ammoniating phosphoric acid to a mole ratio of about 1.9 to 1 and then granulating the slurry to yield a solid product containing about 16 per cent N and 48 per cent P_2O_5. In the last few years, commercial processes have been developed in the United Kingdom and the United States for making monoammonium phosphate (MAP). These methods produce a powdered product that has been widely accepted in the United Kingdom and other countries. However, its adoption in the United States has so far been limited, owing no doubt to preferences for granular bulk-blends and liquid fertilizers.

Powdered MAP is made by ammoniating phosphoric acid under slight pressure and elevated temperature to take advantage of the steep-solubility characteristic of MAP in water. This produces a slurry containing 12–15 per cent water, which is subsequently flashed in a tower to yield a product containing 11–12 per cent N and 47–53 per cent P_2O_5, according to feed-acid purity. Corresponding P_2O_5 water-solubilities are 90–97 per cent and moisture contents are typically 5–7 per cent; particle size is in the 0.1–1.5 mm range.

One popular method of this type is the Fisons "Minifos" process, which is currently used in some eight developed countries to make over 1 million tons of MAP intermediate annually. Investment cost is much lower than that for a standard granulation plant of comparable output; for example, \$340,000 *versus* \$1.7 million for 20 tons-per-hour capacity. Operating costs are said to be 25 per cent of those for a comparable granular ammonium-phosphate plant. The product is claimed to be storable and shippable in bulk, provided it has been produced with a sufficiently low moisture content. It is compatible with urea and ammonium nitrate and can augment or replace SSP or TSP. It can be used to make a wide range of granular products, such as 8–38–16, 12–12–24, 22–11–11 and 16–48–0. Unclarified acid may be used, with some reduction in grade and water-solubility.

A variety of fertilizers likely to be of major importance in the future, especially in the Middle and Far East, are in the urea-ammonium phosphate-potash group. These are high-analysis materials that can provide balanced quantities of nutrients in an agriculturally acceptable form. Powdered MAP would seem to be particularly suitable for this purpose since it is compatible with urea and potash. Moreover, such mixtures may be readily granulated. In view of the large amounts of urea becoming available in many developing countries, imported MAP offers a good way of producing balanced fertilizers in local granulating plants.

Compared with the alternate use of phosphoric acid as a phosphate intermediate, calculations indicate that powdered MAP should yield significant cost advantages. For example, in shipping 84,000 tons per year of P_2O_5 from Florida to India, as a wet-process acid containing 54 per cent P_2O_5, the fixed capital investment in concentration, classification, storage and terminal facilities would amount to about \$3.6 million. Direct operating costs would be \$41.2 per ton. Corresponding costs for the MAP route would be \$2.9 million and \$29.8 per ton. This shows savings of \$700,000 in capital costs and \$11.4 per ton in direct operating costs, representing a total savings of \$13.4 per ton of P_2O_5, assuming the cost of servicing the investments at 22 per cent annually.

A comparison of costs for producing 28–28–0 from granular urea and from the alternate phosphate intermediates also shows an advantage for MAP. Using phosphoric acid would entail a fixed capital cost of \$6.8 million and a direct operating cost of \$14.1 per ton, whereas corresponding costs when using MAP would be \$5 million and \$10.4 per ton, with savings of \$1.8 million in capital costs and \$3.7 per ton in direct operating costs, or a total savings of \$5.1 per ton, based on servicing the capital investment at 22 per cent (10 per cent profit, 7 per cent depreciation and 5 per cent maintenance). These figures do not include the transport of nitrogen covered by the MAP.

Economics of triple superphosphate (TSP) intermediate

During a period of high growth rate it would be difficult to build fertilizer plants to keep in step with demand, and there would be frequent periods of over- and under-supply, with a corresponding inefficient use of capital resources and foreign exchange. Furthermore, transport costs may be about four times greater than for intermediates. These excess costs may be avoided by importing requirements only according to need. Most important, investment savings made during phase 2 may be used to build a sound marketing and distribution system. For TSP, capital investment may be four times greater in phase 3 than in phase 2 (steady-state market conditions).

For TSP, production based on imported acid to meet a zero market growth loses its advantages at amounts greater than 100,000 tons per year. However, domestic production of acid and TSP begins to show savings in the foreign-exchange component (FEC) above 25,000 tons per year and, in some countries, this could soon increase to become the dominant factor. Examples of these proportionate costs are given in table 2.

TABLE 2. PRODUCTION COST OF TSP

Annual quantity (tons/year)	*Intermediate route (dollars/ton)*		*From domestic sulphuric and phosphoric acid (dollars/ton)*	
	Total	*FEC*[a]	*Total*	*FEC*[a]
10,000	72.4	57.9	109.7	65.3
25,000	64.9	55.6	82.2	55.4
50,000	60.8	54.5	68.5	48.7
75,000	59.5	54.1	64.0	48.0
100,000	58.2	53.8	59.6	47.2
135,000	57.4	53.5	56.9	46.1

[a] Foreign-exchange component.

Expanding market conditions

Calculations support the principle of adopting the intermediates route, even when market growth rates exceed the typical 10 per cent yearly figure for developing countries. A case was studied for an annual market growth of 15 per cent where phase 2 requirements rose from 10,000 to 100,000 tons per year of TSP. The economics of building small acid plants equivalent to 25,000 and 50,000 tons per year of TSP during the phase 2 growth period were also investigated (option I, table 3) and contrasted with building a single larger plant of 75,000 tons per year of TSP (option II). For comparative purposes, all costs were discounted to present values over 17 years at 9 per cent. The results, indicated in table 3, demonstrate the financial advantages of intermediates.

TABLE 3. COMPARISON OF THE ECONOMICS OF PRODUCING TSP *VIA* INTERMEDIATE ACID AND DOMESTIC ACID PLANTS

(Million dollars)

Option	*Total expenses discounted*	*Total expenses in foreign exchange discounted*
TSP *via* intermediate acid	14.81	12.47
I – TSP *via* domestic acid plants of 25,000 and 50,000 tons per year	20.14	13.48
II – TSP *via* domestic acid plant of 75,000 tons per year	16.48	12.11

This approach to the economics of intermediates is applicable, of course, to other fertilizer materials in addition to TSP.

VII. RAW MATERIALS AND INTERMEDIATES FOR FERTILIZER PRODUCTION

Electrical energy as raw material

In developing countries where relatively larger hydroelectric power stations have been constructed, the cost of electricity is steadily decreasing, since larger generating plants coupled with distribution and transmission systems are being installed.

When the cost of electricity is sufficiently low, the production of hydrogen for ammonia or the reduction of phosphorus by an electric-furnace process may become economical. Installations of this type carry a steady power demand coupled with high load and power factors. This makes it desirable from the economic standpoint to locate such industry as close as possible to a power station.

Electrolytic hydrogen is very pure, which is advantageous in ammonia production. Thus, the availability of large electrolysis plants coupled with low-cost electricity may make electrolytic hydrogen competitive with other raw materials such as natural gas or naphtha, in some special cases.

There has been a steady increase in the size of electrical furnaces for phosphorus, from 20–25 MW in 1962–1964 to 60 MW in 1966 and 70 MW in 1968–1970, which has resulted in more efficient phosphorus production.

Comparative electro-thermal phosphorus production costs may be further reduced by the possibility of using low-grade phosphate rock (23 per cent P_2O_5), high in silico-aluminates (up to 7 per cent) and Fe_2O_3 (about 3 per cent), whereas $Al_2O_3 + Fe_2O_3$ should not exceed 3 per cent for wet-process phosphoric acid.

Phosphoric acid produced in electric furnaces is sold at premium prices because of its purity and concentration (up to 80 per cent). It is used not only for high-analysis fertilizers but also for the manufacture of industrial phosphates, both of which require high-purity phosphoric acid compared with the wet-process acid sold commercially.

When the cost of electric power drops to 3–4 mills, the cost of producing ammonia with electrolytic hydrogen as an intermediate step becomes attractive. The same applies to the production of furnace-grade phosphoric acid, which could become economic and competitive with the classical approaches used for the production of phosphoric acid.

Phosphate rock: trends in supply and demand in relation to world fertilizer requirements

Consumption of phosphate rock in 1969 was 74 million tons, of which 84.6 per cent was used for fertilizers and 15.4 per cent for non-fertilizers (10.4 per cent for elemental phosphorus, 3.2 per cent for industrial-grade, wet-process phosphoric acid and 1.8 per cent for other non-fertilizer products).[10]

Fertilizer-grade phosphoric-acid production accounted for 25.33 million tons, non-fertilizer thermal phosphoric acid for 5.7 million tons[11] and industrial-grade, wet-process phosphoric acid for 2.33 million tons. Hence, over 33 million tons of phosphate rock went into the manufacture of phosphoric acid alone (45 per cent of total consumption). This proportion has been increasing rapidly during the last 15 years, mainly as a result of the trend towards high-analysis fertilizers requiring phosphoric-acid acidulation. High-analysis fertilizers now account for over one half of the world consumption of phosphate rock for fertilizer manufacture, compared with only one quarter 15 years ago.

In general, demand for phosphate rock is governed largely by the growth in consumption of phosphate fertilizer. This growth has slackened since 1967. From 1957–1965 production and deliveries grew at an average rate of over 8 per cent per annum. Many diverse reasons are given for the reduced rate of growth in fertilizer consumption since 1965. The earlier high rate led to a forecast of phosphate-rock consumption for 1969—made in 1965 at the first UNIDO Interregional Fertilizer Seminar—of 87.9 million tons of rock. The actual consumption in 1969, however, was 73.8 million tons.

In a way this forecast reflected the fertilizer manufacturers' assessment of the market, and it prompted producers of phosphate rock to increase world production capacity from 71 million tons in 1965 to 113 million tons in 1971, equivalent to a 60 per cent increase in six years compared with a rise of only 35 per cent in deliveries.

The effect of this over-capacity may be illustrated by the fact that the United States, which produces about 40 per cent of all world phosphate rock, produced at full capacity in 1965 and at 74 per cent of capacity in 1970. In order to improve their status, the producers have increased their exports from 26 per cent of deliveries in 1965 to 32 per cent in 1970.

Western Europe accounts for about 46 per cent of the international phosphate-rock trade, competing with Morocco, the United States and the USSR, which together accounted for 80 per cent of world phosphate-rock production in 1970. Only Senegal, Togo, the United States and the USSR, however, have gained in this competitive market. The Moroccan and Tunisian sales have been diverted towards Eastern Europe.

The pressure on export prices caused by excess capacity has resulted in decreased earnings for all producers, with the possible exception of the USSR. This, in turn, has given momentum to the trend towards the establishment of export-oriented phosphoric-acid and phosphate-fertilizer production facilities at or near the production site of the raw materials. By 1976, there could be a total export

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[10] International Superphosphate and Compound Manufacturers Association, Limited (ISMA), *Annual Phosphate Rock Statistics, 1969.*

[11] Non-fertilizer elemental phosphorus amounted to 7.67 million tons, of which 5.7 million tons were processed as thermal phosphoric acid (non-fertilizer grade).

capacity of over 1 million tons P_2O_5 as phosphoric acid from these plants, which would account for 3.4 million tons of phosphate rock.

Total world phosphate-rock requirements are estimated to be 105–120 million tons for 1975 and 140–155 million tons for 1980. These figures may be compared with an OECD forecast of 116 million tons for 1975 and 155 million tons for 1980.

It is apparent from announcements that the probable expansion of the phosphate-rock supply will easily cover even the maximum demand levels forecasted to date, at least until 1975 and probably until 1980. The OECD suggests that phosphate rock capacity will increase by 38 per cent between 1969/1970 and 1975 to a total of 143 million tons. TVA predicts an increase of only 21 million tons in the same period, giving a 1975 total of only 121 million tons capacity. There is little doubt that as soon as the phosphate-fertilizer industry begins to recover, there will be a further corresponding expansion of phosphate-rock supplies. This may tend to retard the trend towards processing the phosphate at its point of origin, or even favour the creation of large phosphoric-acid plants at locations in the industrialized countries. There is a degree of uncertainty about the present rapidly changing situation, which demands close, continuous attention. Producers of phosphate rock and manufacturers of phosphate fertilizer share the problem of how to improve profitability, and they are increasingly aware of their world-wide interdependence. They must make serious attempts to co-ordinate development internationally through a better understanding of their mutual relationships.

Sulphur: supply, demand and price forecasts up to 1980

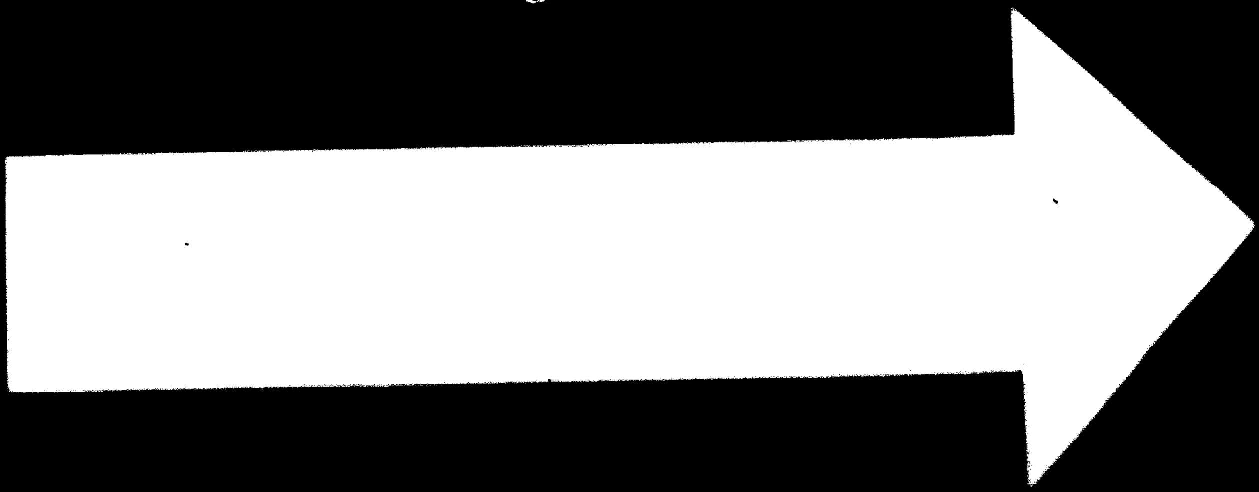
About 80 per cent of sulphur in all forms is used to make sulphuric acid. The main consumer of sulphur in the manufacture of final products is the fertilizer industry, which utilizes approximately 50 per cent. Of the other 50 per cent, carbon disulphide consumes 7 per cent, pulp and paper 5 per cent, titanium dioxide 5 per cent, iron and steel pickling 2 per cent, and 31 per cent is used for various other production.

Thus in countries with market economies, sulphuric-acid production for phosphatic fertilizers determines the demand for sulphur. For example, in 1969 sulphur consumption in all forms amounted to 28.3 million tons, production of sulphuric acid reached 63.4 million tons of acid, and of phosphatic fertilizer, 13.8 million tons of P_2O_5. The 28.3 million tons of sulphur supply consisted of 16.6 million tons of elemental sulphur, 7.3 million tons of pyrite-based sulphur and 4.4 million tons from other sources. For lack of relevant statistical data no world consumption figures can be given. But an estimate based on the figures for sulphuric acid gives a consumption of 32 million tons in 1967 *versus* 26.3 million tons for the same year in market economies.

Over the past 15 years, production of sulphur in all forms grew at a rate of 7.7 per cent per annum, individual rates being 6.5 per cent for sulphur from pyrites and 12.9 per cent for granular sulphur. Over the last three years, the share of pyrites has diminished owing to the increased production of Canadian sulphur from natural gas.

Sulphur resources in the world are enormous and will cover the demand for that raw material in the foreseeable future.

World production of sulphur in all forms for 1969 was 39 million tons, of which 21 million tons were elemental sulphur, 11 million tons were pyrites and 7 million



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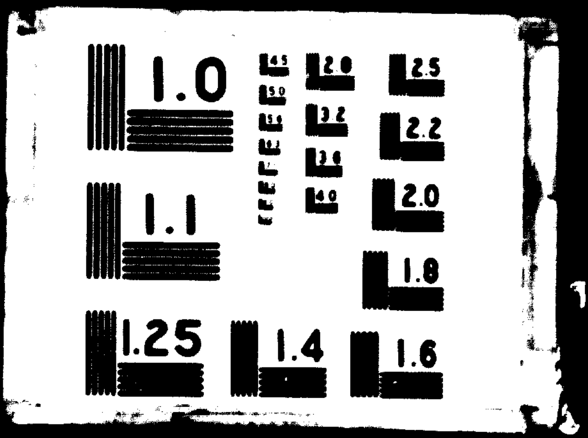

tons represented other forms. Over 80 per cent of all elemental sulphur is produced by the following countries: United States (41 per cent), Canada (18 per cent), Poland (9 per cent), France (8 per cent) and Mexico (8 per cent).

Over the past 20 years periods of sulphur shortages have alternated with periods of over-supply. Shortages developed in 1950, 1957 and 1963–1968. The period 1957–1962 was one of over-supply, and another period of over-supply, which has lasted until the present, began after 1968. Despite this unfavourable situation, Canada must market greater amounts of sulphur derived from sour natural gas (3.2 million tons in 1969 and 4.5 million tons in 1970). Poland has kept on increasing its production from 1.3 million tons in 1968 to 2.7 million tons in 1970.

The large supply of granular sulphur in the world market and its very low price have made many customers revert to granular sulphur as a raw material.

A special trait of the sulphur trade is the current demand for liquid sulphur. By 1970, 43 per cent of Europe's sulphur imports were in liquid form (1.5 million tons). Liquid sulphur is shipped to Europe by French, Mexican, Polish and United States producers. It costs $1.5–$2 per ton more than lump sulphur, but advantages compensate for the slightly higher price.

Granular sulphur accounts for 75 per cent of the total sulphur exports. Canada, France, Mexico, Poland and the United States account for 91 per cent of present over-all exports. Canada is now the major exporter with 34 per cent of all exports, followed by Poland with 28.9 per cent. In 1970, the two largest importers were Great Britain (0.9 million tons) and the United States (1.4 million tons). Trade for these two countries in elemental sulphur was 8.2 million tons in 1970 (37 per cent of world production). The fluctuation between supply and demand led to an all-time high price of $40/ton f.o.b. in 1968. Prices dropped in 1970 to an average $16–$20/ton f.o.b. owing to the over-supply.

By 1975, world demand for sulphur in all forms is expected to be 49.4 million tons and by 1980, 67.8 million tons. Production is estimated at 51.7 million tons of sulphur in 1975 and 68.1 million tons in 1980.

For most of the coming decade there is expected to be an excess supply. The existence of large amounts of Canadian sulphur will tend to lower prices, but if many of the producers on the borderline of production costs limit or stop production, a shortage and increased prices will result. Thus, it seems that prices could stabilize in the $18–$22 range until 1980.

Granular sulphur is a cheaper raw material than pyrites for sulphuric-acid production, basically because it involves a simpler installation. The cost of one ton of sulphuric acid produced in a 1,100 tons-per-24-hours plant is estimated to cost $7.50 when made from pyrite and $2.72 when made from elemental sulphur. The Polish enterprise "Polimex-Cekop" has specialized in transforming pyrite-burning into sulphur-burning plants only.

It may be convenient to change raw materials when local conditions dictate.

