OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

This document has been produced without formal United Nations editing. The designations employed and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations Industrial Development Organization (UNIDO) concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries, or its economic system or degree of development. Designations such as "developed", "industrialized" and "developing" are intended for statistical convenience and do not necessarily express a judgment about the stage reached by a particular country or area in the development process. Mention of firm names or commercial products does not constitute an endorsement by UNIDO.

FAIR USE POLICY

Any part of this publication may be quoted and referenced for educational and research purposes without additional permission from UNIDO. However, those who make use of quoting and referencing this publication are requested to follow the Fair Use Policy of giving due credit to UNIDO.

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

D02571

Distribution: LIMITED

ID/WG.99/87
6 August 1971

Original: ENGLISH

United Nations Industrial Development Organization

Second Interregional Fertiliser Symposium

Kiev, USSR, 21 September - 1 October 1971
New Delhi, India, 2 - 13 October 1971

Agenda item IV/8

SATELLITE FERTILIZER PLANTS IN DEVELOPING COUNTRIES[1]

by

Are Naustdal

Norsk Hydro
Oslo Norway

1/ The views and opinions expressed in this paper are those of the author and do not necessarily reflect the views of the secretariat of UNIDO. This document has been reproduced without formal editing.

id.71-6963

Distribution: LIMITED
ID/WG.99/87 SUMMARY
6 July 1971

United Nations Industrial Development Organization

Original: ENGLISH

Second Interregional Fertilizer Symposium
Kiev, USSR, 21 September - 1 October 1971
New Delhi, India, 2 - 13 October 1971

Agenda item IV/8

SUMMARY

SATELLITE FERTILIZER PLANTS IN DEVELOPING COUNTRIES[1]

by
Are Naustdal
Norsk Hydro A.S.
Oslo Norway

The sources for the three basic nutrients in fertilizers are ammonia (hydrocarbons), phosphate rock and potassium salts. They have in common the feature that they are extracted from naturally occurring, large deposits, which are quite limited in number. The deposits and the extractive capacities are generally sized in millions of tons.

The key words characterising trade in fertilizer raw materials are: low prices, large quantities and long distances.

How can we best comply with, and take advantage of this pattern?

Practically all fertilizer nitrogen is derived from ammonia, and practically all ammonia is produced from hydrocarbon feedstock. In some Middle East countries vast quantities of natural gas are available at low cost. As long as this gas continues to be flared, it is beyond doubt that it is the cheapest feedstock available for ammonia production. Many countries could be supplied with ammonia from the Gulf-area at lower cost than it would be possible for them to produce ammonia from naphta or other feedstocks available indigenously.

1/ The views and opinions expressed in this paper are those of the author and do not necessarily reflect the views of the secretariat of UNIDO. This document has been reproduced without formal editing.

id.71-6964

A modern ammonia plant should have a minimum yearly production rate of at least 150,000 tons of NH_3 to operate economically. Many of the smaller countries can only use a fraction of such quantities in their own markets and the nitrogen should therefore be imported, either as ammonia or as a solid nitrogen product such as urea, ammonium nitrate, etc.

Very few phosphate deposits have been found east of the Suez. Most of the phosphate will still have to be imported from North Africa or USA. It has been shown that instead of importing phosphate rock and elemental sulphur, it could be advantageous to import phosphoric acid in the form of 54 per cent P_2O_5 wet process acid, as superphosphoric acid at over 60 per cent P_2O_5 or even as solid NP products such as ammonium-phosphates.

Phosphoric acid plants are less expensive to build per ton of nutrient than ammonia plants, and do not benefit to the same extent from large scale production. Nevertheless there seems to be a trend to build big plants near the ore deposits.

Most of the potassium also comes from large mineral deposits. In some modern mines the production capacities exceed a million tons per year from a single deposit. Investments in the order of 60 - 100 million dollars may be required to extract such large quantities of ore. Most of the potassium is used as produced from the mine or mixed into NP- or P-products. Relatively little is converted into other forms of K-fertilizers such as K_2SO_4 or KNO_3. There should be a case however for the production of potassium-metaphosphate near the phosphoric acid centers. Also other potassium salts from phosphoric acid and potassium chloride could become commercial products. This development would save on transportation costs for sulphur and the useless chloride.

Technical and economic reasons indicate therefore the development of a few centers for the large scale production of raw materials or intermediates for fertilizer production.