Trends in potash supply

Potash production amounted to 17.2 million tons K_2O in 1970, showing a steady increase after 1950, when it amounted to 4.7 million tons K_2O.

Production for 1970 was 17.6 million tons K_2O and followed sales closely throughout the year.

The number of producing countries has increased from eight in 1940 to ten in 1971. France, Canada, the German Democratic Republic, the Federal Republic of Germany, the United States and the USSR produced 93 per cent of all potash in 1970. This may be explained by the fact that high potash consumption and production generally go hand in hand.

World consumption for 1975 is estimated at 20.3 million tons K_2O and for 1980 at 24.1 million tons. Consumption will grow faster in the developing countries, whose share of the market will increase from 11 per cent of total K_2O in 1970 to 12 per cent in 1975 and 15 per cent in 1980.

The most conservative estimate of potash reserves is 15 billion tons, another is 68 billion and the highest is 122 billion tons. This means that at the present level of consumption potash production could continue for at least a thousand years.

These trends in potash supply clearly indicate that deposits are ample and that plant operations will be flexible enough to fulfil potash demand in any imaginable order of magnitude.

Scientific prediction of likely areas for agrochemical ore prospecting and surveying

Prospecting and geological exploration work for suitable deposits of minerals for use in the agricultural-chemical industry in the USSR has increased. This geological survey work has resulted in the discovery of a number of large deposits, such as Khibini apatites, Kara-Tau phosphorites, and the Verkhnekamsk and Starobinsk potassium-salt deposits.

Of the world's presently known phosphate reserves, 95 per cent are phosphorites.

To locate phosphorite deposits, prospectors in the USSR proceeded on the basis of the following studies and criteria:

A stratigraphic correlation making it possible to evaluate prospects for suitable phosphorite rock formations by first determining the age of the stratum;

A paleographical extrapolation defining the zones where the phosphorite was originally deposited;

The paleoclimatic prerequisites determining the prospects for the ancient climatic zones;

The facies lithological study, which links phosphorite deposits to other rock formations with specific composition, permitting more accurate predictions for the type of phosphorite that could be expected in a formation. (The geotectonic structure assists in mapping the phosphorite deposits according to type);

The mineralogico-geochemical criteria, such as phosphations, dispersion haloes, outcrops, aureoles in bedrocks, soil areas of oxidation and high vanadium concentration, which are also present at times with organic substances;

A measure of radioactivity age, which provides a means of aiding prospecting of phosphorites.

In studying the laws governing ore-deposit location, the use of superimposed maps or charts-to-scale aids the determination of criteria for predicting promising areas. Such aids are then supplemented by geophysical work and drilling. The adoption of these techniques by Soviet specialists led to the discovery of the Siberian phosphorite deposits in the Altai-Sayan region.

Apatites constitute only 4 5 per cent of the world's phosphate resources and are therefore of lesser importance. Recently, in line with the increase in the production of fertilizers, a search was started for the location of apatite ore.

Criteria for prospecting apatite, which have been worked out in some detail, are as follows:

Structuro-geotectonic confinement of platforms and outcrops;

A definition of mineralogico-geochemical connexion with certain other types of rocks and an excess of sodium or potassium in alkali complexes;

High concentration of magnetite in carbonatite complexes:

A phlogopitization and biotitization of ultra-basic alkali rock.

Volcanic sulphur is located in areas of relatively young volcanic activity, such as crater lakes etc. Bright coloured rocks in the volcanic area are another indication of sulphur existence.

Exogenetic sulphur, which is commercially much more important, is associated with strata of sedimentary sulphate rocks. The sulphur ores are always carbonatite-calcite. There are also tectonic laws that tell where to look for this element. Sulphur deposits are always located in oil- and gas-bearing areas and contain definite accumulations of hydrocarbon.

In addition to these prerequisites, prospecting indications are used such as "dispersion haloes" of sulphur, as well as micro-biological, geobotanical and even topochemical indications. The most substantial find in this field has been the existence of the pre-Carpathian sulphur-bearing basin, and its continuation into southern Poland and eastern Romania, where sulphur was discovered.

Soviet geologists have also assisted in discovering apatite deposits in the Democratic Republic of Viet-Nam, phosphorite deposits in Mongolia and phosphorites in Egypt and Siberia.

VIII. DESIGN, CONSTRUCTION, OPERATION AND MAINTENANCE OF FERTILIZER PLANTS, AND POLLUTION CONTROL

Because of the limited availability of foreign exchange, certain developing countries have embarked on large programmes for manufacturing machines, including those required for building plant for the fertilizer industry. It may be expected that the growth of a domestic fertilizer industry will hence be less hampered in the future in these countries.

India, which has a high growth rate of fertilizer consumption, has embarked on a large machine-building programme in recent years. Its endeavours in the field, along with the experience so far gained, may be of interest to other developing countries.

India has at present over 50 fabrication shops with facilities to manufacture various types of equipment required by the fertilizer industry. Eight of these firms can manufacture medium-pressure vessels both in stainless and alloy steels. Several firms also manufacture heat exchangers and large columns in various construction materials. Six large, modern, heavy workshops have been set up in the country with complete facilities for the manufacture of sophisticated and complicated pressure vessels, exchangers and other equipment. One of these firms is also equipped to manufacture, with foreign collaboration, high-pressure vessels of the multi-layer type. These firms would also be capable of designing, engineering and constructing air and gas separation plants in collaboration with foreign associates. All the major shops have adequate testing facilities and can also arrange for inspection under Lloyds Register. Some of the larger shops have design and drawing facilities for the production of detailed shop drawings.

The major problems of a domestic fabrication industry involve limitations in the availability and delays in the delivery of raw materials, both from within the country and from abroad. In some cases limitations in capacities of specific sectors, such as the fabrication of dished-ends etc., pose problems to the industry. Another important consideration is the wide range of standards used, especially where part of the design and engineering is obtained from outside the country. Local manufacture of proprietary items, based on foreign collaboration, also tend to use varying standards, causing problems to the designers and fabricators.

A major effort is being made in India to eliminate some of these problems, and to minimize the outflow of foreign exchange for obtaining design and engineering services from outside the country, by emphasizing the development of local engineering organizations. This has also helped to maintain the desired quality levels in the manufacture of plant and equipment to meet the highly sophisticated requirements of the fertilizer industry. The co-operation of design and engineering organizations with several of the fabricating firms during the planning stage has made it possible to guide domestic industry engaged in allied manufacture to diversify into fields relevant to the fertilizer industry.

An aspect of major importance since the last conference at Kiev is the emphasis on large-capacity, single-stream plants with limited provision for installed spares. For the economic operation of these plants, it is essential that the following requirements are fulfilled:

The plants are built with emphasis on the reliability of process schemes adopted and equipment utilized;

The plants are run with high on-stream factors, using proper and adequate operating and maintenance procedures;

The plants are operated and maintained by personnel who are competent and well trained;

Before building the plants, possible pollution problems are considered in the planning stage and the necessary steps are taken to control or minimize pollution in relation to the environment.

The above considerations are of importance to fertilizer plants irrespective of location, and become much more significant when such plants are built and operated in developing countries.

Building up a well-organized maintenance programme is essential to cut down on time and to maintain a high level of production. The lack of adequate skills and the unavailability of spare parts often pose serious delays in the operation of fertilizer plants located in developing countries.

A well-managed maintenance organization facilitates planning and scheduling maintenance work, with emphasis on cost, control, the efficient use of manpower, maintenance records and work backlog. It makes adequate manpower available to handle emergency jobs expeditiously. Further, scheduled preventive maintenance is necessary to minimize unanticipated breakdowns downtime. Preventive maintenance personnel should be equipped with the necessary tools such as vibration detectors, ultrasonic corrosion analysers and electronic leak detectors. A small group of technical specialists forming a task force for examining plant problems may become the key factor for better plant performance and lower operating costs. To establish this cadre, it is necessary to develop a programme for training key supervisory and maintenance personnel in safety practices and in the maintenance requirements of the plant equipment.

Another important aid for optimizing the performance of fertilizer plants is the use of computers. When adopting computers, it must be ensured that the required number of specialists are available with sufficient knowledge of the technical and economic operating problems. Only about 15 important variables are monitored by computers for plant control, and there would therefore be no significant reduction in operating personnel. The control systems are estimated to cost about 1 per cent of the plant investment and could contribute to an additional yield of about 1 to 2.5 per cent. The use of computers for plant operation in developing countries, however, is expected to be somewhat limited for the time being.

An important development in the use of computers is their adoption for design engineering, recently in the optimization of process schemes and the design of major equipment. Techniques adopted include the development of mathematical models and the study of alternate schemes to obtain higher efficiencies in the on-stream factor, and to control investment costs. It is expected that computer studies will enable the selection of the optimum process routes without sacrificing reliability for the sake of marginal advantages.

Pollution abatement in operating fertilizer plants

Problems of atmospheric pollution have not so far been given adequate emphasis in developing countries, owing to some extent to the lower levels of industrialization. To avoid serious problems of pollution in the future, it is essential that enough emphasis be given to the problem in planning now for new fertilizer facilities for the developing countries.

It is obvious that it is easier and less costly to incorporate adequate equipment for pollution control in new plants than to refurbish existing operating facilities to improve the control of pollution. Consideration must be given to the environment where the plant is situated and also to whether the unit is part of a larger industrial complex.

In the basic fertilizer industry, atmospheric pollution created by vented gas from sulphuric-acid, phosphoric-acid and nitric-acid plants is common. For some time taller vent stacks, and others that dilute the vent gases with additional air, have prevented polluting gases from causing harm to operating personnel and vegetation in the immediate surroundings.

More recently, as a result of increased industrial concentration in the developed countries, additional steps have had to be taken to upgrade pollution control in existing plants and to restrict projected new facilities on the amount of pollutants vented to the atmosphere.

A major pollutant is sulphur dioxide, which is released from sulphuric-acid plants as well as from power-generating plants using fuel with sulphur impurities. Economic recovery is not always possible, but this is no longer a criterion to justify industrial use.

In sulphuric-acid plants the double-absorption system is being increasingly adopted to reduce the SO_2 concentrations vented to the atmosphere. Originally, this system was developed in the mid-1960s in Germany, but now plants built in Australia, Belgium, Japan, the United Kingdom and the United States use this process.

Another approach is the pressure process for sulphuric-acid plants whereby after drying the air, the dried air is compressed to 3.5–6 atm. This process is not considered thermally as efficient as the standard sulphuric-acid plant operating close to atmospheric pressure. Also, for plant capacities that are now being built, the investment cost would exceed that of the dual-absorption plants. It is possible that the process would be economically attractive for very large plants.

Tail-gas treatment coupled with absorption by-product has been considered and adopted for sulphuric-acid plants in Czechoslovakia, Romania and the United States. A single-stage scrubbing can reduce the SO_2 concentration to between 500 and 800 ppm in the tail gas. The scrubbing is done with the addition of ammonia, resulting in the formation of ammonium-sulphite solution; by adding sulphuric acid, this is converted to ammonium sulphate and SO_2. Other acids, such as nitric acid or phosphoric acid, may be used to release ammonia and form ammonium phosphate or nitrate solutions. The addition of ammonia can be controlled by pH.

A magnesium-oxide scrubbing process, with regeneration of SO_2, has been developed in connexion with a project for a power plant in the United States.

Adsorption on solid adsorbents is being studied for SO_2, but this process is still in the development stage.

Solution-scrubbing methods do not normally remove acid mist. Mechanical means using filtration are available, but allowance has to be made for their relatively high-pressure drop.

In phosphoric-acid plants, fluorine is released from the reactors and concentrators. The fluorine present in most phosphate rocks is normally coupled with silicon dioxide as SiF_4. This hydrolizes in saturated gas streams to hydrofluosilicic acid (H_2SiF_6):

$$3SiF_4 + 2H_2O \rightarrow 2H_2SiF_6 + SiO_2.$$

To clean up these gaseous fumes, which are harmful to vegetation as well as to human beings in certain concentration, gas-scrubbing installations have been adopted. Two types of scrubbers commercially available in the US have been used successfully:

Cyclonic scrubbers using water injection in a cylindrical spray chamber;

"Cross-flow" spray chambers with packed section.

Two-stage systems are very often used to obtain the desired efficiency level required for the removal of fluorine from the waste gases.

In the nitric-acid plants, oxides of nitrogen are normally vented in the tail gas. Without treatment, the tail gas contains between 1,500–3,000 ppm[12] by volume of oxides of nitrogen. In the past, decolorization of the vent gases was accomplished by air dilution.

Oxides of nitrogen are reduced to nitrogen catalytically by several manufacturers. Owing to ever-increasing stringency, dual or two-stage systems are being adopted using auxiliary fuel to maintain the temperature of the catalyst at their level of activity.

Absorption methods have also been studied and used that involve adding height to the absorption tower.

The investment and operational cost of these systems increase steeply if a reduction in concentration of nitrogen oxides below 500 ppm (by volume) is required.

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[12] This applies to high pressure of ammonia-oxidation process (8 atm).

IX. PLANNING, FINANCING AND ECONOMICS OF NEW FERTILIZER PLANTS

An interesting contrast in points of view was expressed in papers presented by representatives of the World Bank Group, the Industrial Development Bank of India, the Indian Ministry of Petroleum and Chemicals, the Hungarian Ministry of Heavy Industry, and a leading firm of engineering contractors.

Replies by Governments of developing countries to the UNIDO *Questionnaire on problems facing the fertilizer industry in developing countries* suggested that the major problems of research and development, and central planning, were lack of engineering organizations for the planning, process development and design of new plants, and lack of research and development organizations for the development of new fertilizers and new production processes.

Replies to questions relating to problems of the construction of new plants similarly focused attention on the absence of locally fabricated equipment, the shortage of fertilizer-plant designers and the lack of process know-how, coupled with the high cost of fertilizer plants, the high cost of imported equipment and high royalty charges for foreign process know-how. The need to provide infrastructure was also strongly emphasized. Little significance, however, was attached by these Governments to restrictive policies and lack of investment incentives for foreign capital, or to high import duties on imported equipment and delays in the supply of locally fabricated equipment.

It is noteworthy, however, that the Government of India has taken steps to promote the rapid growth of the fertilizer industry and to attract the flow of capital into it. Such steps include freedom in marketing, preference in the allocation of funds from term-lending institutions, and arrangements for speeding decisions on all matters concerning the industry. In order to achieve the planned target of self-sufficiency in production of nitrogenous and phosphatic fertilizers between 1975/1976 and 1978/1979, the amount of capital needed for investment in the Indian fertilizer industry is estimated to be about $2,000 million, of which about $600–$700 million may be in foreign currency. India's foreign-exchange requirements for fertilizer projects have been and are being met largely from credits available from Italy, Japan, the United Kingdom, USAID and the World Bank, from the Governments of Belgium, Czechoslovakia and France, and from commercial sources, banks and other financial institutions, both in India and abroad. The country is dependent mostly on imported rock phosphate for the production of phosphatic fertilizers, but a start has been made in the exploitation of local deposits at Rajasthan. Schemes have also been devised for the utilization of local sources of sulphur.

As a result of the progress made in the indigeneous fabrication of fertilizer-plant equipment, the foreign-exchange component of the total capital cost of projects currently being implemented has been reduced to an average of no more than 40 per cent and is expected to be reduced further to about 10 per cent before the end of the decade. Indigenous design and engineering services have been developed to the point at which the country is largely self-reliant in this field.

Since its formation in 1964, the Industrial Development Bank of India (IDBI) has assisted three large and three relatively small fertilizer projects. IDBI finds that foreign collaboration is a prerequisite for obtaining management know-how, particularly in fields in which local experience is limited, and that association with reputable foreign firms tends to increase confidence abroad in local projects and encourage assistance by foreign financial institutions. IDBI would prefer foreign assistance to be in the form of credit or facilities for deferred payment rather than equity capital, but in the Bank's experience around 45 per cent of the equity has usually been contributed from abroad.

Much of the success of a project depends on the choice of contractor. This requires competitive bidding, and considerable preliminary work must be done to ensure that the contractor has sufficient experience and fully understands all the problems. Since fees for design engineering are much larger than those for know-how, foreign exchange could be saved first through establishing indigenous design-engineering facilities. (Contrary to the consensus of opinion in the replies to the UNIDO Questionnaire, IDBI has found that delays in the delivery of indigenous equipment have hampered several projects.)

As the ammonia plant accounts for a major portion of most project costs, IDBI advises selecting the minimum-cost process for ammonia. With large-scale single-stream ammonia plants, however, it is preferable not to undertake production at more than 50 per cent of capacity during the first six months of operation, rising to 70 per cent, 85 per cent, 95 per cent and 100 per cent in successive years. Urea plants, on the other hand, may often be operated at around 90 per cent of capacity in the first year, and at full capacity thereafter. Planning must take these factors into account: either excess ammonia capacity (or an additional design allowance in the synthesis-gas compressor and recirculator etc.) should be provided to act as a cushion, or the facilities should be sufficient to fully utilize all ammonia that is produced, since ammonia storage will necessarily be limited. With phosphoric-acid plants it is essential to contract for the supply of proper quality rock consistent with the design of the equipment.

Since fertilizer projects are capital intensive, the annual fixed costs are high. Analysis based on marginal costing, using "contribution" criteria for recovery of the fixed costs, may help in deciding not only on the type of product but also on the profitable phasing of different activities. There are advantages in examining projects on the basis of the "shadow" rate of exchange (internal currency expenditure per dollar saved) and of discounted cash flow (DCF), calculated in terms of foreign-exchange expenditure and savings over the life of the plant. In India, a shadow rate of 25–30 per cent above the official exchange rate was considered acceptable. No general guidelines may be given to developing countries, since the shadow rate depends on the real value of local currency and should be sufficient to service the debt; it will therefore depend on the rate of interest and the repayment schedule of foreign loans for the project.

In Hungary, a computerized linear-programming model of the fertilizer industry is being developed to facilitate future planning. It is designed to optimize, for example, the quantity of raw materials of varying quality obtained from alternative domestic and foreign sources, the installation of new fertilizer production capacity and the expansion of existing capacity. The result is expected to be a more favourable balance of trade.

The World Bank Group, comprising the International Bank for Reconstruction and Development (IBRD) and its affiliates, the International Development Association (IDA) and the International Finance Corporation (IFC), has participated in the financing of a dozen fertilizer plants, ranging in cost from $7 million–$100 million. In their experience, topics that are often inadequately treated in feasibility studies include the following:

Raw materials supply. It is essential to have long-term commitments for the supply (including delivery) of all needed raw materials with a formula for future price determination.

Land. Assurance is necessary either that the appropriate authorities are prepared to proceed with land acquisition if the project goes ahead, or, if government action is not involved, that the sponsor can in fact obtain the necessary land.

Permits. Agreement must be obtained at the outset on such matters as repatriation of foreign partner's earnings and eventually his capital, repayment of the Bank's and other lenders' loans, and permits for the erection of the facilities and for discharging effluents etc.

Market estimates. It is essential to make critical forecasts rather than simply mathematical projections of demand.

Marketing and distribution. Adequacy of rail and road services, storage capacity, marketing channels, credit facilities etc. should be assessed.

Financial projections. Capital-cost estimates should be prepared by a qualified engineering firm with international experience and, depending upon the amount of engineering that has been done in preparing the estimate of capital cost, a general contingency of 10–25 per cent should be added. Estimates of revenue usually err on the high side, because production in the early years is over-estimated and product prices are over-stated.