For some developing countries a logical development pattern would then be:

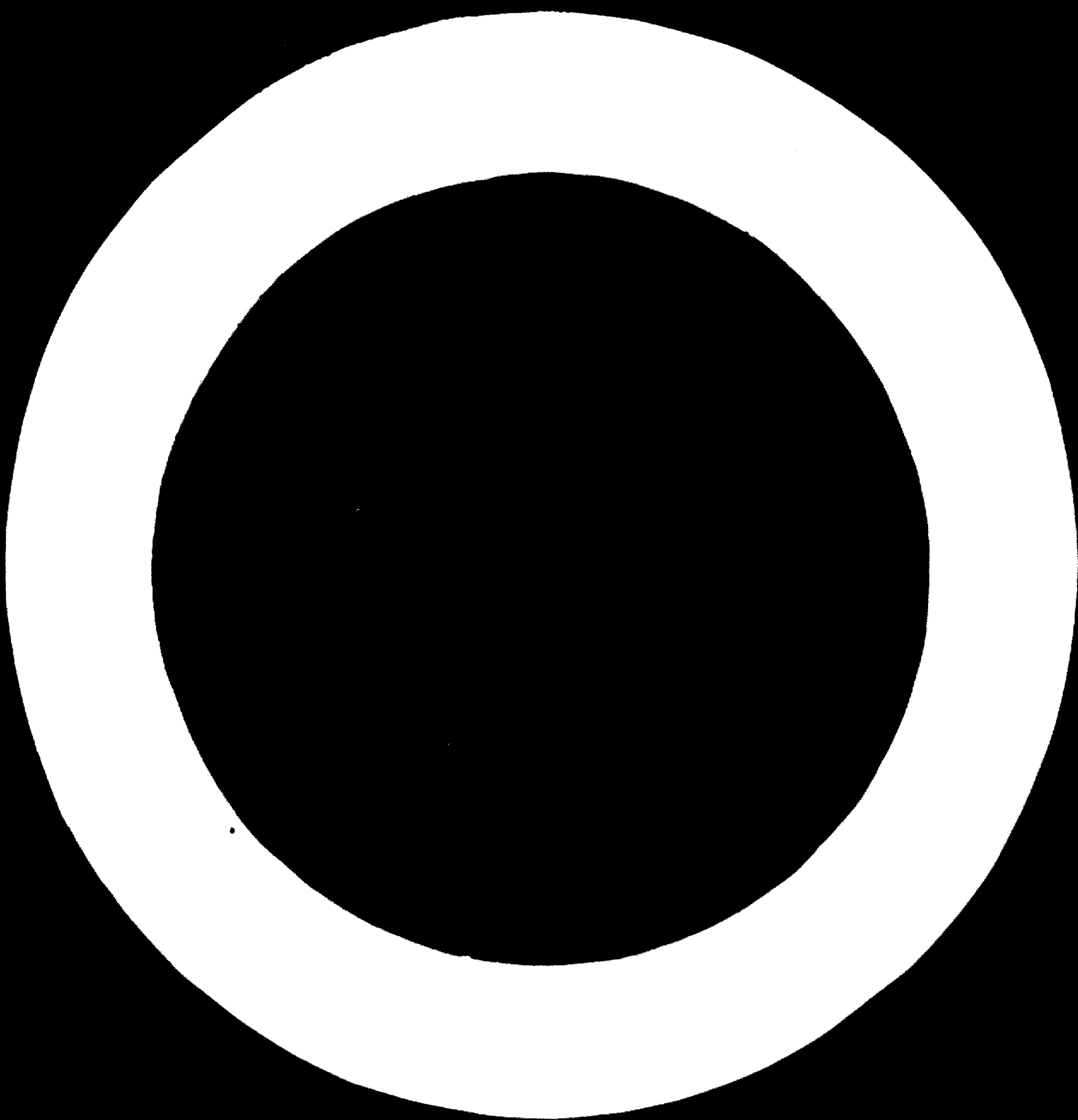
a) import the finished fertilizers until a market is established.

b) build smaller sized plants for mixing of solid imported products to supply a variety of NPK, NP and PK products as the local market may warrant.

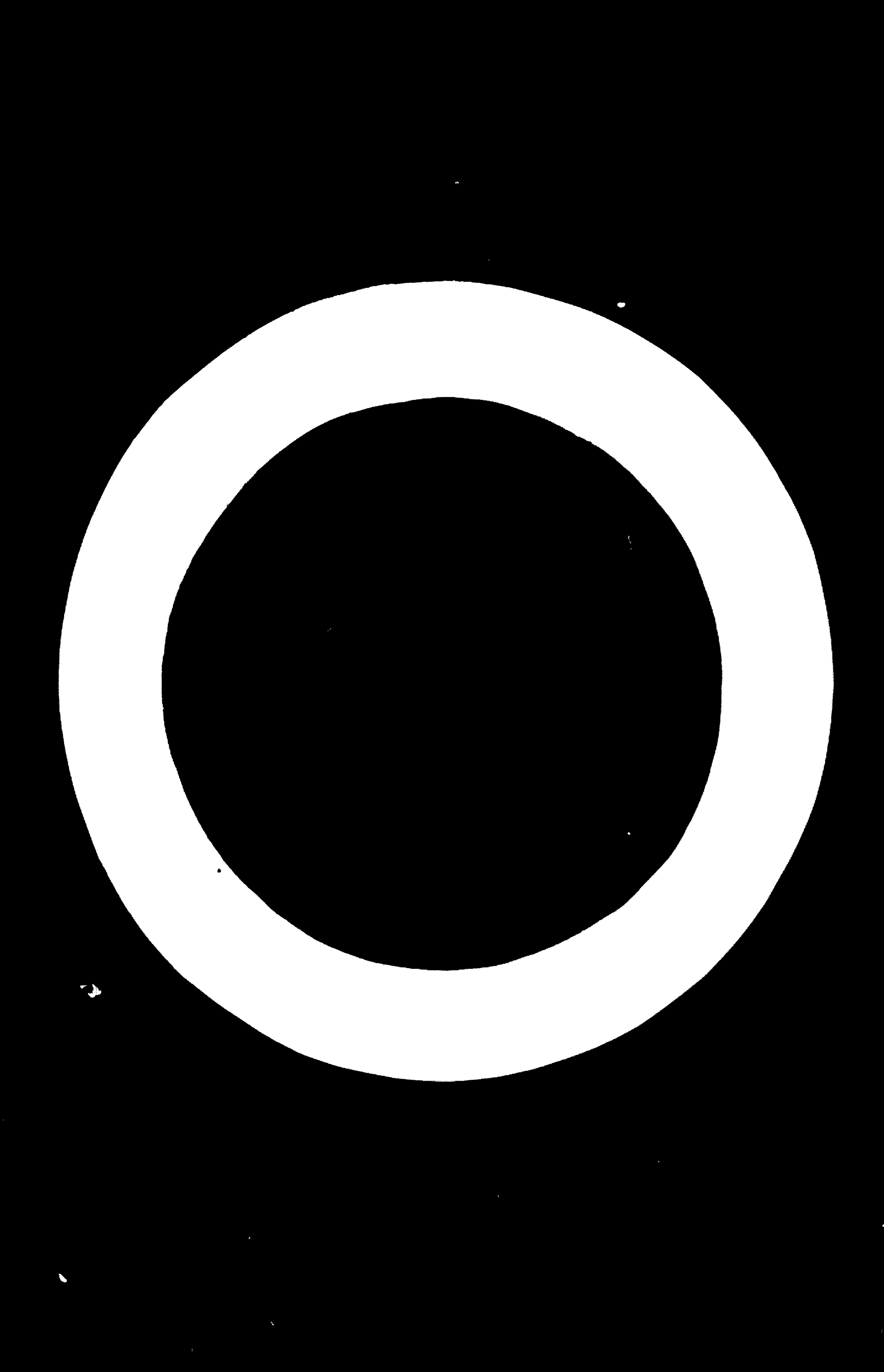
c) build more complex and larger plants based also on liquid intermediates such as phosphoric acid and ammonia.

d) eventually build more sophisticated NPK plants such as modern nitrophosphate plants, which will use phosphate rock instead of phosphoric acid and require no sulphur. Such plants will benefit from a neighbouring ammonia or power plant to supply carbon dioxide.

The plants mentioned under b and c of the above programme could be called down-stream or satellite plants, since they would be tied to larger, remotely located plants for their raw material or intermediate product supply. Such ties could be in the form of long term contracts alone or in combination with part ownership of the mother plants.



CONTENTS



I. INTRODUCTION

1. Vegetations and crops know no national barriers. People are limited in their lives by many barriers of various natures. Many of these barriers are arbitrary and unnecessary.

2. In this paper we shall look at a possible development pattern for fertilizer production, distribution and usage on a world wide scale, but with particular reference to developing countries in the Eastern Hemisphere. This development pattern does not take into account all the man-made limitations such as national boundaries and prestige, tariff barriers, tying of international aid to certain patterns, regional organizations of producers, importers and users. These limitations aim at protecting the respective group interests.