It was stressed by the spokesman for a leading firm of engineering contractors that the method used for preparing generalized production costs should be such that the data produced are closely related to the costs that the accountant would calculate in retrospect after the plant is in operation. The major difficulties lie in the handling of capital charges and overheads. In determining the level of capital charges for generalized production costs, the percentage of the total capital cost charged per annum must enable the plant cost to be amortized over the life of the plant at the rate of return demanded for the project. Inflation itself should not be regarded as a capital charge; if costs are calculated without provision for inflation, the rate of return should be reduced to the level that would apparently be acceptable to the investor if he did not have to cover inflation out of his interest or dividends. In the case of a developing country, the project must be analysed financially for commercial viability, for its impact on the balance of payments and for its impact on the internal economy. To consider the effect on the balance of payments, use should be made of the "shadow" rate of exchange referred to earlier.

For fertilizer projects, the World Bank Group favours a maximum debt : equity ratio of 60 : 40. Before deciding to invest, the Bank makes an economic, financial and technical appraisal, not only to confirm the information presented in the sponsor's feasibility report but also to explore all avenues that may have a bearing on the success of the project, involving detailed discussions with the sponsors, appropriate government agencies, agricultural experimental stations, farmers etc. The Bank's decision to invest improves the credit viability of a project, makes other lenders more ready to participate and encourages investment by nationals of the host country.

For the execution of a project, the World Bank Group usually encourages sponsors to appoint a technical adviser. Considerable care is recommended in preparing the tender documents and in the selection of contractors. Opinion is divided on the respective merits of cost plus fixed-fee contracts, lump-sum, fixed-price contracts and combinations of the two. For procurement of goods and services through international competitive bidding, attention is drawn to a World Bank publication, "Guidelines for Procurement under World Bank Loans and IDA Credits", May 1971. Satisfactory cost-accounting and control, and informative monthly progress reports, indicating delays, shortfalls and action being taken, are regarded as essential.

A participant of the World Bank Group indicated that some 31 new ammonia plants will be needed in the developing countries by 1975 and another 20 in the latter half of the decade, involving a total added investment of $4,200 million with a 60 per cent foreign-exchange component, or $400 million annually. This view was based on the assumption that world consumption/production of fertilizer nitrogen in 1975 will be about 44 million tons N and in 1980 about 60 million tons N, compared with around 29 million at present. Similarly, for phosphatic fertilizers the indications are that 47 new plants will be needed in the developing countries by 1975, and a further 30 by 1980, at a total estimated cost of about $1,420 million. To these figures must be added net imports of nitrogenous, phosphatic and potassic fertilizers currently running at around $1,066 million annually. These import costs are forecast to rise to $1,570 million annually by 1975, and to $2,155 million by 1980. The total funds that will probably be needed to meet the developing countries' future fertilizer requirements are assessed at around $2,600 million annually by 1975, with a net foreign-exchange requirement of $1,600 million, rising to $3,200 million and $1,700 million respectively per year by 1980.

The suggestion was made that the work load for both planners and bidders might be eased by choosing standard sizes and types of plant, but it was felt that over-standardization—particularly in types of plant—might well result in disadvantages, e.g. inability to keep pace with advancing technology and lack of sufficient flexibility to adapt to individual situations, which would outweigh the apparent advantages.

A number of other suggestions were made, but not fully discussed, including the following:

Greater use of local engineering groups in major developing countries;

A study of indirect costs, which will need to be financed until 1980, specifically in marketing (e.g. in the sectors of agriculture, petroleum and mining, railways, site development and ecology);

Assembly of "normal" investment costs for fertilizer plants under conditions of competitive international bidding;

Establishment of standard hypothetical f.o.b. prices for fertilizers and feed-stocks based on production at favourable locations;

Evaluation in detail of shipping requirements for trade in finished fertilizers, intermediates and raw materials up to 1980, including special requirements for shipping phosphoric acid etc.

X. TRAINING OF PRODUCTION AND MARKETING PERSONNEL

In determining the scope of a new project for a fertilizer plant, considerable attention is paid to the basic requirements, such as the financial aspects, raw materials, marketability of the product and, finally, the supply of battery-limit production facilities associated with the necessary offsites. In many cases insufficient attention has been given to the availability and supply of trained personnel, whether it be for production, maintenance, engineering and construction or the erection of plants.

The training of fertilizer plant personnel

The following recommendations were made for a preliminary review and a schedule to be followed when establishing a grass-roots fertilizer plant:

(1) Preliminary studies to cover:
   (a) A review of the labour market, including classification of specialists, their qualifications and skills,
   (b) Preparation of a plant organization chart,
   (c) Procedure for selection of personnel to match job specifications,
   (d) The planning and scheduling of a personnel training programme;
(2) Preparation of a training programme;
(3) Recruiting;
(4) Preparation and selection of supervisory personnel and their training programme.

When applicants are recruited without any industrial experience, after graduating from technical school, the technical training programmes should be planned for three periods:

(1) Applicants should first receive general instruction to complement their theoretical education in thermodynamics, hydrodynamics of the separation process and heat transfer. This instruction should precede lessons in process technology and control, and should be carried out with the use of practical examples.

(2) Trainees should then be familiarized with the broad aims of industry and plant policies.

(3) In on-site training, the personnel are taught the unit operations, the start-up operating instruction, safety regulations and procedures.

The training programme must be planned and undertaken at the same time that the engineering contract is approved.

The Ministry of Industry of Egypt fully realized the importance of the availability of technically trained personnel and took effective steps to establish an institute, which was to become known as the KIMA Institute of Technology, to prepare the technological cadres required for each programme.

The training programme of KIMA consists of:

(1) *Intermediate course.* Selected candidates who upon completion of secondary school education are admitted to:

(a) A theoretical course of study over 25 weeks (600 hours);

(b) A practical training course in the plant over 26 weeks (1,092 hours).

Successful students are qualified as technicians and may apply for admission to higher courses of education.

(2) *Higher course, Part I.* This comprises theoretical studies for a total of six terms, each term being 20 weeks (3,270 hours), and, at the same time, advanced practical experience and training for a period of 130 weeks (5,400 hours).

The personnel are trained to become technicians in various skills and are elegible for appointment to "technical supervisory positions".

(3) *Higher course, Part II.* This comprises higher theoretical studies, which cover a period of four terms (20 weeks each), i.e. 2,400 hours.

The candidates who meet the requirements receive a Bachelor's degree, which is considered equivalent to those offered at universities.

KIMA has been successful in creating a special, new educational system, which could be considered a guideline for other similar developing countries.

The training of plant personnel for the rapidly growing fertilizer industry in India, with particular reference to the Fertilizer Corporation of India Ltd, a public sector undertaking, was described to the Symposium.

Large-scale training programmes for new graduates from engineering colleges and polytechnical institutes have been undertaken in India with the aim of filling 50 per cent of the vacancies created in the new plants. The programme for graduate apprentices emphasizes their training for two- or three-unit operations. The programme also includes assignments to work with operating groups and maintenance departments.

For skilled workers, the training programme stresses adequate theoretical instruction to provide the necessary technical background and training for future supervisory responsibility.

Further training at the supervisory and junior management level consists of courses in preparation for increased responsibility and advancement.

Simulators have been used as an aid in training programmes in a number of both developed and developing countries. A representative of the Carmody Training System described uses of a number of special aids to accelerate the trainee's capacity to learn, adapt and absorb the know-how necessary to perform his job efficiently. The course is designed to encourage the trainee to use his judgment once he gains sufficient familiarity and confidence to control the task assigned to him. This applies particularly to modern, instrument-controlled fertilizer plants such as those producing ammonia, urea etc.

The benefits of training with simulators consist of shortening the period of instruction and the start-up of new plants, fewer costly emergencies, safer operations, fewer personnel problems and, eventually, higher production rates and improvements in product quality.

The estimated marketing of 16.5 million tons of fertilizer material in India by 1973/1974 is expected to place a serious strain on the existing skilled personnel. A limited number of potential managers are available from institutes of management and universities. Facilities also exist for training a few middle-level and senior managers already employed, but more salesmen and dealers must be trained to meet the needs of the country.

Many fertilizer companies organize internal job training through formal courses, sales conferences and executive-development programmes. Manufacturers with foreign associates utilize the training facilities of collaborators. The training of dealers is carried out internally.

The Enterpreneur-Development Scheme of the Fertilizer Corporation of India is a unique experiment and merits special mention. A limited number of the Corporation's marketing staff is sent abroad every year under the Government of India-USAID Participating Training Programme. In spite of this, the present training facilities are inadequate in many ways and can be improved only by the adoption of a multi-agency approach with the co-operation of the fertilizer industry, co-operatives, the Government and specialized organizations like UNIDO and FAO.

XI. MARKETING AND DISTRIBUTION OF FERTILIZERS

In many developing countries the production of fertilizers is often less of a problem than marketing. New plant construction gets quickly under way, and when the plant is commissioned, the product must reach the consumer and be applied to the soil. In some cases, a bottleneck is created between the producer and the consumer, which leads to idle plant capacities, uneconomically high production costs and, finally, high fertilizer prices. On further examination of the facts, it becomes apparent that insufficient preparation and study have been given to the problems of distribution and markets for the product.

Following the initiative of the Fertilizer Industry Advisory Committee (FIAC) of FAO, which is engaged in a world-wide study of fertilizer marketing, distribution and available credit facilities, a country-by-country study is being made for the economic use of fertilizers, starting with one developing country chosen from each of the continents of South America, Africa and Asia. The results of this survey are expected to become available in 1972.

For the marketing and distribution of fertilizers, the studies encompass three different functional levels:

The farmer or agricultural consumer;

The national or government agency responsible and active in this field;

The regional or intermediate agency engaged in this area.

The farmer-consumer level is obviously the most complex one, consisting of a large heterogeneous group of individuals who, in many cases, are not exposed to sufficient education. The farmer's approach is conservative and he is reluctant to adopt new methods of agricultural production until it is proved to him that he can get a higher yield from his crop and be reimbursed for the cost of fertilizer upon sale of his produce.

It is often stressed that the initiatives and measures of provincial or state agencies will become successful and effective only when the majority of farmer-consumers are convinced that the use of fertilizers, at the prevailing prices and conditions, offer a reliable and attractive return.

From the farmer's point of view it is also important that he becomes familiar with:

The type of fertilizer and its application suited for the land he tills and the produce he grows, and how it fits in best with his system of agricultural production, water management etc.

The seasonal and timely availability of fertilizer and how fertilizer is best applied with the tools or equipment he has at his disposal.

The terms of payment for the fertilizer, credit or cash, and his ability to invest on the best prevailing terms and realize a profit on his investment.

Accessibility of distributed fertilizer, local storage etc.

The responsibility of maintaining the conditions acceptable for the farmer-consumer depends upon the co-operation of industry, government and, in some cases, national fertilizer association, or trade organizations. For this reason a long-term "fertilizer plan" based on well-oriented and well-defined policy is required.

As regards the use of fertilizer, the major considerations are:

Infrastructure, transportation and distribution systems:

Storage facilities.

The adoption of High-Yielding Varieties (HYV), resulting in the increased consumption of fertilizers, requires the maintenance of an efficient infrastructure for the distribution of fertilizer from producer to consumer.

The seasonal demand for the consumer market requires that the product be available at the proper time. This varies not only regionally but may be influenced to some extent by climatic conditions.

Public facilities for transportation—railroad, shipping and road haulage—must be able to handle fertilizers in large tonnages to cope with the consumer's demand.

In case other agencies are involved and the fertilizer plan calls for intermediate, satellite storage facilities, these must be established to co-ordinate supply and demand and be equipped to handle the product in bulk or in bags with proper weighing facilities.

The logistics for a fertilizer plan should ensure that:

Storage facilities have adequate capacity to cope with seasonal excess demand and to maintain the quality of the product.

The lines of communication between producer, distributor and consumer are maintained.

Losses owing to poor storage and careless handling are very common. Hence, storage facilities should be checked periodically.

A number of measures may be taken to promote and encourage optimal conditions for the consumer farmer:

The creation of advisory services consisting of qualified personnel who would be available on a regional basis to advise and help the farmer;

Practical demonstrations for the application of fertilizers in the field that would include pilot schemes covering advanced agro-economic programmes for testing;

The transmittal of country-wide agronomic research data to improve the local soil and methods of fertilizer application.

Depending on the situation in each country, the development of a fertilizer plan will require considerable financing for a period, and in some cases, years before becoming effective.

In many cases co-operatives and Governments take care of such tasks.

Financial credits and funds should also be made available to assist the farmer. This funding has three major objectives:

A well-organized wholesale and retail sales system may assume part of this credit; alternatively, national or co-operative credit systems are necessary to keep credit costs and terms at an acceptable level for the farmer.

Funds will be needed for the construction of satellite storage facilities at appropriate market centres, at a range not exceeding 15–20 km from the consumer.

Financing, within the framework of national policy, will be required for education and advisory services.

The USSR provides for farmers' relief in case of crop failure. In the Western countries, funds are provided either by credit extension or insurance coverage. The kolchozes in the USSR receive subsidies in the amount of the average income of the kolchoz in the preceding year.

The pricing of food grains is a matter of political concern to all Governments. Therefore, the costs incurred in the production of food grains are receiving attention and are subject to government intervention to influence the value-cost ratio for fertilizers. This may take the form of price controls, subsidies for either fertilizers or agricultural products, or a combination of both.

The replies to the UNIDO questionnaire bring out the fact that of the 36 countries responding, 14 found the fertilizer prices too high.

In many regions the consumer pays double or more of the ex-works price for the delivered fertilizer, which reflects on the shortcomings of the fertilizer plan and endangers the future development of the market.

To forestall such problems it is recommended that the developing countries take advantage of the services of international agencies such as UNIDO and FAO. Co-operation in the pre-investment studies could assist the development of a harmonized fertilizer plan with a well-defined scope, based on the experience of these organizations with government and industry, and with the marketing and distribution of fertilizers.

XII. USE OF FERTILIZERS IN AGRICULTURE

Fertilizer is by far the most important agricultural input; compared with other agricultural materials, it is exceeded in total tonnage only by such major agricultural products as wheat, rice, maize and milk. Together with improved seed, the use of pesticides and water management, fertilizer is a prime factor in raising agricultural productivity. In the 1960s it proved to be the item of input most easily taught to and accepted by the farmers, and no insurmountable problems were created by its adoption. Yet some problems are still ahead.

The main questions related to the use of fertilizers in agriculture may be summarized as follows:

Strategies adopted to increase the economic use of fertilizers in developing countries;

The role of fertilizers in the Green Revolution (as applied to rice, wheat crops, other cereals, maize, millet and sorghum);

The application of fertilizer materials;

The use of fertilizers in the USSR and the Council for Mutual Economic Assistance (CMEA) countries;

The use of computers in estimating the nutrient needs of agriculture.

Strategies adopted to increase the economic use of fertilizer in developing countries

In developing countries most of the resources of land and labour are devoted to agriculture, primarily because productivity in this sector is low.

Owing to the rapidly growing population in the developing countries, the production growth rate target for agriculture has been set at 4 per cent per annum, but over the last 10–15 years an average growth rate of only 2.7 per cent has been achieved.

A highly productive agriculture is characterized by high yields. A high level of production per unit of land and labour is dependent on efficient institutions and use of modern agricultural techniques and inputs. Fertilizers have been identified as prime yield-raisers, which may be correlated with the *per capita* growth of the national product and other productivity indexes. The correlation between agricultural productivity and the quantity of fertilizers used is well-known from examples such as the history of the development of yield increases in the United States.

TABLE 4. FERTILIZER USE PER HECTARE OF ARABLE LAND, YIELD-VALUE INDEX AND *PER CAPITA* GDP, FOR 31 COUNTRIES, 1952–1954 AND 1964–1966

	1952–1954			*1964–1966*		
Country	*Fertilizer use*^{a}	*Yield-value index*	*Per capita GDP*^{b} *(dollars)*	*Fertilizer use*^{a}	*Yield-value index*	*Per capita GDP*^{c} *(dollars)*
Pakistan	0.4	107	82	5.8	136	101
Argentina	0.5	136	...	2.2	152	782
Turkey	0.9	126	159	6.7	154	258
India	0.9	71	62	5.7	83	95
Brazil	3.4	142	...	9.2	146	207
Mexico	3.8	119	232	18.5	137	441
Yugoslavia	5.3	115	...	58.1	231	...
Philippines	5.6	169	170	12.8	118	240
Canada	6.0	138	1,517	16.1	165	2,161
Chile	11.9	172	...	28.1	206	486
South Africa	15.4	80	312	35.9	90	521
Australia	20.4	160	994	28.6	171	1,823
Greece	20.5	177	190	66.9	269	591
Spain	21.0	138	230	37.4	182	632
Portugal	27.8	121	177	40.5	132	373
Ceylon	28.3	267	114	50.8	336	140
United States	30.9	203	2,090	63.5	288	3,233
Italy	40.7	226	353	68.5	314	1,011
Egypt	47.0	335	92	118.6	447	167^d
Peru	48.4	282	...	53.1	305	237
Austria	59.7	252	750	212.9	328	1,107
France	64.6	256	866	149.6	349	1,732
Sweden	67.1	218	982	128.2	290	2,406
Republic of Korea	71.1	192	...	162.7	252	107
Israel	79.4	166	361	162.1	384	1,243
Denmark	117.5	308	791	183.6	347	2,078
United Kingdom	118.3	291	818	220.3	382	1,590
Federal Republic of Germany	198.1	339	615	347.1	368	1,667
Japan	198.6	272	196	326.3	386	838
New Zealand	390.8	525	1,050	556.5	672	1,878
Netherlands	422.7	468	530	593.0	563	1,400

Sources: FAO, *Fertilizers: An annual review of world production, consumption, trade (and prices) 1955/69*, Rome; FAO, *Production Yearbook*, 1955–1969, Rome; and United Nations, *Yearbook of National Accounts Statistics*, Vols. I and II, New York, 1970.

[a] kg/ha of arable land.

[b] 1953.

[c] 1965.

[d] 1966 estimate.

Another useful measure at the national level is the yield-value index. This index relates the price weights to agricultural crop production, and it is measured per unit area, as illustrated in table 4 where the yield-value index is correlated with fertilizer use and *per capita* GDP for 31 countries.

The consumption of fertilizers also depends on the intensity of agriculture in certain countries. Countries with large cultivated areas *per capita* use less fertilizer per unit area than countries with smaller cultivated areas *per capita*.

The use of fertilizers at the farm level depends on the extent of the technical knowledge to apply them, the confidence of the farmer in achieving profitable results, and many other related factors pertaining to the marketability of the added yield, the availability and cost of fertilizer credits etc. Two measures are used to ascertain the profitability of fertilizer use at the farm level.

> The net return per unit area. This is the value of the additional yield to the farmer minus the cost of the fertilizers applied.
>
> The value-cost ratio (VCR). This is the ratio of the value of extra crop to the cost of fertilizers; it indicates to the farmer the return he should expect on the money invested.

In the case of the farmer who has enough funds to purchase the fertilizers, the net return per unit area is the most useful measure. In the case of the farmer who has limited cash available for the purchase of fertilizer, the VCR is the most useful measure.

In order to promote agricultural production, farmers need the incentive to do so. The Government should adopt an incentive policy so that the farmers' decisions on production coincide with the national interests. The factors to be considered are institutional as well as economic.