3. It should not be inferred that all these limitations are harmful, unnecessary, or holding back the proper development of mankind. Sometimes, however, it may be well to stop and think about the advisability of our self-imposed restrictions. This may be done by simply disregarding them and then try to see how things would look without these limitations. There is no danger of our forgetting these limits to our freedom, all too often people are forcefully reminded that these boundaries are very real.

4. In short, in this presentation we have considered the world as one technical and economic entity, and tried to find a rational pattern for supplying the correct types and quantities of fertilizers needed.

II. THE PATTERN OFFERED BY NATURE

5. The three basic plant food nutrients in fertilizers are nitrogen, phosphorus and potassium. Other nutrients are required, but will not be discussed. There is however nothing in the following presentation that limits the inclusion of any major or minor nutrient. On the contrary, the suggested development pattern is

well suited for flexibility in composition, distribution and application of any fertilizer combination of practical significance.

6. The origin for the three basic plant nutrients are naturally occurring deposits of hydrocarbons, phosphate rock and potassium chloride. Other sources and methods such as for instance electric power, water and air, are used for production of nitrogen compounds, but these can be disregarded in considering the broad and general picture. However, it should perhaps be mentioned that such special sources and methods may be economically utilized under certain circumstances.

7. These naturally occurring deposits are quite limited in number. They have in common the fact that the deposits, to be economically utilized, are measured in millions of tons and also extractive capacities are often expressed in terms of millions of tons. Let us take a brief look at the situation regarding the three basic nutrients:

a. Nitrogen

8. Practically all fertilizer nitrogen is derived from ammonia, and practically speaking all ammonia is produced from hydrocarbon feedstock.

9. In countries like Iran, Kuwait, Saudi-Arabia, Qatar and others in the Persian-Arabian Gulf-area, vast quantities of natural gas are available at low cost. As long as the major part of this gas continues to be flared off, it is beyond doubt the cheapest feedstock available for ammonia production.

10. It has also been shown (1) that for instance India and many other countries could be supplied with ammonia from the Gulf area at lower cost than it would be possible for them to produce it themselves from naphtha or other feedstocks.

11. A modern ammonia plant should have a daily production rate of at least 600 TPD to operate economically. This corresponds to 150 - 200.000 tons of NH_3 per year.

12. If one assumes a potential application rate of say 4 tons of N per km^2 (40 kg N/ha) of cultivated land, which is somewhat less than the average consumption in Europe (4,3 tons of N per km^2 in the mid-sixties), then an ammonia plant of minimum economic size could supply nitrogen enough for <u>40,000 km^2 of cultivated land</u> (one yearly crop). If one compares this with the data given by UNIDO (2) for 15 East African countries for example, it is seen that only three of these countries have a cultivated land area exceeding 40,000 km^2, namely Ethiopia, the United Republic of Tanzania and Uganda with 250,000 km^2, 94,000 km^2 and 44,000 km^2 of cultivated land area respectively. A 1970 forecast of consumption by the Economic Commission for Africa shows a figure of 15,000 tons of N for Ethiopia in 1980, 21,000 tons of N for Tanzania in 1980 and 27,000 tons of N for Uganda in 1980 (2).

13. It will therefore be clear that even the combined consumption of these three large agricultural areas in the foreseeable future can only amount to a fraction of the output of a modern ammonia plant of minimum economic size.

14. The solution for many developing countries, which do not have cheep natural gas available, is therefore to import the nitrogen either as ammonia or as a solid nitrogen product such as urea. This solution is clearly indicated from the angles of raw material supply, ecomomic production rates and size of domestic markets.

15. Table I gives an overall picture of the effect of plant size on investment and manufacturing costs for ammonia, based on naphtha as feedstock, for some developing countries.

16. If these considerations are disregarded and a developing country proceeds to build an uneconomic ammonia plant, it will be faced with the problems of supporting the production with subsidies or creating customs barriers for shorter or longer periods of times. Sometimes these supposedly temporary periods may be prolonged indefinitely.

<u>b. Phosphorus.</u>

17. The only source of phosphorus of practical significance is

phosphate rock (although in some countries sizeable quantities of phosphates are derived from steel production). Phosphate rock occurs in large deposits frequently amounting to hundreds of million tons of ore. Unfortunately very few deposits have been found in Asia and East Africa. There are only a dozen or so countries exporting large tonnages of rock.