The institutional measures include those ensuring that the fertilizers are supplied at the appropriate time and place and at favourable prices. This requires an efficient marketing, grading and distribution system, storage facilities, adequate amount of credit on reasonable terms, and good research and extension services. In many developing countries, these facilities are either poorly developed or do not function efficiently. As a result, the cost of fertilizers tends to be high or the crop prices low. Also, most conditions of tenure are not favourable to the farmers, and fertilizers may help to arrest the practice of shifting cultivation, which is still widely practised in countries of Africa and Latin America.

The economic measures that may be taken include:

> *Price supports.* Prices of fertilizers rather than of agricultural produce should be subsidized where necessary.
>
> *Price stabilization.* This measure is more complicated since it involves over-all economic planning of agriculture at the national level, and it works only if farmers are represented in the institutions formulating the policy, as for instance, marketing boards.
>
> *Subsidies.* These are used mostly to control price relationships of inputs and output products in agriculture. They are very useful in helping to orient decisions at the farm level to coincide with national project policies. A formula has been developed by FAO for calculating the optimum level for a fertilizer subsidy.

$$\mathrm{VCR}_1 = \frac{\mathrm{VCR}_F \times 100}{100 - \text{subsidy}}$$

where:

$$\mathrm{VCR}_F \text{ is } \frac{\text{Value of yield increase}}{\text{Cost of fertilizer unsubsidized}}$$

$$\mathrm{VCR}_1 \text{ is } \frac{\text{Value of yield increase}}{\text{Cost of fertilizer to farmer}}$$

The VCR_F is obtained from field data, and the VCR_1 is the value considered necessary to provide the incentive for farmers to use fertilizers. For example, if the VCR_F obtained from field data is 2 and the incentive VCR_1 is 3, the fertilizer subsidy should be 33 per cent of the farm price

$$\frac{2 \times 100}{100 - 33} = \frac{200}{67} = 3.$$

This formula provides a good basis for determining incentive rates of subsidy, assuming sufficient field data are available to determine a representative VCR_F for different crops (see table 5).

TABLE 5. ECONOMIC DATA FROM TRIALS AND DEMONSTRATIONS OF FERTILIZER PILOT-PROJECTS, 1961/1962–1967/1968[a]

Region and country	*Number*	*VCR*[b]
Near East and North Africa	*27,863*	*3.5*
Lebanon	872	6.7
Morocco	3,984	2.8
Syrian Arab Republic	2,023	3.2
Turkey	20,984	3.6
West Africa	*18,360*	*5.7*
Cameroon	339	6.0
Ghana	6,735	5.7
Ivory Coast	215	2.6
Nigeria, W., M-W., E.[c]	8,010	6.0
Senegal	1,918	4.9
Sierra Leone	906	4.8
Togo	237	2.9
East Africa	*330*	*2.0*
Ethiopia	330	2.0

TABLE 5 *(cont.)*

Region and country	*Number*	*VCR*[b]
Northern Latin America	*5,549*	*5.5*
Colombia	459	18.7
Costa Rica	487	5.7
Ecuador	1,103	5.6
El Salvador	1,114	4.0
Guatemala	1,338	3.4
Honduras	454	3.8
Nicaragua	298	4.3
Panama	296	3.2
Total	52,104	4.5

Source: FAO, Fertilizer Programme: Physical and economic summary of trial and demonstration results, 1961/62–1967/68, Rome, 1970, unpublished.

[a] Includes one or more seasons.

[b] Average trial and demonstration VCR of the best treatment of each set weighted by the number of trials and demonstrations included in each set. A set is one or more trials and demonstrations by crops and location having the same treatment.

[c] Former West, Mid-west, East Regions.

The recognition that agricultural production is closely related to fertilizer consumption, and that investment to intensify the production of the soil per unit area is less than that required to enlarge the cultivated area, has led FAO to set up assistance programmes for countries in need of the development of fertilizer use. Such countries may be divided into three groups:

Countries needing basic know-how in the application and economics of fertilizer use;

Countries where the importance of fertilizers are known but where their use is restricted by the limited availability of foreign exchange;

Countries that already have relatively efficient infrastructure and reasonable demands but, owing to scarce foreign exchange, cannot expand the use of fertilizers at a satisfactory rate.

The following aims have been established in soil-fertility projects:

Increasing yields:

Bridging the protein gap;

Preventing the waste of resources;

Increasing the standard of living in rural areas;

Earning and saving foreign exchange.

Together with UNDP and the Freedom from Hunger Campaign, the main activity of FAO for about 12 years has been to organize development projects in fertilizer use, aiming for both technical and economical improvements and employing the following strategies:

The rational use of fertilizers according to soil and climatic conditions, based on information from experimental work;

Extension of the information gathered for farmers and farm advisers and demonstration of the value of fertilizers;

Study of related economic factors and an attempt to solve economic problems;

Establishment of pilot schemes for fertilizer distribution and credits;

Development of infrastructure, organization of credit facilities and storage facilities etc;

Long-term planning, which may lead to the establishment of local production facilities.

One of the most important projects initiated by FAO has been the UNDP technical assistance programme, which provides experts to Governments in an advisory capacity. This programme has been operating in 24 countries since 1950.

Another important project is the UNDP Special Fund. This applies to research and investigations intended to give pre-investment assistance to Governments. The Special Fund projects on soil fertility and fertilizer use strongly emphasize promotion. The Fund provides for five to seven experts, equipment, and ten or more fellowships. The duration of the projects is from three to five years. Fertilizer projects have been developed under the Special Fund in Iran, Pakistan, the Philippines, the Republic of Korea and Thailand.

A completed project in Pakistan may be cited as an example. The project established the following work guidelines:

Making projections of fertilizer demand;

Determining optimal level of use;

Choosing the types of nutrient carriers;

Determining agricultural practices;

Improving distribution and storage;

Providing agricultural credits.

The fertilizer projects sponsored by the Freedom from Hunger Campaign are financed partially by the fertilizer industry, by donor Governments and by non-governmental organizations. They were started in 1961 and include:

Trials and demonstration programmes;

Pilot schemes for distribution and credits.

The Freedom from Hunger Campaign operates in 27 countries of Latin America, North and East Africa and Asia. The tangible results are:

Yearly consumption in all countries where the project has operated tripled in seven years to nearly 875,000 tons of nutrients by 1967/1968. The investment in added quantities of fertilizers represented a total value of $40 million annually. In return, the farmers received a 350 per cent return on their investments.

Five thousand extension workers and supervisors have been trained.

Fertilizer use is economically justified.

Fertilizers have been proved indispensable for the cultivation of high-yielding varieties in order to exploit their full production potential.

The subsidy of fertilizers is economically justified, even with subsistence crops whenever these limit food supplies.

The introduction of fertilizers in some countries has identified other limiting factors and problems.

Soil-fertility and fertilizer projects have been undertaken in 34 countries, and 21 pilot schemes have been initiated. FAO also co-operates with other international agencies, such as UNIDO, IBRD, OECD, OAS, EEC and many others.

Economic data from the results of over 52,000 trials and demonstrations of fertilizers are summarized in table 5.

The future requirements for expanding the fertilizer-assistance projects are as follows:

Research on practical needs, experimental programmes, study of economic aspects, effective soil and plant analysis;

Training of extension personnel;

Shift in emphasis to improve the supply and distribution of and credits for fertilizers and other agricultural inputs;

Government promotion of fertilizers and assistance in formulation of policies and strategy;

Active participation of private enterprise in fertilizer distribution;

Multilateral development aid and co-ordination of activities of multilateral agencies in the fertilizer field.

The place of fertilizers in the Green Revolution – as applied to rice and wheat crops

Integrated plant breeding, which was started in Mexico in the 1940s, led in the late 1950s and 1960s to the development of seed varieties of the major crops, which were selected for the high yields of their usable portion.

Plants have been selected and bred ever since Mendel bred peas in a monastery in the 1830s. The difference in developing the HYV lies in the introduction of the complete plant production, breeding and selection system, which creates varieties that have responded to the use of fertilizers and other modern agricultural inputs.

Using rice and wheat as examples, table 6 indicates that HYV without fertilizers are essentially no better than the good local varieties. They respond only with fertilizers, giving a 130–170 per cent yield increase.

TABLE 6. AVERAGE YIELDS AND NET RETURNS FOR WHEAT AND RICE IN FAO PILOT PROJECT, INDIA, 1968–1970

Variety and practice	*Wheat* Yield (kg/ha)	Total cost[a] (Rs/ha)	Net return (Rs/ha)	*Rice* Yield (kg/ha)	Total cost[a] (Rs/ha)	Net return (Rs/ha)
HYV						
Recommended	5,578	1,333	4,010	5,561	1,148	2,737
Farmer's	2,911	–	1,702	2,539	–	868
Local improved						
Recommended	3,955	1,384	1,819	3,565	927	1,877
Farmer's	2,034	–	749	2,417	–	749

Source: Couston, J. W., *Second Report on Two Pilot Schemes on Fertilizer Distribution, Marketing and Credit in Lucknow and Unnas Districts, Uttar Pradesh, India, 1967/70*, Rome, 1971.

[a] Includes fertilizer, other inputs, cultivation and harvesting costs.

Two main centres are developing HYV. The initial work was done by the Rockefeller Foundation in Mexico, which grew the short-stemmed wheat varieties. The rice varieties were developed at the International Rice Research Institute (IRRI) at Los Baños in the Philippines. Many local plant breeders are working towards the same end, and are making a substantial contribution. The Ford and Rockefeller Foundations, the main sponsors of the IRRI research station in the Philippines, have realized this and have lately signed agreements with centres in Burma, India, Indonesia, Pakistan and other countries. They are assisting local breeders by sharing with them the integrated approach and by developing the local improved breeds. The main benefit derived from this international co-operation is the free across-the-border exchange of know-how and breeding materials, an exchange that is not restricted just to the developing countries. Many European countries and the United States are also co-operating in such projects.

The procedure for introducing HYV into a country usually starts with testing the improved varieties already developed in other countries, cross-breeding them with local varieties and then making a selection. In the end, only the locally developed HYV are used commercially.

The primary characteristics of the HYV are morphological, agronomical and economic. The main morphological features that distinguish them from their predecessors are:

They are short with thick stems, which prevent lodging even with high levels of fertilizers.

They have upright-growing leaves that prevent mutual shading and increase photosynthesis and respiration. This feature is of particular economic importance in the tropics where one of the main limiting factors is only 45 days of sunlight in the growing period for rice.

Wheat and the original rice varieties especially have a wider-spread root system, which enables them to absorb more nutrients and moisture.

Agronomically, the mere fact that they do not lodge makes these varieties easier to handle and prevents losses. By far their greatest advantage is a response to high levels of fertilizers, particularly of N, which are often three to five times higher than those used for the local varieties.

The first Mexican wheat varieties were very susceptible to smut (fungus disease), but this has been overcome to a large extent by breeding hardier varieties.

Economically, HYV have more output per unit area, but the cost-value ratio alone does not give the true picture of their profitability, since other inputs are needed to exploit their full yield potential. In most cases they are more profitable, since the input-output ratio with such high yields is more favourable.

There are two limitations, however:

The first HYV of wheat, as well as those of rice, did not have the same baking and cooking quality as the local varieties. Hence, they had to sustain a reduction in price. In West Pakistan the farmers went back to their old variety of Basmati rice because they could not get the comparable price per unit area from the HYV that were introduced.

The added inputs, particularly of fertilizers, make it imperative for the farmer to obtain credits. The unavailability of credits for the added inputs have made the richer farmers the main growers and beneficiaries of the HYV.

Quite a few varieties have been developed, notably, the Mexican wheat and the IRRI rice varieties. However, the best economic results were achieved with pearl millet in India. The new varieties, together with optimum inputs, have increased the yields from 300 kg to 3,500 kg. The new varieties of millet with their larger root system can absorb the limited moisture available more efficiently.

Experiments have been made with maize, but as yet most of the new lines are no better than the maize hybrids commonly developed and used.

The first rice varieties developed at IRRI in the Philippines, IR8 and the IR5, have now largely been surpassed by the IR20 and IR22, which have better cooking qualities. However, IR8 may be used as a base for developing a rice variety for upland cultivation, because of its large root system.

The main response of HYV has come from large quantities of nitrogen in most soils. Wheat has responded well to large doses of N up to 150 kg/ha, accompanied by medium quantities of P_2O_5 (90–60 kg/ha) and K_2O (60 kg/ha). The IR varieties of rice respond well to 200 kg N/ha and reach a total yield of about 6–7 tons/ha. The response to P and K is somewhat more erratic. In areas where these are minimal, in nearly all old terrace soils, P and K must be added. Where it is possible to cultivate three HYV per annum in some countries, the P and K status of these soils must be checked every season to prevent deficiencies. In some cases, notably the Philippines, the response to K in the first year has been negligible, but beginning with the second season, the response became economical. In other cases, however, such as the example from the young volcanic soils well supplied with P and K at the IRRI station at Los Baños, no deficiency of these two nutrients has appeared after 21 croppings with high yields.

The pH of the soils already has some influence on rice cultivation, since under flooding the pH comes up to around neutral (7.0).

Micro-nutrient deficiencies occur quite frequently with the increased use of HYV. Zinc deficiency is quite prevalent in the seed-beds of rice, and it is marked during the first six weeks of growth in the seed-bed when it can do a lot of dammage. Other deficiencies, of copper, boron, sulphur etc., have been overcome by dipping the roots into a solution of micro-nutrients before planting.

No known study has been made of rice in order to measure the removal of nutrients by the HYV.

TABLE 7. THE GREEN REVOLUTION IN THREE PHILIPPINE MUNICIPALITIES DURING THE WET SEASONS, 1966 AND 1969

	Adoption of HYV (per cent)		*Nitrogen applied (kg/ha)*		*Grain yield (tons/ha)*		*Net return[a] (pesos/ha)*	
	1966	*1969*	*1966*	*1969*	*1966*	*1969*	*1966*	*1969*
Binan	0	80	8	47	1.9	2.5	525	565
Cabuyao	1.9	68	16	51	2.2	4.3	625	1,357
Calamba	1.2	61	22	44	2.9	4.0	955	1,283

Source: Barket and Cordova, *Fertilizers: An annual review of world production, consumption, trade (and prices), 1955/69*, FAO, Rome.

[a] All production costs, fixed and variable, are included.

It is interesting to observe the pattern of adoption of the high-yielding varieties by the farmers. Details are given in the examples of three Philippine municipalities shown in table 7. In quite a few instances improvements had to be made in the supply of irrigation water, market channels for the produce had to be organized and credits made available before farmers would use the HYV. The IRRI introduced their HYV successfully by sending out rice kits, which included 5 kg of the improved seeds, the necessary pesticides and quantities of fertilizers for use on an area of approximately one acre. These were sent to selected "leader farmers". In areas with good response, the trials were followed up by an intensive demonstration and other extension methods.

Adoption of the HYV has by no means been uniform. In several instances adoption became widespread only after a local improved variety was developed that was of a quality required by the population and adapted to local agronomic conditions.

There are a number of disadvantages in the use of HYV, which have come to light with their increasing cultivation.

They lack resistance to drought;

They give only a marginal added yield without added inputs;

They require an increase in agricultural inputs with repeated cultivation, since some nutrients are removed from the soil (PK micro-nutrients);

The need for added inputs limits their use to wealthy farmers or to those who have cheap sources of finance;

In some areas and countries they have resulted in over-production, and unless adequate marketing channels and storage are organized, the farmers' prices will drop and the main beneficiaries of added production will again be the middlemen.

The HYV are not a miracle. They are a catalyst to increased production when in the hands of a trained farmer who has the means to obtain the necessary inputs at a reasonable price at the right time. There is no one variety that will do the job under all conditions. The breeders of these varieties have evolved a breeding and selection system, and a method of co-operation that can benefit any location in the world. The urgent need for research is now shifting from the plant breeder to the production agronomist to develop the practical means of realizing the potential of HYV.

The Green Revolution will not be achieved until the necessary institutional framework has been established, so that the full benefit of increased production will flow back to the farming population.

The application of fertilizer materials

A lot of research has been done on the various nutrient carriers. Different fertilizer materials are promoted for some crops in various countries. Some of the preferences are based on production priorities for certain areas, but the majority are based on experimentation and field-trial results.

The nutrients by themselves theoretically should give the same effect in any carrier, but since they are usually mixed with other nutrients or with an inorganic filler, the complete fertilizers behave differently in different soil complexes under different climatic conditions.

Agronomically, it is known that as soon as the anhydrous ammonia is injected into the soil it combines with water to form an ammonium hydroxide. It then behaves just like aqua ammonia and forms a base exchange of soil organic matter and clay, called ammonium organic matter and ammonium clay. When anhydrous ammonia is released and not completely covered by the soil, the soil heat gasifies parts of it, forming a white cloud which evaporates. Aqua ammonia, when not completely covered, also escapes but is invisible. A wide-bladed knife with a point at the bottom of the cultivator aids in ammonia sealing. These forms of ammonia move little from the point of application. It is known that ammonia as a source of nitrogen nitrifies more slowly in low pH soils than in soils of high pH.

Anhydrous ammonia is usually more effective than solid ammonia fertilizers in pre-plant applications. However, it is not commonly used as a side dressing since the solids have a slight advantage. Van Burg shows that wider spacing of the applicator results in increased concentration, less leaching and high yields. Anhydrous ammonia, or branded solid N forms, has proved superior when the soil contains undecomposed combinations of farbonaceous materials such as grain straw; it has also proved better on rice soils in California where it has been drilled under the soil in the pre-flooding stage, since on flooded soils the area of one quarter of an inch below the soil surface is anaerobic. Under these conditions, the anhydrous ammonia remains in the ammonia form until the plant needs it.

The use of liquid fertilizers is more economic even with high investment in equipment and storage. It is estimated that in the US the farmer pays $25 less for ammonia in liquid form than in the solid forms. The safety factors for applying anhydrous ammonia are usually built into the equipment, and labour may be trained to use it efficiently wherever tractors are available. In the initial stages of development, horse-drawn ploughs were fitted with injectors, but this equipment would not be economical in most cases today. However, liquid fertilizers will not fill the entire fertilizer demand for many farms, and equipment will have to be available to handle the solid fertilizers that are also required.

The liquids are the most economical form, particularly of N, but also of NPK, and in production will save a sizable investment in added production equipment. It has been suggested that the FAO and UNIDO should initiate a joint study, including pilot schemes, on the techniques of production and application of liquid and anhydrous ammonia in developing countries. In some of these countries, notably in Egypt, plans are afoot to set up a wide distribution network for the use of anhydrous ammonia and liquid fertilizers.

One of the main problems, which comes up for repeated discussions in meetings, is the controversy over the use of ammonium and nitrate fertilizers on rice. This problem has now been studied extensively in Japan. The results are useful and worthy of consideration by countries wanting to import or manufacture ammonia or urea. Earlier studies indicated that owing to excessive leaching and denitrification losses, use of a nitrate is not recommended on paddy cultivation. Furthermore, nitrate formed by reduction under flooded conditions may be harmful to the plants. Recent experiments were conducted to test the possibility of the use of nitrate nitrogen as top dressing in later stages of growth; its effects on ripening, root growth and lodging; and its use when applied in large quantities and frequently. A high-analysis NPK fertilizer based on nitrophosphates was tested against the conventional urea ammonium phosphate with similar analysis, at various rates and numbers of top dressings.