18. It is necessary to digest the phosphate rock with a mineral acid in order to make the phosphorus available for the plants. (For the purposes of this presentation we may disregard possible future production and shipping of elemental phosphorus for fertilizer consumption). The question that arises is whether this digestion should be done at or near the phosphate mines or in the importing, developing country.

19. A modern wet process phosphoric acid plant of minimun economic size would have a capacity of around a 100 TPD P_2O_5. If one assumes that N : P_2O_5 : K_2O is or should be used in the ratio 2 : 1 : 0,6, then the usage of P_2O_5 would be 2 tons of P_2O_5 per km^2 to correspond with the previously assumed 4 tons of N per km^2. The plant would require 15,000 km^2 of cultivated area to operate at full capacity. As an example, at least 9 of the previously considered 15 East African countries should, according to this point of view, be in a position to consider building a phosphoric acid plant. In this respect a phosphoric acid plant differs from an ammonia plant.

20. Looking at the prospects of domestic consumption, however, only one out of the 15 countries will be likely to have a domestic market sufficiently large enough by 1975 to take the production from a phosphoric acid plant of minimum economic size. This country is Rhodesia, which already has a relatively advanced phosphate industry.

21. However, instead of importing phosphate rock for acid production, it has been shown that it may be economically preferable under certain conditions (3) to import the acid, or salts of the acid such as mono- or diammonium phosphates. Ammonium polyphosphates and potassium metaphosphates may in the future also be possible products for import.

22. Even if a phosphoric acid plant of minimum economic size is less expensive to build than an ammonia plant of minimum economic size, there seems to be a trend to build very big phosphoric acid plants near the ore deposits. Plants with capacities up to 1,500 TPD P_2O_5 have been built.

c. Potassium

23. Most of the potassium also comes from large mineral deposits. In modern mines the production capacities may run up to several million tons per year of potassium chloride from a single deposit. Investments in the order of 60 - 100 million dollars may be required to extract such large quantities of ore.

24. Most of the potassium is used in the form of crystalline potassium chloride as produced from the mine, or it is mixed into NP or P products. Relatively little is converted into other forms of K fertilizers such as potassium sulphate (K_2SO_4) or potassium nitrate (KNO_3). There might be a case, however, for the production of potassium metaphosphate near the phosphate rock or phosphoric acid production centres. Also other potassium salts from phosphoric acid and potassium chloride could become commercial products, suitable for bulk shipment over long distances. Such developments would save on transportation costs for sulphur and for the useless (and sometimes even harmful) chloride .

25. To think of starting a potassium chloride plant in a developing country, would have little connection with developing a domestic fertilizer industry. It should be thought of as a separate venture to exploit a naturally occurring resource. With the present over-supply situation, the deposit must be very promising in order for the venture to become profitable.

26. The foregoing indicates therefore the development of relatively few centres for the large scale production of raw materials or intermediates for fertilizer production.

The key words characterizing trade in these raw materials are:

low prices
large quantities
long distances

27. This pattern has emerged partly because nature has arranged it so, and partly because economic and technical forces have been at work making this pattern possible and perhaps also desirable. How can the developing countries comply with, and take advantage of, this pattern?

III. SOME PROBLEMS OF THE DEVELOPING COUNTRIES

28. Let us again by way of example consider the 15 East African countries. Their populations are largely occupied with agriculture, 80 - 90% of the total population in general. The per capita income does not exceed 300$ in any of the countries, and is as little as 50$ in some of them. It is widely recognized that it would be of little use helping only an isolated segment of the national economy. Simultaneous attacks on many sectors seem to be necessary.

29. If a developing country suddenly started to use fertilizers of the correct amounts and types, the increased argicultural production could not be sold, there would not be sufficient buyers and no money to pay for the additional production. Similarly, storage and transport facilities would be lacking. Fertilizers can in reality never be effectively utilized without adequate amounts of water, and in addition better seed varieties and pest control measures would be needed.

30. In order to use fertilizers effectively it is necessary to know what types and amounts to use on the various crops. The first problem is therefore to find this out by field trials and thereafter inform the farmers. But the farmer need money to buy the fertilizers and must have somebody willing to buy his products. In many instances it is belived that cooperatives can be helpful with information, with purchasing and distribution of seeds, fertilizers, and pesticides, as well as with buying, hiring out and maintaining mechanical equipment, and buying, storing and distributing farm products. Farm cooperatives could perhaps operate on credit from the government in the initial phases and with some help from international agencies.

31. The agricultural population will probably decrease very rapidly in the years to come as a result of improved agricultural practices, perhaps from 80 - 90% to 10 - 20% in the course of the next few decades. For this reason not too much attention should be given to this part of the economy. It will be necessary to think of the useful occupation of the people beginning to be released from direct farm operations.

IV. INDUSTRIAL DEVELOPMENT IN GENERAL

32. Since it appears necessary or inevitable that the developing countries will change the economy from the natural household type to the modern industrial and business type of economy, it would be very desirable if some of the drawbacks of "developed" economies and societies could be avoided. Little would be gained if the population just started migrating to new slums in cities, and if pollution, noise and dust made life less pleasant throughout the countries. Developing countries where hunger is not prevalent, should therefore give considerable thought to finding their own ways in their own good time. Planning for the future may easily in itself carry with it the thought or feeling of a necessity for moving very rapidly. If they try to do what is really ten years work in one year, they are well on their way to filling mental hospitals, which they then will have to build and equip.

33. Perpaps the most overriding consideration should be respect for the people's time. The thought that "a man's time" is a commodity that can be bought and sold is a new and unpleasant thought to many of the less "advanced" peoples. The labour should never be thought of as "cheap labour". However, it must be admitted that we are now talking of attitudes and perhaps not so much of the practical steps to be taken. Allow us anyway the final remark that even in the most advanced economic thinking some economists are reconsidering the value of using GNP or GDP as the only or even the best measure of the soundness and progress of the economy.

34. From the foregoing comments it should not be inferred that

the developing countries should be self-sufficient, or that the developed nations should abstain from giving help and advice. In giving help and advice it is necessary to have opinions on the proper way to proceed. Very briefly we will try to summarize some general guidelines for development of the economy as a whole, and then finally suggest a pattern for developing a fertilizer industry which fits these guidelines.

35. As agricultural production increases through extension of knowledge and availability of fertilizers, seeds, pesticides and so on, there will simultaneously arise a need for moving large quantities of goods efficiently. This means providing for highways, waterways, railroads, harbours, warehouses, refrigerated storage facilities and the like. In short it will be necessary for the government in question to take care of

Education
Health
Transport
Public works: Power, water, communications

Whether the industries should be owned and operated by the government or by the "private economy" may be less important than finding the best solutions concerning types of industry, sizes and locations of the plants and so forth. In any case it is necessary that the government cooperates with the industries in planning and supporting them.

36. Industrial plants in general should preferably be:

1. Modern and economic (profitable) from the start.
2. Labour-consuming rather than capital-consuming. (But not so that an over-abundance of "cheap labour" is used to replace capital).
3. Require little supporting industry.
4. A necessary part of the economy, not stray projects.
5. Flexible, so that part of initial investments can be used as industry and plants grow.

37. Industrial plants should preferably not:
   1. Be a hindrance to the next step in the development.
   2. Involve such large investments that a large part of the economy is involved, these projects may later on become heavy burdens on the economy.
   3. Be established to support national or political prestige.

V. THE FERTILIZER INDUSTRY

38. Two overriding considerations for the fertilizer industry in addition to the above comments on industrial planning in general are:
   1. It should be borne in mind that the agricultural population will decrease and that the overwhelming importance of agriculture and feeding the population will diminish as other sectors of the economy develop.
   2. Correct fertilizer use is an absolute requirement in order to obtain a good return on any investment in the fertilizer field.

39. Therefore establishing agricultural schools and universities, training and experimental stations is just as important as building fertilizer plants, and will probably give economic return much sooner. It is necessary to find out what kind and amount of crops should be cultivated, and what types and quantities of fertilizers are needed before establishing fertilizer plants at large expenditure.

a. Suggested steps in building up a fertilizer industry

40. Perhaps it is somewhat superfluous to mention it, but in suggesting a step-wise approach, it has not been the intention to provide a cookery book and cure-all for all developing countries. There is still need for meticulous investigation of each particular situation and plant under consideration. The following steps should be considered:

Step 1. Import of solid fertilizers.

a) In bagged form
b) In bulk form

Step 2. Building of mixing and granulation plants

a) Solid mixing plants
b) Liquids mixing and granulation plants

Step 3. Building of "basic" NPK plants

Nitrophosphate or wet process phosphoric acid routes.

b. Discussion of the suggested development approach

Import steps

41. The import of fertilizers is recommended because it is necessary for establishing recommendations for use, as well as for building up a market and distribution system. In this phase the educational programmes should be implemented. In small quantities bagged fertilizers are easier and simpler to handle than the bulk fertilizers, and require less investment in storage and handling equipment.