Nitrate nitrogen gave a better response when top dressed at the later, ear-formation stage than earlier. Most experiments indicated a higher response from top dressing at the ear formation, or both ear-formation and heading stages, from the ammonium fertilizer than from the nitrate, owing to decreased number of ears. The thousand-grain weights and ripening were not affected. Increased yields were obtained by using side dressing and top dressing frequently with ammonium plus nitrate nitrogen, the latter consisting of about 40 per cent of the total nitrogen in the top dressing. The results suggest that benefit may be derived from nitrate nitrogen only with frequent split applications (three to four times) at the later stages of growth, and with more frequent applications necessary in soils with high percolation.

The benefits of nitrate nitrogen are considered to be: improved ripening of rice grains, decreased weight of rice screenings and a decrease in unfertilized grains, and the prevention of severe lodging in cool autumn weather.

Although these results are applicable directly to Japanese conditions, they may or may not apply to tropical countries. It is important to know that the economics of growing rice in the tropics are apt to be different from those in Japan, where one kilogram of paddy pays for one kilogram of N.

The facts brought out by this experiment raised the question whether the reduction of the number of ears was owing to the application of nitrate nitrogen or to the delayed application of phosphate.

The danger of toxicity resulting from the transition from nitrates to nitrites arises in very rare cases in soils high in organic matter and low in easily reducible compounds.

The use of potassium (K) in the developing countries has long been questioned by both agronomists and soil scientists. However, experiments in many parts of the developing countries of Asia, Africa and Latin America have demonstrated that, sooner or later, potassium is needed in fertilization. For most crops the removal of potassium from the soil through harvests is greater than the removal of nitrogen and phosphates.

TABLE 8. MAIN EFFECTS OF N, P_2O_5 AND K_2O IN SIMPLE TRIALS CARRIED OUT UNDER THE FAO FERTILIZER PROGRAMME BETWEEN 1961/1962 AND 1967/1968

Region and crop	*Number of trials*	*Yield increase (kg/ha)*		
		N	*P_2O_5*	*K_2O*
Near East and North Africa[a]				
Wheat	**148**	**235**	**221**	**81**
Maize		**546**	**369**	**259**
Cotton		**320**	**240**	**126**
Potatoes		**1,387**	**1,121**	**481**
West Africa[b]				
Maize	**949**	**189**	**179**	**154**
Rice	**598**	**238**	**230**	**166**
Yams	**435**	**932**	**872**	**915**
Millet	**125**	**148**	**134**	**103**
Sorghum		**134**	**132**	**34**
Forage		**3,825**	**545**	**151**
Onions		**334**	**133**	**186**
Northern Latin America[c]				
Maize	**225**	**428**	**389**	**98**
Rice	**85**	**301**	**161**	**−17**
Potatoes	**78**	**2,847**	**1,726**	**880**
Forage	**57**	**10,425**	**2,756**	**1,137**
Beans	**57**	**248**	**199**	**105**
Tomatoes		**5,909**	**1,273**	**5,432**
Onions		**873**	**764**	**613**

[a] Total number of trials: 238.
[b] Total number of trials: 2,398.
[c] Total number of trials: 724.

Why is it then that potassium is very frequently applied at a lower rate than nitrogen? In many developing countries starting out with fertilizer application, the misconception is prevalent that soils are well supplied with this nutrient. It is true that the response to potassium is the last among the macro-elements to be detected. Frequently, only long-term trials bring out the deficiency factor and the positive economic response to this element. A good example is a long-term experiment in the Republic of Korea on rice, where in the first year there was only a 5 per cent response to the potash in the NPK application. By the third year this difference had increased to 25 per cent and made up a quarter of the total yield. Thus, the results obtained during the first few years may be misleading so far as the response to potassium is concerned.

Soil tests are not always the most reliable indicator of the need for potash. There are many examples of good response to potash after the soil test showed a high amount of available K_2O. For local varieties the release of K from the soil may have been sufficient to support the traditionally low use. But the new varieties with a high-yield potential will soon exhaust the K supply in the soil. Therefore, a reappraisal must be made of soil-test interpretation and standards, and of fertilizer recommendations.

Even the results of the fertilizer trials on cultivated fields, which are carried out on a large scale by the FAO and other institutions in various developing countries of Asia, Africa and Latin America, prove that potash applied in addition to NPK produces high-yielding results which are profitable to the farmers.

Table 8 indicates that in most regions where the FAO fertilizer programme has been in progress there has been some response to potash.

The profitability of the use of K has repeatedly been questioned. Table 9 shows clearly that the money spent on potash in certain regions, on the crops mentioned and other crops, gives the best returns for the money invested compared with the N and P applications.

There is a problem in translating the results of research into fertilizer recommendations, which are relayed to farmers by the extension service. This is especially true with the results of long-term trials, which in most cases provide the most reliable experimental results possible.

TABLE 9. YIELD INCREASE PER DOLLAR SPENT ON FERTILIZER–EXPERIMENTAL RESULTS FROM INDIA, 1968

	Fertilizer price at farm level[a] *($/100 kg)*	*Rice*[b] *(kg)*	*Wheat, irrigated*[c] *(kg)*	*Wheat, not irrigated*[d] *(kg)*
N	20.9 (urea)	51.7	67.5	36.4
P_2O_5	22.6 (SSP)	31.4	38.5	18.1
K_2O	7.4 (KCl)	56.8	71.6	51.3

Source: Seth & Associates.

[a] FAO, 1969.

[b] 5,139 trials.

[c] 2,844 trials.

[d] 766 trials.

With a view to solving the problems of underutilization of potash for the benefit of the farmer in developing countries, the following measures are recommended:

The introduction of higher K rates in fertilizer experiments in conformity with the increased nutrition needs of new varieties;

The introduction of a large number of long-term trials for the correct determination of N, P and K requirements;

The evaluation of yield data corresponding to the use of fertilizer, and of crop quality and resistance to pests;

The reappraisal of the threshold values in soil-test interpretation, based on new fertilizer experimental data. The usual low-medium and high-nutrient measurement expressions for a country as a whole are of little value;

The thorough instruction of extension agents on the actual importance of potash and balanced NPK applications;

The revision of fertilizer recommendations to include the results of both the field trials and long-term trials, including the adequate amounts of potash;

Immediate utilization of research findings as a guide to government policy, extension policy and fertilizer recommendations. If local data on NPK are missing, the experience obtained in more advanced developing countries should be utilized.

A subject frequently discussed is the best choice between nitrophosphates and ammonium phosphate-based complexes. On this subject an important large-scale study has been made in West Pakistan on irrigated crops. In 1967–1968, Mexipak-65 and other Mexican wheat were sown in a substantial area with the provision of incentives and under excellent weather conditions. Wheat production was increased by 48 per cent in irrigated areas. Compounds combined with nitrogen of DAP (18–46) were imported and some nitrophosphate (20–20) with 30 per cent water-soluble phosphate was also used. The trials were large-scale trials in farmers' fields. Further trials were conducted on wheat, maize, rice, cotton, sugar-cane, oil-seeds, some vegetables and fruits.

The agronomic and agro-economic results showed that nitrophosphate that was 80 per cent water-soluble (23–23–0) gave a better result than any other complex fertilizer nitrophosphate (20–20) MAP, DAP and even mixtures of simple fertilizers. The agronomic results were analysed further to compare production costs for the various fertilizers, and the above product also proved to be the most economical. The following points were summarized by the West Pakistan Fertilizer Committee as the basis of their preference for installing nitrophosphate production:

The manufacture of nitrophosphate requires the importation only of rock phosphate, and not of sulphur or phosphoric acid for MAP and DAP;

The cost of production per unit of nitrophosphate in comparison with MAP and DAP–the two latter being up to 80 per cent water-soluble phosphoric acid–adequately meets the agronomic requirements of crops. This fertilizer is quite suitable for the soils of West Pakistan;

Nitrophosphate gives the highest yield and income in comparison with other NP fertilizers;

The proportion of NP is 1 : 1. This seems to be a favourable proportion under the conditions needed in West Pakistan;

It has good storage capacity and is easy to handle;

It contains 55 per cent nitrogen in ammonia form and 45 per cent in nitrate form, which becomes readily available to new emerging seedings.

Although the experience in Pakistan, as shown by the above experiment, favoured nitrophosphate, each country must decide on the effectiveness of different fertilizers by actual use for various soils, crops and climate.

Use of fertilizers in the USSR and other CMEA countries

The total area of the USSR is 2,211 million hectares; 10.7 per cent of the area is cultivated.

Lately, 40 million hectares have been improved for cultivation. This potential has a direct effect on the intensity of fertilizer application in the USSR. In 1969, the average fertilizer used per hectare in the various Soviet Republics was:

	kg/ha
Turkmen SSR	216.7
Estonia	183.1
Latvia	151.2
Byelorussian SSR	134.6
Ukraine	54.4
Moldavia	41.5
Russian Soviet Federated Socialist Republic (RSFSR)	28.9
Average for the entire USSR	40.3

As early as 1925 the Scientific Institute for Fertilizers and Insecto-fungicides made the first survey on fertilizer response and could utilize the results of more than 17,500 experiments. By 1932 the Institute was able to co-ordinate 3,800 field experiments carried out by 317 experimental stations.

The positive influence that fertilizers have on agricultural crop yields and on their quality in all agricultural districts of the USSR has been established, for both the irrigated and non-irrigated zones.

Fertilizer experimentation may be characterized in the USSR as long term. Some rotation experiments have been continuing for 24 years. Experiments are organized by local State Agricultural Research Institutes and by the All-Union Institute of Agricultural Chemistry and Agro-Chemical Services. The main soil types are sod podzolic, grey forest, leached and ordinary chernozems, and are found in nearly all geographical zones. The effect of fertilizers on the main crop of wheat by soil types and districts is illustrated in table 10.

TABLE 16. THE EFFECTIVENESS OF EXTRA NITROGEN FERTILIZATION OF WINTER WHEAT IN THE EUROPEAN PART OF THE USSR, IN AUTUMN AND SPRING PERIODS OF APPLICATION

(Average figures for 1958 1970)

Soils	*Yields on control centner*[a] *(kg/ha)*	*Additional yields from extra nitrogen application (kg/ha)*		*Number of investigations*
		Autumn	*Spring*	
Sod-podzolic sandy loam, light loamy soil, mechanical composition of type and claying soils	18.3	3.0	6.8	20
Sod-podzolic loam, Baltic Republics and central non-chernozem belts of the USSR	21.5	4.9	6.3	19
Grey forest soils of eastern regions of RSFSR	20.2	3.8	3.6	16
Sod-podzolic, grey forest soils and podzolized chernozems of the right bank and western districts of RSFSR	28.0	6.0	6.4	9
Leached and ordinary chernozems of the Ukrainian SSR and central chernozem belts of the RSFSR	26.1	3.9	3.6	11
The southern chernozems of the eastern regions of the European parts of the RSFSR, Ukraine and Crimea; the chernozems of Transcaucasia	20.6	3.3	3.4	8
Pre-Caucasian carbonaceous black earth	32.6	1.5	1.8	5
Total number of tests:				98

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[a] Centner equals 100 kg.

Response of non-irrigated crops to fertilizer

The range of response to fertilizers on various non-irrigated crops has been indicated, and reference has been made to the large number of experiments carried out by the All-Union Institute in the USSR. Nitrogen proved most effective in non-chernozem zones without irrigation. Phosphates were second in effectiveness, and potassium was third in all districts (see table 11).

TABLE 11. EFFECTIVENESS OF THE USE OF FERTILIZERS DURING IRRIGATION ON MAJOR AGRICULTURAL CROPS IN CMEA COUNTRIES

Country	*Soil*	*Crop*	*Crop capacity (centner/ha)*[a]		*Addition from use of fertilizers (centner/ha)*[a]	*Source of information*
			Without fertilizers	*With fertilizers*		
USSR	Chestnut	Winter wheat	28.7	56.2	27.5	All-Union Institute of Agricultural Engineering Development
USSR	Gray	Winter wheat	16.6	35.5	18.9	Kirghiz Research Institute of Land Cultivation
Bulgaria	Lixiviated black earth	Winter wheat	36.5	47.4	10.9	Edaphology Institute
Romania	Lixiviated black earth	Winter wheat	25.2	59.1	33.9	Central Research Institute of Agriculture
Czechoslovakia	Lixiviated black earth	Winter wheat	31.1	51.2	20.1	Scientific and Research Institute of Primary Agricultural Engineering
Romania	Lixiviated black earth	Maize	52.8	108.1	55.3	Scientific and Research Institute of Primary Agricultural Engineering
USSR	Chestnut	Maize	46.0	72.9	26.9	All-Union Institute of Agricultural Engineering Development
Bulgaria	Carbonate black earth	Maize	45.0	123.9	78.9	Edaphology Institute
Hungary	Carbonate forest	Maize	60.1	82.8	22.7	Agricultural University
USSR	Gray	Sugar-beet	411	676	265	Kirghiz Research Institute of Land Cultivation
USSR	Chestnut dark	Sugar-beet	469	678	209	Ukrainian Scientific Institute of Irrigated Land Cultivation
Bulgaria	Lixiviated black earth	Sugar-beet	358	663	305	Edaphology Institute
Romania	Lixiviated black earth	Sugar-beet	378	655	283	Central Research Institute of Agriculture

[a] Centner equals 100 kg.

An economic response was obtained from phosphates alone in a few districts only. Additional yields of hay were achieved when nitrogen was applied to grassland; an additional yield of 25 kg per unit N applied is most profitable. The NPK fertilization of fodder crops in a total non-irrigated rotation system, using over 1,200 test crops in four soil types, gave an increase in productivity from 20–125 per cent over the control. These tests were carried out with the addition of farmyard manure to fertilizers.

By the beginning of 1971 the irrigated area in the USSR encompassed more than 10 million hectares, and present plans are to double the area under irrigation over the next 10–15 years. Much research has been carried out on the optimal doses of nutrients and soil-moisture relationships, and further examinations are in progress. The main irrigated crops studied have been cotton, irrigated wheat, maize, rice, sugar-beet and vegetables. The fibre yield of cotton in the USSR is 785 kg/ha, as compared with a 341 kg/ha world average.

The USSR cultivates 7.6 per cent of the world acreage of cotton. For the cotton crop both the long and the short staple varieties were studied in over 600 different experiments. The highest increase in raw cotton was achieved with the use of about 200 kg N and 100 kg P_2O_5 per hectare. There were two tons and 560 kg of additional yield in raw cotton from nitrogen and phosphates, respectively. An addition of 60 kg of K_2O increased the yields still further in most cases, especially with high doses of N and P. In some experiments the potassium fertilization also counteracted a decrease in yield caused by an overdose of phosphatic fertilizers.

TABLE 12. YIELD INCREASE OVER CONTROL WITH APPLICATION OF NP AND NPK FERTILIZER ON IRRIGATED WHEAT, BEZOSTARA I VARIETY

Fertilizers applied in kg/ha			*Yield increase in kg/ha*	
N	*P_2O_5*	*K_2O*	*Ukrainian Scientific Research Institute*	*Krasnodar Region*
60	60	–	12.10	
90	60	–	16.20	
90	90	–		9.60
90	90	60		11.60
120	120	90		12.50
150	120	–	17.40	
150	120	60	17.30	

In Middle Asia, more than 45 per cent of land devoted to irrigated cotton and about 70 per cent of the land to be cultivated are subject to a certain degree of salination. Salinity caused by irrigation is studied in the USSR with special reference to the nutrient needs of these soils. In order to increase the production of grain from 9 million tons in 1970 to 12 million tons under irrigation in 1975, fertilization of these crops was specially studied.

NP fertilization also had a positive effect on the quality of irrigated wheat, namely in protein content, grain hardness, gluten per cent and bearing strength. The response was similar with maize for grain in 105 recorded experiments. With the application of over 250 kg nutrients of 1–1–1.7 ratio, the average additional yield was over 30 per cent. Sugar-beet responded well to a 120–90–90 application of fertilizers, with a yield increase of 24 per cent.

Average rice yield in the USSR during 1970 was 3.5 tons/ha, but some regions yielded a six-ton average. Nitrogen is the most effective fertilizer, having five to seven times the response of P_2O_5. In general, an NP combination is applied at a rate of 120–90–0 in an area with high yields. Additional quantities of N did not give a significant response. It is normally recommended to apply 30–45 kg of K_2O per hectare. Further research demonstrated that response to ammonium sulphate was slightly higher than to urea and ammonium chloride, but the differences were insignificant. No response was observed from a top-dressing application of N fertilizers on grains.

Vegetables, especially tomatoes, respond well to high N P_2O_2 rates of 180 kg/ha. A 30 per cent increase in yield was obtained, making a total yield of 9.3 tons/ha.

The research in irrigated crops is now directed to predicting planned yields with the input of predetermined quantities of water and fertilizer combinations for various soil types and locations.

Tea, citrus and laurel *(Laurus nobilis)* are grown in the province of Georgia, which is known for its red soils. These soils (rose polosolyc) are very acid and have a low degree of natural fertility. With rainfall of more than 2,500 mm and high temperatures, organic matter is mineralized more quickly and fertilization thus becomes of prime importance.

With the application of fertilizers, production of a tea plantation has increased five to eight times. The present average yield of 4.5 tons/ha of green tea leaf ranks third in the world. Nitrogen is the most important nutrient. Two applications of 200 kg N/ha are recommended (2/3 in the spring and 1/3 in July); 300 kg N/ha have also given economic response. The nitrogen fertilizers used primarily are ammonium sulphate, ammonium nitrate and calcium cyanamide. Phosphates in the form of single and double superphosphates have given economic response up to the rate of 500 kg P_2O_5. Phosphates have increased the yield as well as the quality of tea. Research has shown that the fertilizers should be placed at a depth of 7 cm. Potassium is applied at the rate of 300 kg/ha to the developed plantations and gives a 10 per cent yield increase in most areas. New plantations do not respond to potash. Where magnesium and manganese deficiencies have been discovered, the addition of these elements to the fertilizers has resulted in a yield increase of from 10–20 per cent.

Georgia is the northernmost point of the citrus-growing area of the world. Both marginal climatic conditions and low-soil fertility add to the importance of proper nutrition in attaining high production. Nitrogen is applied at about 240 g of N per tree, split into four to six applications; 40–60 per cent is given before flowering. Best yields are achieved in citrus fruit by applying alkaline forms of phosphate fertilizers, such as basic slag precipitate, a phosphate meal, at the rate of 500 kg P_2O_5/ha. A 31-year experiment gave a 90 per cent improvement in yield from the application of potassic fertilizers at a rate of 60–100 kg K_2O/ha. The application of organic manure in combination with mineral fertilizer has proved beneficial. Green manure has had no effect on both the citrus and laurel crops. The use of lime is recommended to keep the soil neutral.

For laurel plantations, 200 kg N/ha are recommended. This has resulted in yield increase up to 127 per cent when using a basic dressing of PK and CaO. The application of potassium and magnesium is also very important for this crop.

Experiments with fertilizer materials in the USSR

Varied conditions of the USSR agriculture make it possible to employ most forms of fertilizers successfully. But great territories and big agricultural enterprises make it most desirable in the USSR to use concentrated and complicated fertilizers. Among them, the most important are ammonium phosphates, complex fertilizers on the basis of ammonium phosphate, nitrophosphate, nitroammonium phosphates, ammonium nitrate, urea and potassium chloride. It is preferable to produce liquid nitrogenous and complex fertilizers, carbo-ammophosphates, complex magnesium-ferrous fertilizers with micro-elements and magnesium.