42. Bulk import should be considered if it turns out that utilization of particular fertilizer types becomes sufficiently voluminous to warrant this. Generally this would be when ship loads of say over 2 - 3,000 tons could be received. These imports could then be bagged in the importing (developing) country. The bagging and handling operations are generally labour-consuming and require only modest investments. It may give rise for instance to local manufacture of plastic bags. This may be an economic proposition, particularly if bags for agricultural and other products could be produced simultaneously.

43. The bagging and handling in and out of storage are industrial operations which require mechanical equipment and maintenance of this equipment. Only the most modern and labour-saving equipment should be purchased. It is essential that the fertilizers become available to the farmers at the lowest possible prices. Therefore

the importing company should give attention to low-cost handling, storage and distribution.

44. The importing company could be owned by farmers cooperatives or be a private company. In any case, the company should start a customer service program either alone or in cooperation with government authorities or farmers cooperatives.

45. By proper planning much of the investments in these steps could be used in later steps. This would apply to such things as piers, warehouses, unloading and transport equipment, offices, workshops and so on.

<u>Mixing steps</u>

46. In general the trend in fertilizer production world wide is to make available to the farmers complete, tailor-made fertilizers of high concentrations. This saves the farmer the time and trouble of mixing the fertilizers himself and saves time in applying the fertilizers.

47. Very simple and inexpensive plants are required for a solid mixing plant. In the USA a plant for say 5,000 tons/year can be built for 15 - 20,000$. The mixing operations require considerably more skill than the bagging operations. It is necessary to know how the various fertilizers act singly and in all the possible combinations. Not all possible combinations are practical, considering storage and handling properties, or safety aspects. A wide variety of products can be produced in a mixing plant, and the products will be tailor-made for local soils and crops, with inclusion of minor and micro-nutrients such as sulphur, magnesium, copper, boron and others.

48. The mixing plants in the USA operate primarily for the immediate vicinity and the bagging of mixed products is generally not practised. In developing countries it would be necessary to transport the products over long distances, and bagging may be advisable to preserve storage and handling properties, and to avoid too much segregation of the mixed components. Probably the most serious problem in solid mixing operations is the

segregation. There is a need for single fertilizers to be produced in a form suitable for mixing. This they would be if the components were of the same particle size, and preferably also of similar shape.

49. The liquid mixing operation is again a step further in complexity and investments, but has the advantage of using lower cost semifinished materials. The mixing of liquid components will involve chemical reactions, and we have in reality a complete chemical plant with all that this involves, such as liquid storage and pumping, instrumentation for controlling temperatures, pressures, pH and so forth, chemical analysis of products to ensure quality, in short all the basic elements of the chemical process industry. The liquid ingredients may be ammonia or ammoniating solutions and phosphoric acid.

50. In all probability the liquid mixing operation will deliver the product in dried and granulated form. But the possibility of introducing liquid fertilizers remains open with this type of operation, and it is conceivable that liquid mixtures could be economically justified in some instances.

51. Otherwise the liquid mixing operation would be able to utilise many of the installations used for the solids mixing operation, such as workshops, warehouses, offices. None of the skills necessary for the solids mixing operation would become obsolete in the liquid mixing operation, and both operations could be carried out in the same plant.

Basic NPK plants

52. The term "basic NPK plant" is used to indicate that phosphate rock is digested in the plant. The plant would be called basic even if ammonia and/or sulphuric acid were not produced in the plant. If captive production of ammonia and/or nitric acid and/or sulphuric acid were included, the plant would be even "more basic", but we use no special terms for these variations.

53. Basic NPK plants represent the final step in the present state of the fertilizer industry. As previously discussed, basic plants should only be constructed on the basis of an established market and distribution system for the major part of the production.

54. As is shown in table 2, the investment in basic facilities may require something like 10 times the investment required for solids mixing operations per ton of plant nutrient in the product.

55. Table 3 shows the different operations required for the steps considered. It shows the gradually increasing complexity in numbers and types of operations.

56. Table 4 shows skills required in the stepwise development and indicates the increase in skills required through the steps.