In studying the effect of nitrogenous fertilizers, wide use has been made of the isotope ^{15}N. In a large number of tests made over wide areas the coefficient of utilization for nitrogen by plants (Rainfed) was from 40–60 per cent. Dicalcium phosphate and basic slag compared well with superphosphate in seed-bed dressing.

The choice of potassium fertilizers depends on the soil, climate and the particular need of the crop. Potassium fertilizers, which usually contain some minor elements, have in addition to their effect on quantity an effect on quality in sandy as well as clay soils.

The agro-chemical research in the USSR on new forms of fertilizers is extremely important. Experiments are under way both in the USSR and in other countries to study combinations of red phosphorus, phosphamide, oxalamide and others.

The use of micro-nutrients

The Plant Physiology Research Institute of the Ukrainian Academy of Science at Kiev is studying the effects of the various aspects of plant nutrition on the physiology of the plants.

Several years of research in the Ukraine have shown that various trace elements, such as manganese, zinc, boron, molybdenum, lithium and others, which are very important for the structure and functions of the plants, are needed to prevent deficiencies that might disturb their physiological activities. These deficiencies lower the resistance of plants to various unfavourable conditions and to fungus and bacterial diseases.

Fertilizers containing trace elements have resulted in increased crops, yields and quality. The effectiveness of fertilizers containing trace elements depends on: the content of available forms of such elements in the soil; characteristics of the crop; climatic conditions; the form in which the element is given; and the dose and the method of application. Efficient and cheapest forms of trace elements in the Ukraine are from inorganic sources—in contrast to the belief that the best sources are organic chelates. As early as 1949 the main source was from ores and their by-products.

For proper use of trace elements in Ukrainian agriculture, cartographic maps have been prepared showing the various deficiencies in these elements (see table 13). The supply and distribution of fertilizers containing trace elements to the collective and state farms is planned, using optimum doses and proper rates, according to these maps.

TABLE 13. TYPES OF MICRO-ELEMENTS FOR CROPS

	Crops	*Material*	*Dosage*
Iron deficiency	Apples, pears, cherry trees, grapes, oil-yielding roses, hops	DTPU PPPU } chelates	0.2–0.5% 50-litre solution
Zinc deficiency	Apples (rosette microphyllous disease)	$ZnSO_4$	Injection in tree trunk
Manganese deficiency	Sugar-beet, winter wheat, millet, corn	Manganic slime industrial waste 14–22%, MnO + 1.5–5% $MnCO_2$	Superphosphate + 1.6–2.5% MnO_2, NPK + 1% MnO_2, Mn SO 5 kg/ha
Molybdenum deficiency	Winter wheat, sugar-beet, corn, peas	Superphosphate 0.26% molybdenum, ammonium molybdate	200–300 kg/ha 1 kg MoS/ha
Boron deficiency	Peas, corn, hops, flax	Superphosphate, borate, boric acid	1 kg/ha
Copper deficiency	Sugar-beet, flax, millet	Blue vitriol (pyrite) cinder Cu 50	205 kg/ha 500 kg/ha

When using superphosphate and nitrophosphate, trace elements of manganese, molybdenum, boron, zinc and copper have been incorporated, in a special liquid preparation applied prior to sowing, in order to bring them into wider use for agriculture. Production of fertilizers containing micro-elements takes into account the quality and characteristics of the various soils.

Manganese, boron and molybdenum have all been shown to be closely connected with the process of photosynthesis. The research in the Institute has also shown positive effects of molybdenum on increasing the module activity of legumes in the tropics. Molybdenum seems to stimulate nitrogen metabolism. Some of these trace elements may have toxic effects, however, when used in excessive quantities.

In the 1980s, it is planned to use fertilizer on fodder crops for farm animals, especially on meadow-hayland or pasture grasses.

With increasing yields, the employment of growing quantities of fertilizers increases their share in agricultural production. According to certain calculations, the share of fertilizers in providing nitrogen, phosphorus and potassium, which are removed from the field by harvests in the USSR, was only 20 per cent in 1964. In 1971, it will increase to approximately 40 per cent and by 1976, to about 50 per cent. Thus, approximately one half of the extracted nitrogen, phosphorus and potassium will be taken from the field at the expense of the soil, and the other half will be returned to it by the chemical industry.

The future aim is to bring the NP ratio from 1 : 0.5 to 1 : 1. With the increased concentration of phosphate it is envisaged that the long-term ratio will stabilize at 1 : 0.7.

Co-ordination of fertilizer research in CMEA countries

The CMEA countries have a Standing Committee on Agriculture, whose task is to further the agricultural productivity in member countries. From the start of its activities, the Committee paid special attention to the further use of mineral fertilizers. It organized a systematic exchange of experience and proposed the practical use of the results of the latest agricultural research in member countries in the following spheres:

Expansion of the types of fertilizer used;

The optimum nutrients to be used on various crops;

The application of fertilizers under various soil and climatic conditions.

These aims are to be attained by the following strategies:

Developing country and field laboratories;

Completing soil-fertility surveys, which will take five years;

Processing models for the use of computers in agronomic and soil-fertility surveys. (These models are discussed in the section on modern information services below.) Every country is developing these methods independently, and the best methods should be selected and adopted. In this regard, an exchange of information between the CMEA countries and FAO would be profitable;

Increasing the concentration of NPK in the various compound fertilizers;

Establishing agro-chemical centres for experiments and field tests. Such centres have been created by the Standing Committee in nearly all the CMEA member countries. One of the results of this work may be seen in table 11.

The task of the Soil Fertility Department of the CMEA Standing Committee on Agriculture is to stimulate the expansion of fertilizer use. No provision has been made to co-ordinate the production of fertilizers in member countries. The Committee does not envisage any problem in meeting the increased fertilizer needs of agriculture.

The use of computers in the expansion of agricultural inputs

The modern methods of data collection and analysis have provided planners with tools to survey animal and plant production together.

Agriculture is now in a phase of rapid development, exemplified by high yields and increased fertilizer use. The relationship between the chemical industry and agriculture is very close and takes manifold forms. Several factors influence agricultural production, and an analysis of these factors can now be conducted in a short period of time. The practical farmer has neither the time nor the resources to do this, and computers are therefore suitable for the job.

The Association of Hungarian Chemical Industries has developed methods, by using computer techniques, to make more efficient use of chemicals, and to ensure the control and regulation of the chemical industry.

The following models have been successfully tested and used:

A correlation model of relationship between NPK and yield, which serves to show the ratio of accumulation and utilization of the various components in parts of the plant, using data collected over a period of five to eight years of experiments on main crops and soil types, and under different climatic conditions. This model determines the effect of these factors on the yield and the components of the plant, and calculates the most economic combinations.

A model of technical consultation on fertilizer application, which permits rapid preparation of recommendations for fertilizer application shortly after laboratory testing. It indicates how fertilizers may be used most economically, giving several alternatives depending on the fertilizers available and the prices of fertilizer and crop.

A model optimizing the yearly plan of a farm operation, which permits a separate study of the two important branches—crop and livestock production—with special reference to optimum fodder demand, minimum cost and area, and the optimization of crop production and fertilizer use.

A model of the computer testing crop production, which is used to analyse the effects of agricultural practices and factors, such as showing data, plant population, climate etc. It permits an analysis to be made of each factor separately or in combination, and it allows for tests of hypothesis, and the determination of constants and relationships, correlations and regressions.

The model optimizing the yearly plan of a farm operation may well be used to study the various aspects of over-all country or area planning. All the models are designed to detect the limitations of the farming system, which can then be corrected. The models have been planned for a study that covers the whole area and that does not take into account the seasonal pattern of distribution, of climate etc. during the year. Such factors will be incorporated in future models.

All the models have been tested in practice and the CMEA member countries are starting to use them. It was suggested during the discussions at the Symposium that the international bodies should co-operate in making use of these models for the analysis of national and international projects.

XIII. PROBLEMS FACING THE FUTURE DEVELOPMENT OF THE FERTILIZER INDUSTRY IN DEVELOPING COUNTRIES

In order to obtain a better understanding of and to identify problems that developing countries confront in the future development and expansion of their fertilizer industry, UNIDO circulated a questionnaire covering the following major headings:

I. Problems of production in existing plants

II. Problems of construction of new plants

III. Problems of research/development and central planning

IV. Problems of importing fertilizers

V. Problems of exporting fertilizers

VI. Problems of consumption, marketing and distribution

Respondents were asked to give one of the following ratings to each of the 87 problems in the questionnaire:

4 = most important problem

3 = very important problem

2 = moderately important problem

1 = small importance

0 = no importance

X = not relevant or not applicable

The questionnaire was sent to 70 Governments through the United Nations Development Programme (UNDP) Resident Representatives in each country, or through UNDP Regional Representatives in some areas. It was also sent to 134 operating fertilizer companies in developing countries, including companies in both private and public sectors.

Thirty-eight of the 70 Governments to which the questionnaire was sent completed and returned it. A summary of their responses is contained in table 14.

Of the 134 fertilizer companies, 35 returned usable questionnaires, and the response showed a close correlation with the 38 questionnaires returned by the Governments.

Analysis of the response

Table 14 gives the actual numbers of respondents who gave ratings of 0, 1, 2, 3, or 4 to each problem and, in the last column, the percentage of respondents giving either of the two highest ratings (3 or 4).

TABLE 14. SUMMARY OF RESPONSE FROM GOVERNMENTS TO UNIDO QUESTIONNAIRE ON PROBLEMS OF THE FERTILIZER INDUSTRY IN DEVELOPING COUNTRIES

	Number of respondents giving ratings of					*Per cent of respondents giving ratings of*
	0	*1*	*2*	*3*	*4[a]*	*3 or 4*
I. Problems of production in exporting plants						
High cost of production of fertilizers	2	1	10	12	4	55
High cost of raw materials	5	2	8	11	3	48
Supply of spare parts	2	3	9	8	5	48
Inadequate supply of potash	4	3	5	6	3	43
Inadequate supply of phosphate rock	7	2	6	8	3	42
Existing plants too small	4	1	8	7	2	41
Shortage of qualified personnel	4	3	8	9	1	40
Low production of plants in relation to capacity	7	3	5	5	4	37
High maintenance costs	1	6	11	8	2	36
Inadequate supply of naphtha	4	3	0	4	0	36
Inadequate supply of sulphur	8	5	6	6	4	35
Shortage of skilled workers for maintenance	5	6	7	8	1	33
Shortage of maintenance personnel	3	7	8	5	3	31
Shortage of plant operators	4	7	8	6	1	27
Excessive downtime of plants	7	3	7	3	3	26
Shortage of qualified managers	4	2	14	5	2	26
Shortage of qualified engineers	3	2	15	6	1	26
High cost of electricity	6	3	13	5	2	24
Processes need modernization	7	4	8	3	3	24
Shortage of natural gas	11	2	1	2	2	22
Shortage of coal	2	2	3	2	0	22
Time required for repairs	7	7	7	4	2	22
Inadequate supply of electricity	9	10	2	4	1	19
Storage and despatch	14	10	3	6	0	18

TABLE 14 *(cont.)*

	Number of respondents giving ratings of					*Per cent of respondents giving ratings of*
	0	*1*	*2*	*3*	*4*[a]	*3 or 4*
Shortage of fuel oil	6	6	2	2	0	13
Inadequate variety of products	12	3	6	1	1	9
Quality control of products	11	12	1	2	0	8
High labour costs	9	8	8	1	1	7
Products not suitable	13	3	4	0	1	5
II. Problems of construction of new plants						
No production of locally fabricated equipment	1	4	2	8	9	71
High cost of fertilizer plants	2	3	7	7	10	59
Shortage of fertilizer plant designers	4	6	4	9	0	58
Lack of process know-how	5	7	1	7	11	58
High cost of imported equipment	2	3	8	10	10	57
Need to provide infrastructure	5	4	4	10	6	55
High royalty charges on foreign process know-how	2	7	6	7	9	52
Shortage of local capital	5	2	8	5	11	52
Shortage of foreign capital	3	4	7	6	8	50
Lack of demand for fertilizers	5	5	6	12	4	50
Shortage of fertilizer plant construction engineers	5	9	4	9	6	46
High cost of locally fabricated equipment	3	4	6	9	2	46
Shortage of potash	7	2	5	5	7	46
Shortage of sulphur	8	4	6	6	8	44
Lack of investment incentives for local capital	5	5	5	6	5	42
Shortage of naphtha	9	3	2	6	4	42
Shortage of phosphate rock	8	3	7	5	7	40
Poor quality of locally fabricated equipment	5	6	0	6	1	39
Shortage of natural gas	12	4	1	3	7	37
Shortage of coal	8	3	3	2	4	30
Need for housing and other amenities	6	7	8	7	2	30
Shortage of skilled construction workers	7	10	5	6	3	29

	Number of respondents giving ratings of					Per cent of respondents giving ratings of
	0	*1*	*2*	*3*	*4*[a]	*3 or 4*
Delay in supply of locally fabricated equipment	6	5	5	4	1	24
High import duties on imported equipment	14	6	1	5	1	22
Lack of investment incentives for foreign capital	5	5	5	6	5	21
Restrictive policies on foreign capital	10	5	5	3	1	17
Shortage of fuel oil	12	7	3	2	2	15
III. Problems of research/development and central planning						
Lack of engineering organizations for the planning, process development and design of new plants	3	3	6	13	10	66
Lack of research/development organizations for the development of new fertilizers and new production processes	2	4	7	6	13	59
Inadequate central planning and development institutions	5	10	9	7	4	31
Lack of research organizations supplying data on crop responses, soil analysis, soil classification etc.	6	7	9	7	2	29
IV. Problems of importing fertilizers						
Shortage of foreign exchange and/or credit	8	4	5	7	6	43
High prices of imported fertilizers	10	7	3	8	3	36
Importing fertilizers in bags because of lack of bulk-handling facilities	8	6	5	5	5	35
Inadequate transportation from ports	9	8	7	6	1	23
Lack of knowledge of type of fertilizers needed	10	7	5	2	4	21
Inadequate port facilities	13	5	6	5	1	20
Lack of policy decision to import fertilizer intermediates	10	5	5	5	0	20
Difficulty of making contact with foreign sellers of fertilizers	25	3	2	0	0	0

TABLE 14 *(cont.)*

	Number of respondents giving ratings of					*Per cent of respondents giving ratings of*
	0	*1*	*2*	*3*	*4*[a]	*3 or 4*
V. Problems of exporting fertilizers						
Competition from other countries	0	1	2	11	13	89
Fluctuations in world prices of fertilizers	3	0	5	9	8	68
High cost of shipping fertilizers	2	2	4	10	6	67
Lack of sales representatives in foreign countries	4	3	2	8	4	57
Inadequate marketing information and marketing know-how	5	1	10	8	2	39
Lack of storage facilities at ports	7	3	8	5	0	22
Difficulties in exporting owing to balance of payments	9	6	3	3	0	14
Inadequate quality control of products	10	5	5	2	1	13
VI. Problems of consumption, marketing and distribution						
Low prices of farm products	3	3	8	15	8	62
Difficulty of educating farmers to use optimum economic quantities of fertilizers	1	6	8	11	10	58
High prices of fertilizers	4	7	6	11	9	56
Inadequate supply of irrigation water	4	4	7	15	4	56
Shortage of credit for fertilizer purchases	8	1	9	12	6	50
Inadequate facilities for marketing farm products	6	4	9	10	6	46
Lack of storage facilities for fertilizers in consuming areas	6	4	10	12	3	43
Inadequate agricultural extension services for farmers	4	6	12	12	2	39
Inadequate supply of improved seed varieties	7	5	11	12	1	36
Inadequate transportation of fertilizers	4	6	12	10	2	35
Short supply of fertilizers	10	10	4	8	1	27

[a] Key to ratings:
4 = most important problem
3 = very important problem
2 = moderately important problem
1 = small importance
0 = no importance

The percentages in the last column were calculated on the basis of the number of respondents giving ratings of 0, 1, 2, 3 or 4 to each problem. It might have been more significant statistically to have used 38 respondents as the basis of calculation for all problems, regardless of how many respondents gave ratings to each problem. However, there were so many gaps in the response, i.e. no rating, that it was felt to be more consistent and more meaningful to use *the actual numbers of respondents rating each problem.* For example, the first problem listed in section 1 of table 14 had a score of 2–1–10–12–4 for a total of 29 respondents out of a total of 38 questionnaires analysed. Therefore, the percentage of respondents giving the two highest ratings was calculated as 16/29 X 100 = 55 per cent.

The results summarized in table 14 are broken down further in table 15.

TABLE 15. PER CENT OF RESPONDENTS GIVING TWO HIGHEST RATINGS

	Less than 25 per cent	*25–50 per cent*	*Over 50 per cent*
Section I	12 problems	16 problems	1 problem
Section II	5 problems	12 problems	10 problems
Section III	–	2 problems	2 problems
Section IV	5 problems	3 problems	–
Section V	3 problems	1 problem	4 problems
Section VI	–	6 problems	5 problems
Total, all sections	25 problems	40 problems	22 problems

A detailed picture of the degree of importance given to individual problems by the responding countries may be obtained by a study of table 14.

Section I – Problems of production in existing plants

The highest importance among the problems cited in section I was accorded to "high cost of production of fertilizers", 55 per cent. This problem is obviously related to one of the highest rated problems in section VI, namely, "high prices of fertilizers", 56 per cent. The high price of fertilizers is a problem in many developing countries and, in some cases at least, it is directly related to the high production cost of fertilizers in existing plants.

Some other problems in section I that were highly rated in importance were:

High cost of raw materials	48 per cent
Supply of spare parts	38 per cent
Inadequate supply of potash	43 per cent
Inadequate supply of phosphate rock	42 per cent
Existing plants too small	41 per cent
Shortage of qualified personnel	40 per cent

Section II – Problems of construction of new plants

The highest importance among the problems cited in section II was given to "no production of locally fabricated equipment", 71 per cent.

Following this, the next problems in order of importance were:

High cost of fertilizer plants	59 per cent
Shortage of fertilizer-plant designers	58 per cent
Lack of process know-how	58 per cent
High cost of imported equipment	57 per cent
Need to provide infrastructure	55 per cent
High royalty charges on foreign process know-how	52 per cent
Shortage of local capital	52 per cent
Shortage of foreign capital	50 per cent
Lack of demand for fertilizers	50 per cent

It is quite clear that the responding countries accord generally higher importance to "problems of construction of new plants" than they do to "problems of production in existing plants".

The problem of "lack of demand for fertilizers" is fundamental. Many of the developing countries have such a small demand for fertilizers that they cannot support even one fertilizer plant of a minimum economic size, *if the plant starts with the basic raw materials.* The concept of "satellite plants" based on intermediates, such as ammonia, phosphoric acid and ammonium phosphates, which was discussed in several papers at the Symposium, is very important for countries with a small present demand for fertilizers.

Section III–Problems of research/development and central planning

The two problems of highest importance in section III were:

Lack of engineering organizations for the planning, process development and design of new fertilizer plants, 66 per cent;

Lack of research/development organizations for the development of new fertilizers and new production processes, 59 per cent.

The other two problems cited in section III were rated much less important by the respondents.

Section IV–Problems of importing fertilizers

The three problems of highest importance in section III were:

Shortage of foreign exchange and/or credit	43 per cent
High prices of imported fertilizers	36 per cent
Importing fertilizers in bags because of lack of bulk-handling facilities	35 per cent

However, the highest ratings in section IV were much lower than the highest ratings in sections I, II and III.

Shortage of foreign exchange and/or credit for purchase of fertilizers, as well as for purchase of other commodities and capital equipment, is a chronic problem in many of the developing countries.

High prices of imported fertilizers is, of course, a relative concept. Ex-factory prices of fertilizers from the developed countries are at the lowest levels in history, but this is offset in many cases by increased transportation costs. Ex-factory prices of fertilizers can hardly go any lower without bankrupting some producing companies. Also, it is significant that prices of delivered fertilizers are usually lower than the cost of domestic production in most developing countries, but many developing countries nevertheless prefer to produce their own fertilizers, even at higher cost than importing.

Section V–Problems of exporting fertilizers

Four problems stand out as of the highest importance in section V:

Competition from other countries	89 per cent
Fluctuations in world prices of fertilizers	68 per cent
High cost of shipping fertilizers	67 per cent
Lack of sales representatives in foreign countries	57 per cent

Competition from other countries is, of course, undesirable from the standpoint of exporting countries, but that is the "name of the game" in international trade.

Fluctuations in world prices of fertilizers have been downwards for the past three or four years, and this is naturally undesirable from the standpoint of exporting countries, but, on the other hand, it is desirable from the standpoint of importing countries.

Section VI–Problems of consumption, marketing and distribution

Five problems in section VI were given highest importance by the responding countries:

Low prices of farm products	62 per cent
Difficulty of educating farmers to use optimum economic quantities of fertilizers	58 per cent
High prices of fertilizers	56 per cent
Inadequate supply of irrigation water	56 per cent
Shortage of credit for fertilizer purchases	50 per cent

Six other problems had percentages running from 46 down to 27 per cent.

Low prices of farm products is, of course, fundamental. Farmers must receive high enough prices for their products to make it economically attractive for them to use more fertilizer. However, demonstrations and field trials by FAO and by other organizations during the past decade have shown value-cost ratios of 3, 4, 5 and even as high as 20 for the use of increased amounts of fertilizer on a wide variety of crops in many of the developing countries. (The value-cost ratio is the value of additional product divided by the cost of the fertilizer needed to produce the additional product.)

Therefore, it would seem that "low prices of farm products" is, in many cases, a matter of education for farmers as to the economic value of using more fertilizers, provided it is used in the right way at the right time on the right crops. This is the subject of the second problem cited above, "difficulty of educating farmers to use optimum quantities of fertilizers".

"High prices of fertilizers" was discussed under section IV. The same comments apply here.

Inadequate supply of irrigation water is also fundamental since it is generally true that fertilizers are much more productive and hence more economic when used in conjunction with an adequate supply of water, either from rainfall or by irrigation.

Besides fertilizers and water supply, the other key input for productive agriculture is good seed varieties. Seeds, water and fertilizer are the three key inputs of agriculture—the triangular base on which agriculture rests. It is noteworthy that "inadequate supply of improved seed varieties" received a composite rating of 36 per cent, indicating that supply of seeds is less of a limiting factor in productive agriculture than fertilizer and water.

Shortage of credit for fertilizer purchases refers to shortage of credit to farmers. This is a chronic problem in many developing countries and one to which the national banks and finance ministries need to address themselves.

Conclusion

The obvious awareness of the importance of the problems in the UNIDO questionnaire among the responding countries is encouraging because the identification of a problem is the first step in solving it.

The goal to be reached in every developing country is a fertilizer consumption level equal to or near the optimum fertilizer use that corresponds to each country's economic requirements and that, at the same time, represents a first-hand prerequisite for economic fertilizer production. Here the relation between economic use of production capacity and the market demand has to be stressed.

Optimum fertilizer use, moreover, is a primary factor in creating purchasing power within the farming community, allowing its members to become buyers of other industrial products besides agricultural inputs.

There is, of course, no doubt that in most cases the solution of the problems set forth in the questionnaire will require considerable time, funds and organization, as well as legal action by the Governments, taking some years to a decade, if not a generation or more. Therefore, it appears logical that thorough and realistic study of market conditions and prospects, and related elements, should form the basis of priorities for investment in the fertilizer field, and that investment in the creation of an effective fertilizer marketing and distribution system cannot be separated from investment in fertilizer production.

The time factor for creating a fertilizer market should also be carefully taken into consideration when deciding about priorities, not only by the developing but also by the developed countries. The developed countries have been and are still learning about the relationship of market demand and production capacity.

Most of the measures to be taken to solve the problems in the fertilizer field will have, as soon as they become effective, a beneficial influence on the national economy far beyond the fertilizer field (improvement in transport facilities, reduced import of food, export of agricultural products, food processing industries etc.).

XIV. ROLE OF NATIONAL AND INTERNATIONAL ORGANIZATIONS IN HELPING THE DEVELOPING COUNTRIES MEET THEIR FERTILIZER NEEDS DURING THE 1970s

The development of the fertilizer industry has engaged the serious attention of UNIDO in the last four years and before that of its predecessor the Centre for Industrial Development (CID).

UNIDO has assisted member countries in the following types of operational activities:

Provision of experts to assist developing countries;

Fertilizer market surveys;

Feasibility studies;

Preparation of tender documents;

Analyses of tenders;

Assistance to existing plants for trouble shooting, starting up etc.;

Establishment of pilot demonstration plants;

Assistance in the development and use of natural gas for the fertilizer industry;

Product diversification;

Assistance in obtaining finance;

Training of personnel.

The supporting activities of UNIDO consist in backstopping operational projects and in carrying out certain important studies and projections of value for developing countries. The projections for fertilizer supply and demand during the Second Development Decade may be mentioned in this connexion.

Meetings to transfer technology and know-how are organized in the form of expert group meetings, seminars and symposia. Examples are the Interregional Seminar on the Production of Fertilizers held in Kiev, USSR, in 1965, and the Second Interregional Fertilizer Symposium.

Although UNIDO cannot invest directly in the fertilizer industry, it can assist member countries in all facets of the pre-investment stage. UNIDO's efforts have contributed in a large measure to the following developments:

Acceptance of the idea in developing countries of large single-train fertilizer plants, thus ensuring economy of scale;

Widespread use of gaseous and liquid fuels for feed-stock, especially in countries where abundant and cheap supplies are available;

Production and use of multi-nutrient high-analysis fertilizers;

Import of intermediates like ammonia and phosphoric acid, thus supporting regional co-operation;

Standardization of plant capacities, products and processes to help in training and use of spares;

Assistance in reducing underutilization of existing capacities.

In the course of the Symposium the work of other specialized agencies of the United Nations was discussed.

The United Nations Development Programme (UNDP) is financing many major projects in the developing countries, including one for country programming which is coming into operation in 1972. This is a scheme whereby a country adjusts its requirements for United Nations' assistance to conform with its national plans.

The World Bank Group expressed its hope that more fertilizer projects could be financed in the future from the IBRD, although seven to ten projects, requiring an investment of nearly $200 million, have already been undertaken by the World Bank Group. The importance of presenting viable fertilizer projects in the form required by the World Bank was stressed in order that assessment for financing may be expedited.

In technical papers presented to the Symposium, and in discussions, representatives of FAO described the work they are doing in the fertilizer field and the nature of the co-operation between FAO and UNIDO. The importance of marketing and distribution of fertilizers in many developing countries was highlighted.

XV. CONCLUSIONS AND RECOMMENDATIONS

On future symposia to be organized by UNIDO

Conclusion: The Second Interregional Fertilizer Symposium clearly conveyed the technical, economic and agricultural possibilities of developing the fertilizer industry in the countries of the participants. It served to transfer technological information and to clarify many questions pertaining to the industry.

Recommendation 1: An interregional fertilizer symposium should be held every three or four years. This is the maximum time that should elapse between the meetings, considering the rapid changes in technology and in the economics of production of fertilizer and its use in agriculture. Preferably, the symposium should divide the participants into major groups concerned with agriculture, technology, marketing, financing etc.; it should not last more than two weeks, and the venue should be restricted to one host country.

On the technology of the production of ammonia and nitrogen fertilizers

Conclusion: On the basis of the technology currently in world-wide use, and the experience gained, only the most economic-size ammonia plants should be built in developing countries.

Recommendation 2: Developing countries with large markets for nitrogen fertilizers, e.g. 100,000 tons N per year or more, should give serious consideration to building nitrogen fertilizer plants with a capacity of 150,000 tons N per year or more and avoid uneconomic investments in plants smaller than this size.

Conclusion: Urea and ammonium nitrate are the two leading nitrogen fertilizers; both are suitable for various crops and soils.

Recommendation 3: Developing countries should carefully compare the relative merits of urea and ammonium nitrate to meet their basic needs for nitrogen fertilizer, considering the relative production costs in the particular country and the pattern of crops. (Urea and ammonium nitrate are the only two realistic choices for meeting the basic needs for nitrogen in a form of single fertilizer in most developing countries, although ammonium chloride, ammonium sulphate, ammonium phosphates, calcium nitrate, sodium nitrate and anhydrous ammonia may be supplementary sources of nitrogen in many cases.)

On the technology of the production of phosphate and potash fertilizers, including mixed, complex and liquid fertilizers

Conclusion: **Wherever large internal or export markets for phosphate fertilizers exist, viable economic-size phosphoric-acid plants should be built; for smaller markets, the import of phosphoric acid may be more economical. Production and distribution of fertilizers containing all three plant nutrients, N, P + K, should be encouraged. The economics of production and the use of liquid fertilizers are attractive.**

Recommendation 4: Developing countries with large markets for phosphate fertilizers, e.g. 80,000 tons P_2O_5 per year or more, should give serious consideration to building phosphoric-acid plants in sizes of 100,000 tons P_2O_5 per year or larger, followed by conversion of phosphoric acid to ammonium phosphates or TSP.

Recommendation 5: Developing countries should produce and distribute NP and NPK fertilizers wherever the market is large enough to warrant indigenous production, rather than continue the traditional practice of producing and distributing N, P and K fertilizers separately.

Recommendation 6: Developing countries should give consideration to the production and use of liquid fertilizers (including anhydrous ammonia, aqua ammonia, nitrogen solutions, NP solutions and NPK solutions) as alternatives to the more traditional solid fertilizers.

Recommendation 7: UNIDO, in co-operation with FAO, should establish one or more pilot demonstration projects in selected developing countries for the production, storage and application of liquid fertilizers and should bring the results to the attention of all developing countries.

On the technology of the production of nitrophosphate fertilizers

Conclusion: Several new processes for the production of nitrophosphates with varying degrees of water-solubilities have been developed, and commercial units based on them have been built and are operating satisfactorily.

These processes are particularly appropriate for a country that has a present or potential supply of ammonia but does not have an indigenous supply of sulphur. The economic benefits may be quite significant in some cases, but a thorough techno-economic analysis should be made before reaching a decision.

Recommendation 8: **Many developing countries could utilize to advantage the new nitrophosphate processes for the production of NP or NPK fertilizers.**

On fertilizer intermediates and the concept of satellite plants

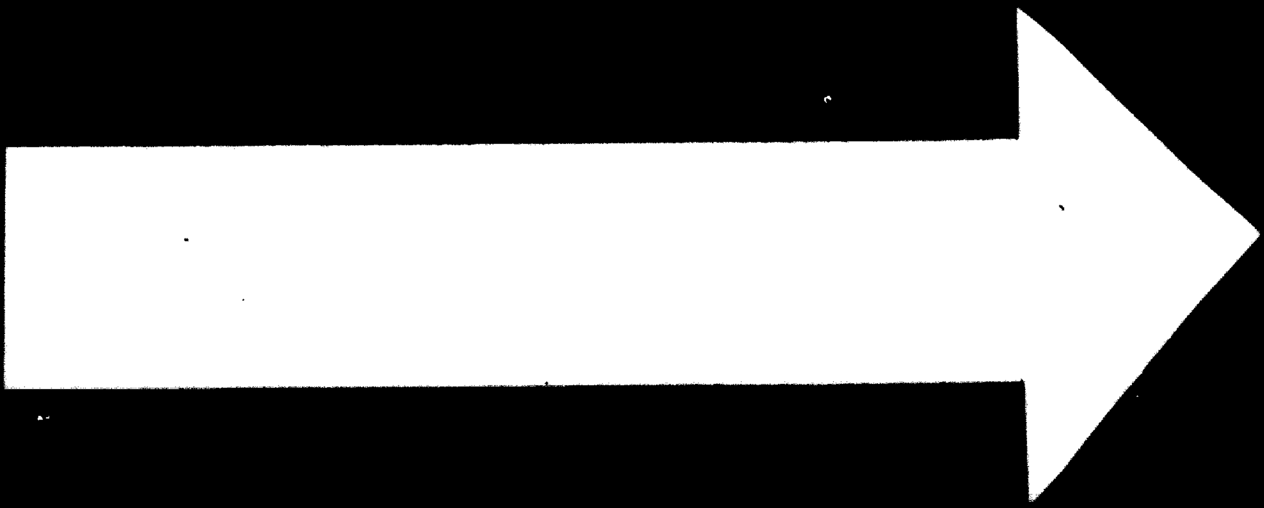
Conclusion: **Primary nutrients, nitrogen (N) and phosphates (P), can be produced very economically at the location of large sources of cheap raw materials such as gas and phosphate rock and/or sulphur. Well-proved and economic bulk-carriers have been developed for water transport of both ammonia and phosphoric acid.**

Recommendation 9: **Developing countries with medium-sized markets for fertilizer should give consideration to the importation of ammonia, urea, phosphoric acid and/or ammonium phosphates to use in satellite plants for the production of NP or NPK fertilizers, as an alternative to primary production of ammonia and/or phosphoric acid. The adoption of satellite plants is indicated for countries having a market for nitrogen fertilizer from 20,000 to 100,000 tons N per year and/or a market for phosphate fertilizer from 10,000 to 80,000 tons P_2O_5 per year.**

Recommendation 10: **Developing countries with markets for fertilizer that are smaller than those cited in the preceding recommendation should probably import finished fertilizers, with or without simple mixing operations for production of NP and NPK mixed fertilizers.**

On raw materials for fertilizer production

Conclusion: **Gaseous and liquid hydrocarbon raw materials for the production of ammonia are the most economic in certain areas of the world, and processes based on them are easy to operate; the supply of other raw materials such as phosphate**



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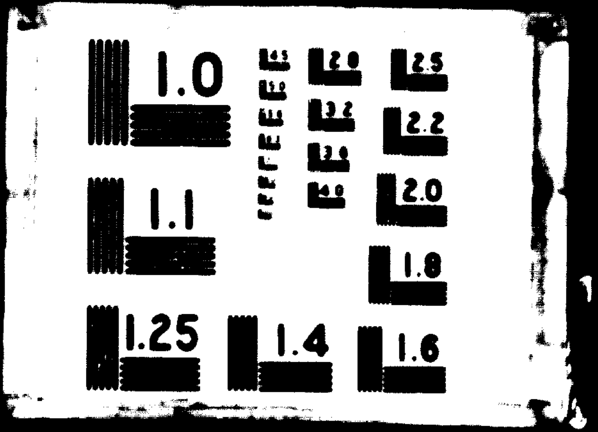


rock, potash and sulphur are adequate to meet the demand of industry on a world-wide basis. The price of sulphur has largely stabilized in the world market.

Recommendation 11: Developing countries that have indigenous supplies of gaseous or liquid hydrocarbon materials should utilize these feed-stocks for the production of nitrogen fertilizers, but developing countries that do not have these materials should consider the use of coal or lignite as feed-stocks, and make a thorough analysis of all alternatives.

Recommendation 12: UNIDO should make a study of ammonia plants based on coal and lignite throughout the world to evaluate the capital and production costs (including maintenance costs) of such plants as a guide to developing countries.

Recommendation 13: UNIDO should assist developing countries in choosing raw materials, particularly for ammonia production, in view of the complex nature of such a decision.

Recommendation 14: UNIDO should assist developing countries in conducting surveys to locate new sources of raw materials for the fertilizer industry, particularly phosphate rock, sulphur and potash, utilizing the most modern and sophisticated techniques.

Recommendation 15: Developing countries should give increased attention to bulk unloading and internal shipping of fertilizer raw materials, such as phosphate rock, potash and solid and molten sulphur, and to fertilizer intermediates such as ammonia, urea, phosphoric acid and ammonium phosphates. UNIDO might assist the developing countries in this respect.

On the design, construction, operation and maintenance of fertilizer plants and pollution control

Conclusion: On the average, fertilizer plants in developing countries operate much below design capacity. Lack of proper and timely maintenance is one of the major reasons. Removing bottlenecks and bringing existing units to full capacity must be given highest priority. Assistance needed in this effort should be sought from bilateral or international agencies. Developing countries that plan to build additional plants have a chance to develop design and equipment and spare-parts manufacturing facilities. Problems of environmental pollution arise during production in fertilizer plants and in the use of fertilizer products in agriculture.

Recommendation 16: Most developing countries need to increase the percentage output of existing fertilizer plants, which frequently operate at 40–70 per cent of design capacity on an annual basis.

Operation at 90–100 per cent of capacity should be the goal. Frequently, this will require additional investment for eliminating bottlenecks and modifying equipment.

Recommendation 17: Most developing countries should improve the maintenance of existing fertilizer plants. Poor maintenance is probably a major factor in production below rated capacity now being realized in many plants in developing countries.

Recommendation 18: The larger and more advanced developing countries should plan to produce an increasing amount of the equipment needed for the construction of new fertilizer plants and of spare parts and other materials needed for maintenance of existing plants.

Recommendation 19: The World Bank and other international lending agencies should establish special loan programmes for developing countries to assist them in eliminating bottlenecks and improving maintenance and indigenous production of fertilizer plant equipment.

Recommendation 20: All countries, including the developing countries, should give increased attention to designing and operating fertilizer plants with a minimum of environmental pollution by gaseous, liquid and solid effluents.

Recommendation 21: UNIDO should proceed with the proposed "global project" for UNDP financing on the effect of the manufacture, distribution and use of chemical fertilizers on the environment, and the control of pollution.

On the planning, financing and economics of new fertilizer plants

Conclusion: Financing agencies require more comprehensive feasibility and pre-investment studies before assessing new projects or expanding existing production facilities.

Recommendation 22: Most developing countries should improve their preparation of project reports requesting loans from the World Bank and other sources of funds. UNIDO might assist the developing countries in preparing better project reports with more precise economic data and evaluation.

Recommendation 23: The World Bank and other lending agencies should give a higher priority to loans for the fertilizer industry in developing countries than they have in the past, in view of the rapidly increasing demand for fertilizers in these countries.

Recommendation 24: Developing countries should not underestimate the potential contribution of private capital, both domestic and foreign, to the development of their fertilizer industries.

On the training of production and marketing personnel

Conclusion: The training of personnel for production and maintenance and for marketing of fertilizers is inadequate in many developing countries.

Recommendation 25: Most of the developing countries need to give greater attention to the training of both production and marketing personnel in the fertilizer industry.

Recommendation 26: Developing countries that are more advanced in development of the fertilizer industry, such as Egypt, India, the Republic of Korea and Mexico, could be of great assistance to other developing countries in the training of production and marketing personnel.

On marketing and distribution of fertilizers

Conclusion: The institutional framework and physical facilities for the marketing and distribution of fertilizers are inadequate in many developing countries.