57. <u>To summarize</u> the advantages of the suggested fertilizer development pattern:

1) Investments are at kept low at initial levels, requiring only a fraction of what starting out "basic" would cost.
2) Flexibility and contact with markets and users is maintained, so that the fertilizer industry at all times serves the needs of agriculture, and not vice versa.
3) Process routes are not frozen early due to heavy investments in basic plants.
4) Investments in transport facilities, warehouses, workshops, offices, bagging and so forth may to some extent be carried over into later steps.
5) The suggested stepwise development pattern makes maximum use of world resources.

58. The world is getting smaller. This conference reminds us of this. More and more people will come to think of our entire globe as a space ship travelling in the void. Let us not worry too much over this evolution, it is inevitable. Let us rather think and act as if people can and will eventually be able to render each other effective help, if not for any other reason than that it will in the end be <u>necessary</u> not only for the survival of us all, but also because it will make survival appear worth while.

TABLE I

AMMONIA PLANT SIZES, INVESTMENTS AND MANUFACTURING COSTS IN DEVELOPING COUNTRIES*.

Plant size	Investment	Investment per yearly ton	Manufacturing costs	Import cost cif
330,000 TPY 1,000 TPD	30 mill $	90 $	49 $/T	
200,000 TPY 600 TPD	20 mill $	100 $	53 $/T	40-45 $/T
50,000 TPY (150 TPD)	10 mill $	200 $	91 $/T	

*

This table is adapted from a 1969 TVA report (1). The developing countries considered are India (1 000 TPD), South Vietnam (600 TPD) and Uruguay (150 TPD).

Plant investment costs and manufacturing costs based on naphtha at 19 $/MT.

It is believed that the table gives a reasonable over-all picture. However, investment costs may today be higher, whereas ammonia probably could be imported at lower prices than indicated.

TABLE II

INVESTMENTS FOR MINIMUM ECONOMIC PLANT SIZES.

Type of plant	Minimum economic plant size	Investment	Investment per yearly ton of nutrient
Ammonia	600 TPD NH_3	20 mill $	120 $/ton N
Urea	200 TPD Urea	6 mill $	200 $/ton N
Phosphoric acid	100 TPD P_2O_5	5 mill $	150 $/ton P_2O_5
Potassium chloride	1000 TPD Kcl	30 mill $	170 $/ton K_2O
Solid mix NPK	5000 TPY	20.000 $	10 $/ton of $N + P_2O_5 + K_2O$

TABLE III

OPERATIONS REQUIRED IN SUGGESTED PROGRAM.

Operations	Import		Solid Mixing	Liquid Mixing	Basic NPK
	Bagged	Bulk			
1) Unloading	*	*	*	*	*
2) Dry Storage	*	*	*	*	*
3) Liquid Storage				*	*
4) Pumping				*	*
5) Weighing		*	*	*	*
6) Prescription Formulating			*	*	*
7) Dry Mix.			*	*	*
8) Liquid Mix.				*	*
9) Chem. Reactions & Control				*	*
10) Drying				*	*
11) Screening				*	*
12) Crushing				*	*
13) Dust Collection			*	*	*
14) Waste Control			*	*	*
15) Bagging		*	*	*	*
16) Finished Storage	*	*	*	*	*
17) Distribution	*	*	*	*	*
18) Transport	*	*	*	*	*
19) Utilization (Customer Service)	*	*	*	*	*

TABLE IV

SKILLS REQUIRED IN SUGGESTED PROGRAM.

Basic Skills needed * some ** considerable	Import Bagged	 Bulk	Solid Mixing	Liquid Mixing	Basic NPK
Commercial skills:					
Buying & Expediting	*	*	*	**	**
Budgeting, Accounting etc.	*	*	*	**	**
Shipping	*	*	*	**	**
Marketing	*	**	**	**	**
Technical skills:					
Mechanical Eng.	*	*	**	**	**
Electrical Eng.		*	**	**	**
Civil Eng.	*	**	**	**	**
Chem. Eng.				*	**
Know how:					
Local markets	*	*	**	**	**
Customer needs	*	*	**	**	**
Agricultural expertise	*	*	**	**	**

VII. REFERENCES

1. Economic Comparison of Overseas Manufacture and Importation of Anhydrous Ammonia. G.G. Patterson, J.K. Metcalfe and J.R. Douglas. Tennessee Valley Authority. March 1970.

2. Directory of Fertilizer Production Facilities. Part 1. Africa. UNIDO 1970.

3. Economic Evaluation of Overseas Shipment and Utilization of Phosphoric Acid for Fertilizer Production. D.A. Waitzman, N.L. Spencer and M.A. Tchantre. Tennessee Valley Authority. 1968.

23. 6. 72