Recommendation 27: Most developing countries need to give much greater attention to the marketing of fertilizers in order to develop a demand commensurate with the true economic need for fertilizers. This involves establishing more efficient distribution systems, education of farmers, training of marketing personnel, provision of credit to farmers, pricing policies etc.

On the use of fertilizers in agriculture

Conclusion: Pre-investment studies and projects for the use of fertilizers have been carried out successfully by FAO. In many developing countries they have proven that fertilizer use raises production and is economical and acceptable to farmers. It is necessary to continue these programmes and to strengthen them by the assistance of government, non-governmental agencies and private enterprises. There must be continued emphasis on field demonstrations and extension work, fertilizer distribution and credit schemes.

High-yielding varieties (HYV) have proven to be most effective when used together with other agricultural inputs such as fertilizers, pesticides and good water and farm-management techniques. In a number of cases no provision has been made by the countries concerned to develop the infrastructure necessary to supply the inputs and to organize the marketing channels for the added production. Valuable work has been done by the plant physiology institutes in the Ukraine in experiments and soil-testing methods as well as in the development of fertilizers containing micro-elements derived from ore residues. With increased yields, the use of improved varieties and other agricultural inputs, the micro-element deficiencies are becoming more and more important in agriculture.

The use of liquid fertilizers together with solids, and particularly the application of aqua and anhydrous ammonia, has been found most economical in some of the developed countries. The demand for this fertilizer material is growing rapidly.

The field experiments carried out in Japan on the use of nitrate fertilizer on rice as well as the studies in West Pakistan have proven the agronomic benefits of its use under certain conditions.

The need for potassium as an ingredient in balanced fertilization has been demonstrated in many areas of developing countries, and its use has proven economically beneficial to the farmer. With more frequent cropping and higher yields, it becomes imperative to review the response to potash together with nitrogen and phosphate by long-term experiments made at frequent intervals. In all FAO fertilizer projects the role of potassium is tested the same way as that of nitrogen and phosphate.

Models for the use of computers to assist in planning agricultural production and inputs have been developed by many national and international bodies. FAO within the last three years has developed a computerized soil-data processing system, and it is in the course of preparing systems for storage, analysis and evaluation of soil data with special reference to fertilizer use and related soil improvement.

Recommendation 28: Developing countries planning to utilize the new HYV on a large scale should plan for adequate supplies of fertilizers as well as increased irrigation, more pesticides and agricultural machinery.

Recommendation 29: Most developing countries need to give greater attention to a more balanced ratio for the main plant nutrients–NPK–in relation to the increasing use of HYV and improved methods of cultivation.

Recommendation 30: UNIDO and FAO, as appropriate, should make a joint study of the requirements for secondary and micro-nutrients in the developing countries in which these needs arise, and should develop techniques for incorporating the necessary secondary and micro-nutrients in commercial fertilizers.

Recommendation 31: Developing countries in which rice is a major crop should not be too dogmatic regarding the use of nitrate fertilizers on paddy cultivation, but they should be guided by realistic cost-benefit analyses comparing nitrate fertilizers with urea and other non-nitrate nitrogen fertilizers.

Recommendation 32: UNIDO and FAO should collaborate to collect information about computer models developed by some countries to assist the marketing, distribution and use of fertilizers in agriculture, and to make such computer models available to the developing countries on request.

On the problems facing the future development of the industry in developing countries

Conclusion: On the basis of an analysis of the replies received to the questionnaire sent out by UNIDO, the important problems are:

High cost of production from existing plants;
High capital cost of new plants;
Lack of engineering and fabrication facilities;
Shortage of foreign exchange and/or credit for imports;
Competition in exports;
Low price on farm products.

Recommendation 33: Urgent steps should be undertaken by developing countries to bring existing units to full production, thereby lowering the cost of production (see also recommendations 16 and 17).

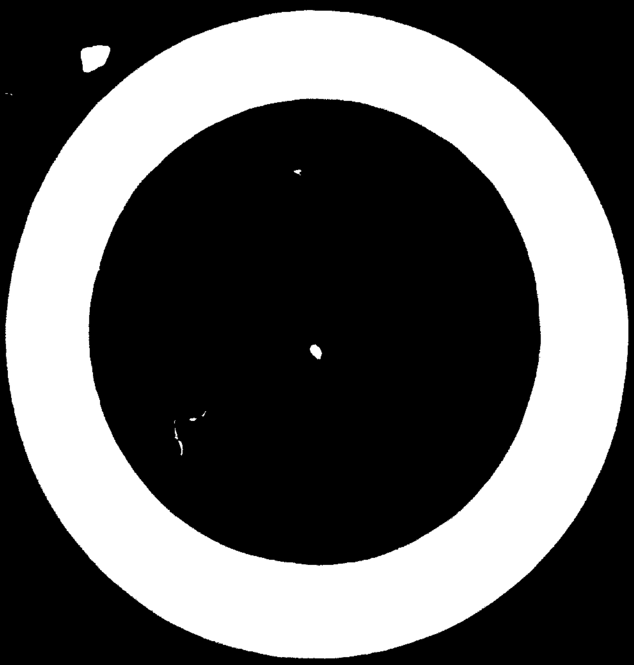
Recommendation 34: Thorough and realistic studies of internal and external markets and prospects for sales and related elements should form the basis for priorities of investments in new fertilizer projects. Fiscal and agrarian policies of Governments should promote fertilizer production and use.

On the role of national and international organizations in helping the developing countries meet their fertilizer needs during the 1970s

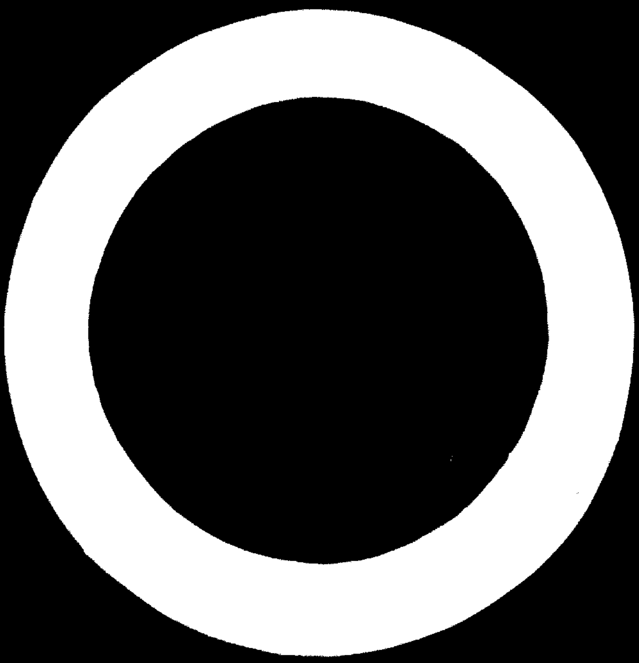
Conclusion: Developing countries have realized that the experience gained by national and multi-national enterprises, and international organizations, in helping to set up regional fertilizer production facilities and the infrastructure for use of indigenous raw materials and marketing of products, will be of great value to them. Assistance from international organizations in the choice of processes will be valuable to countries in the early stages of planning fertilizer projects.

Recommendation 35: UNIDO should take the initiative, in collaboration with the World Bank, FAO, ECA, ECAFE, ECE, ECLA and UNESOB, in promoting the development of regional schemes for the production and distribution of fertilizers, in order to utilize most effectively the raw materials in various regions and to make fertilizers available to all countries at the lowest cost.

Recommendation 36: UNIDO should assist developing countries in deciding what processes to use in the production of fertilizers and in choosing raw materials (see also recommendation numbers 11–14). These are very complex decisions that require information and advice from many sources.



ANNEXES



ANNEX I

AGENDA

1. Opening statements
2. Adoption of the agenda
3. General introduction
4. Production technology and plant operation
5. Raw materials and intermediates
6. Planning, organization, financing and economics of new plants
7. Training of production and marketing personnel
8. Marketing and distribution
9. Use of fertilizers in agriculture
10. General session
11. Problems facing developing countries in the further development of their fertilizer industries
12. Role of national and international organizations in helping the developing countries meet their fertilizer needs during the 1970s
13. Conclusions and recommendations
14. Closing statements

ANNEX II

LIST OF PAPERS PREPARED FOR THE SYMPOSIUM[a]

Symbol	*Title*	*Chapter of this report*
ID/WG.99/1	Agenda	
ID/WG.99/2/Rev.1	List of documents	
ID/WG.99/3/Rev.4	List of participants	
ID/WG.99/4/Rev.1 and Summary	Review of world production, consumption and international trade in fertilizers with projections to 1975 and 1980 *UNIDO*	I
ID/WG.99/5 and Summary	Estimation of fertilizer requirements in developing countries in 1975 and 1980 in relation to desirable nutritional and agricultural development goals *FAO*	I
ID/WG.99/6/Rev.1	Financial implications of meeting the fertilizer needs of developing countries in 1975 and 1980 *E. H. Becker-Boost, United States of America*	IX
ID/WG.99/7 and Summary	Recent advances in ammonia production technology *J. A. Finneran, L. J. Buividas and N. Walen, United States of America*	III
ID/WG.99/8/Rev.1 and Summary	Ammonia production based on various raw materials *K. S. Viswanathan and S. K. Mukherjee, India*	III
ID/WG.99/9 and Summary	Technical and economic survey of nitrogenous fertilizer production *N. A. Afanasyev, State Institute for Nitrogenous Fertilizers, Ministry for Chemical Industry, Union of Soviet Socialist Republics*	III
ID/WG.99/10 and Summary	Large-capacity plants for the production of granulated ammonium nitrate *A. T. Zotov, Union of Soviet Socialist Republics*	III
ID/WG.99/11/Rev.1 and Summary	TECHNIP Mavrovic heat recycle urea process *I. Mavrovic and M. Bergonzo, France*	III
ID/WG.99/12 and Summary	The Mitsui Toatsu urea process *M. Yakabe and T. Sato, Japan*	III

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[a] A limited number of copies are available upon request.

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ID/WG.99/13 and Summary	The Chemico thermo urea process: a future forerunner *L. H. Cook, United States of America*	III
ID/WG.99/14 and Summary	The Montedison urea process for large capacity plants *G. Nardin, Italy*	III
ID/WG.99/15 and Summary	Large-capacity ammonia synthesis reactors and plants: construction of models and optimization *M. B. Aizenbud, Union of Soviet Socialist Republics*	III
ID/WG.99/16 and Summary	Present state of the technology for the industrial production of phosphoric acid *N. D. Talanov, Union of Soviet Socialist Republics*	IV
ID/WG.99/17 and Summary	Extraction and refining of potash ores in the USSR *R. S. Permyakov, Union of Soviet Socialist Republics*	IV
ID/WG.99/18 and Summary	Ammonium sulphate in the production of nitrophosphate *F. E. Steenwinkel, Netherlands*	V
ID/WG.99/19 and Summary	Norsk Hydro nitrophosphate process *S. G. Terjesen and J. F. Steen, Norway*	V
ID/WG.99/20 and Summary	Typpi Oy's solvent extraction process for producing compound fertilizers *N. Lounamaa and L. Niinimäki, Finland*	V
ID/WG.99/21/Rev.1 and Summary	Ammonia production on the basis of coal and lignite–technical and economic aspects *E. Goeke, Federal Republic of Germany*	III
ID/WG.99/22 and Summary	Nitrophosphate process using direct cooled continuous crystallization–Chemoprojekt-Bamag Process *J. Kotisek, Czechoslovakia, L. Hellmer and H. P. Bethke, Federal Republic of Germany*	V
ID/WG.99/23 and Summary	Comparative production cost of fertilizers made by nitrophosphate processes and by conventional sulphur-based processes *UNIDO*	V
ID/WG.99/24 and Summary	New and improved fertilizer materials based on urea *T. P. Hignett, United States of America*	IV
ID/WG.99/25 and Summary	Liquid fertilizer production and distribution *T. P. Hignett, United States of America*	IV
ID/WG.99/26 and Summary	Development of new catalysts for the fixation of nitrogen in the USSR *A. N. Alexeyev, Union of Soviet Socialist Republics*	III
ID/WG.99/27	Role of the Economic Commission for Asia and the Far East in assisting the countries in the development of fertilizer industry *ECAFE*	XIV
ID/WG.99/28 and Summary	Pollution control in acid plants *J. M. Connor, G. J. Dell and D. J. Newman, United States of America*	VIII

Symbol	*Title*	*Chapter of this report*
ID/WG.99/29/Rev.1 and Summary	Establishing a domestic fertilizer industry based on imported phosphoric acid *T. Gans, D. Braude, R. Brosh, P. Shapiro and Z. Itzkovitch, Israel*	VI
ID/WG.99/30 and Summary	Use of computers in fertilizer plant design and in operation of fertilizer plants *J. Saietz, Denmark*	VIII
ID/WG.99/31 and Summary	Production and application of fertilizers with micro-elements in the Ukrainian SSR *P. A. Vlasyuk, Union of Soviet Socialist Republics*	XII
ID/WG.99/32/Rev.1	Electrical energy as raw material *M. Taha Zaky, Egypt*	VII
ID/WG.99/33/Rev.1 and Summary	Phosphate rock: Trends in supply and demand in relation to world fertilizer requirements *K. L. C. Windrige, United Kingdom*	VII
ID/WG.99/34/Rev.1 and Summary	Sulphur: Supply, demand and price forecasts up to 1980 *J. Lastowiecki, Poland*	VII
ID/WG.99/35/Rev.1 and Summary	Trends in potash supply *A. von Peter, Switzerland*	VII
ID/WG.99/36 and Summary	Scientific prediction of likely areas for agrochemical ore prospecting and surveying *A. S. Sokolov, Union of Soviet Socialist Republics*	VII
ID/WG.99/37 and Summary	Production of compound fertilizers from intermediates in local plants *R. D. Young, United States of America*	VI
ID/WG.99/38/Rev.1 and Summary + Summary Corr.1	Role of United Nations Industrial Development Organization in the development of the fertilizer industry *UNIDO*	XIV
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ID/WG.99/41 and Summary	Experience in planning the fertilizer industry in India *V. N. Kasturirangan and M. Satyapal, India*	IX
ID/WG.99/42 and Summary	Production of fertilizers in the USSR *V. M. Borisov, Union of Soviet Socialist Republics*	II
ID/WG.99/43 and Summary	Forecasting production costs for fertilizer processes *J. R. Potter, United Kingdom*	IX
ID/WG.99/44	The preparation of the technical staff and personnel for the fertilizer industry *M. Taha Zaky, Egypt*	X

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ID/WG.99/49 and Summary	Experience with credit for farmers in India *D. C. Datey, India*	XI
ID/WG.99/50 and Summary	Comprehensive marketing: a prerequisite for economic fertilizer production *D. J. Halliday, Italy*	XI
ID/WG.99/51 and Summary	Transportation and storage of fertilizers *Coromandel Fertilizers Limited, India*	XI
ID/WG.99/52 and Summary	Projected requirements for fertilizers, their varieties and means of rationalizing their use, taking into account climatic, soil and other factors *A. V. Sokolov, Union of Soviet Socialist Republics*	XII
ID/WG.99/53 and Summary	Fertilizer control laws and regulations *W. B. Andrews, United States of America*	XI
ID/WG.99/54 and Summary	Use of fertilizers in developing countries *FAO*	XII
ID/WG.99/55 and Summary	Economic aspects of fertilizer use at the national and farm level in developing countries *FAO*	XII
ID/WG.99/56 and Summary	Direct application of anhydrous ammonia and aqua ammonia *W. B. Andrews, United States of America*	XII
ID/WG.99/57 and Summary	Problems in use of nitrate nitrogen in paddy rice culture *T. Hayase, Japan*	XII
ID/WG.99/58 and Summary	Underutilization of potash in agriculture in developing countries *G. Kemmler, Federal Republic of Germany*	XII
ID/WG.99/59 and Summary	Agronomic results from nitrophosphate fertilizers in West Pakistan *A. Wahhab, Italy*	XII
ID/WG.99/60 and Summary	Use of fertilizers in irrigated agriculture in the USSR *I. N. Chumachenko, Union of Soviet Socialist Republics*	XII
ID/WG.99/61 and Summary	Use of fertilizers on non-irrigated soil in the USSR *D. A. Korenkov, Union of Soviet Socialist Republics*	XII
ID/WG.99/62 and Summary	Experience in the use of fertilizers for tea and subtropical crops in the USSR *O. G. Oniani, Union of Soviet Socialist Republics*	XII

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ID/WG.99/63 and Summary	Simulators for training plant personnel *R. E. Buckley, United States of America*	X
ID/WG.99/64/Rev.1 and Summary	Stamicarbon's urea stripping process *J. D. Logemann, Netherlands*	III
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ANNEX III

LIST OF PLANTS VISITED

USSR:

Chemical Fertilizer Complex
Cherkassy, Ukrainian SSR

Institute of Plant Physiology
near Kiev, Ukrainian SSR

Sovietskaya Ukraina Collective Farm
Belaya Tserkov, Ukrainian SSR

Agro-Technical Depot
Belaya Tserkov, Ukrainian SSR

India:

Shriram Chemical Industries
Kota, Rajasthan

Gujarat State Fertilizer Company Ltd
104, Fertilizer Nagar
Baroda, Gujarat

Fertilizer Corporation of India
Trombay Unit
P.O. Chembur
Bombay 74 AS, Maharashtra

Fertilizer Corporation of India
Nangal Unit
P.O.
Naya Nangal, Punjab

Fertilizer Corporation of India
Sindri Unit
P.O. Sindri
Dt. Dhanbad, Bihar

Fertilizer Corporation of India
Durgapur Unit
Durgapur 11, West Bengal

Indian Explosives Ltd
Panki
Kanpur, Uttar Pradesh

Fertilizer and Chemicals Travancore Ltd (FACT)
Udyogamandal
Alwaye, Kerala

Madras Fertilizer Ltd
Manali, Tamil Nadu

Coromandel Fertilizer Ltd
Visakhapatnam, Andhra Pradesh

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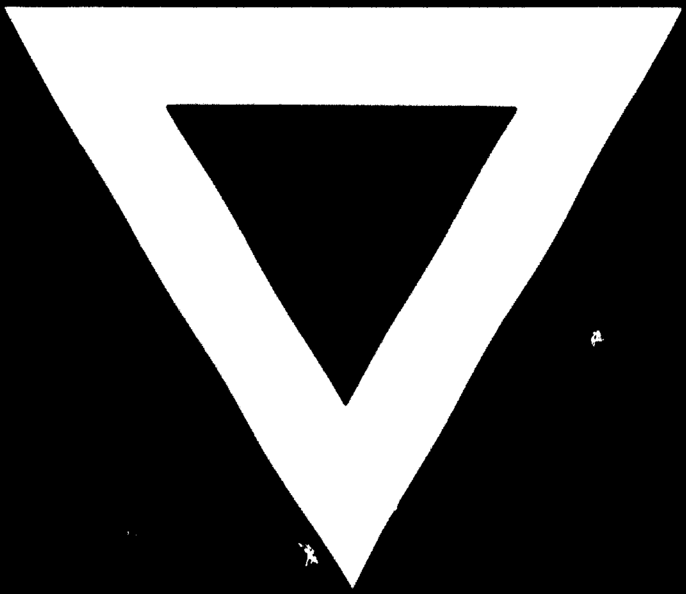

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