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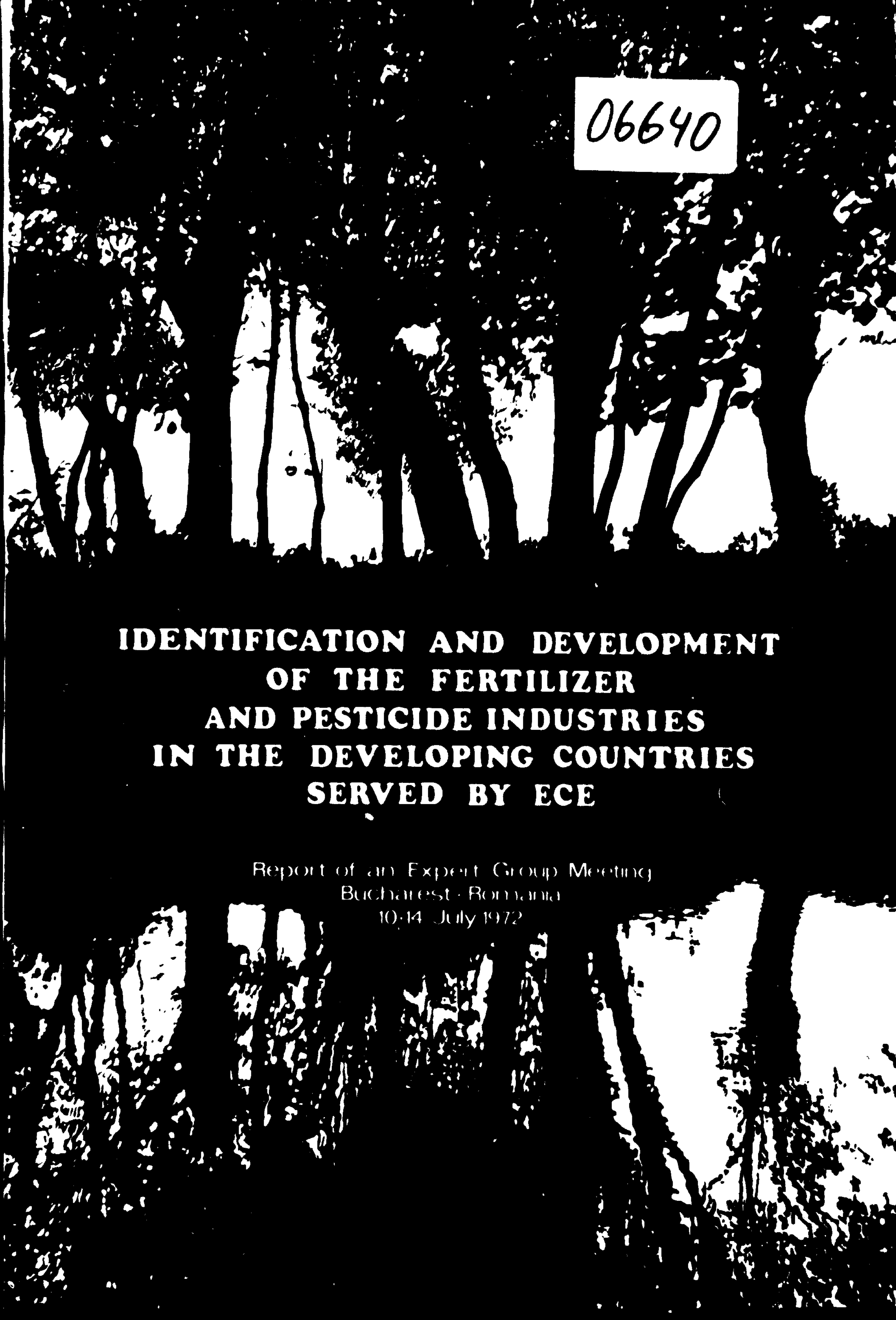
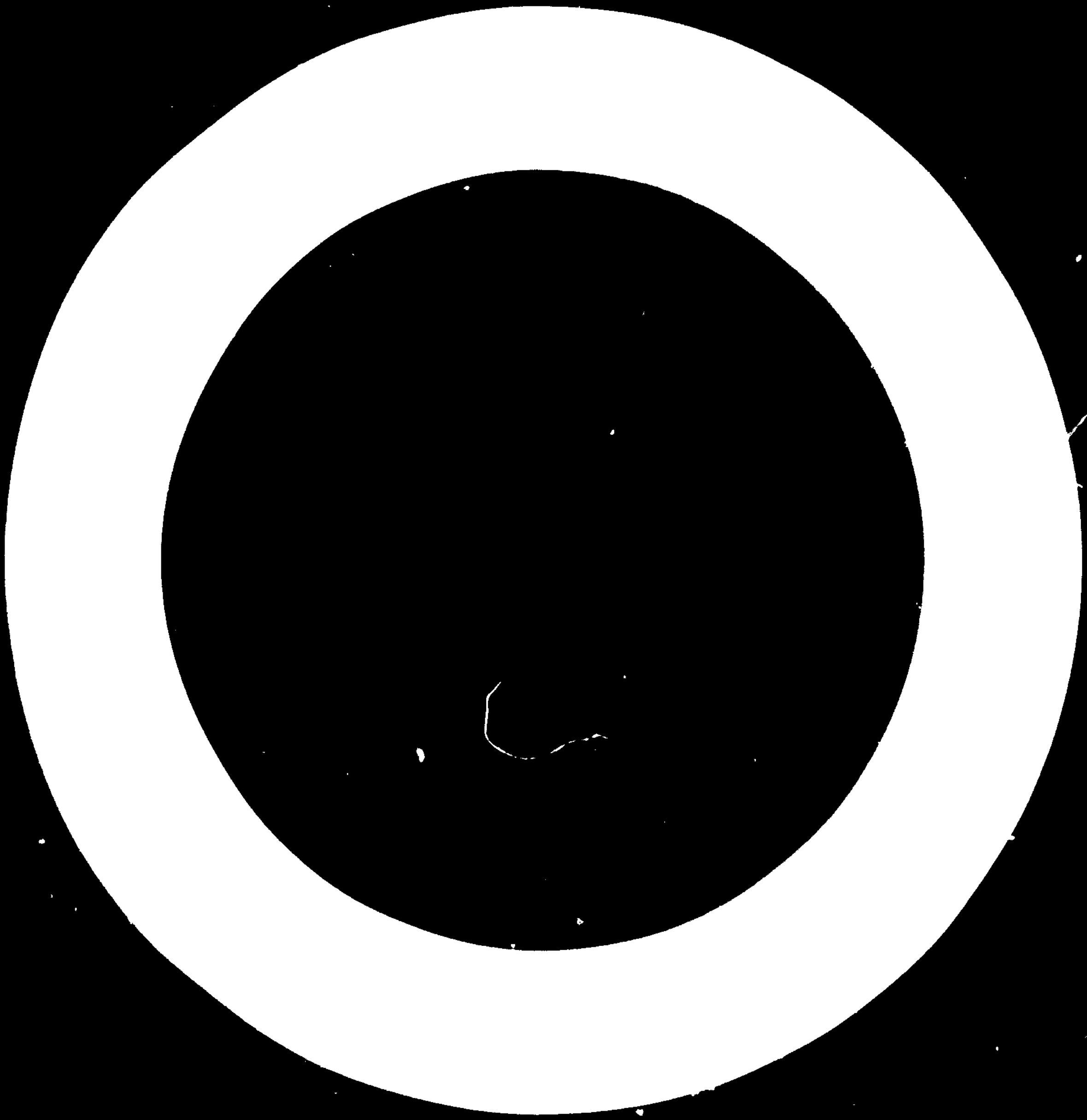


IDENTIFICATION AND DEVELOPMENT OF THE FERTILIZER AND PESTICIDE INDUSTRIES IN THE DEVELOPING COUNTRIES SERVED BY ECE

Report of an Expert Group Meeting
Bucharest - Romania
10-14 July 1972



UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
VIENNA

IDENTIFICATION AND DEVELOPMENT OF THE FERTILIZER AND PESTICIDE INDUSTRIES IN THE DEVELOPING COUNTRIES SERVED BY ECE.

Report
of an Expert Group Meeting
organized by the
JOINT UNIDO/ROMANIA CENTRE,
~~for~~ International Co-operation in the Chemical
~~and~~ Petrochemical Industries for the Benefit of ~~the~~
Developing Countries,
BUCHAREST, ROMANIA,
10—14 July 1972,

EXPLANATORY NOTE

The Expert Group Meeting on the Identification and Development of the Fertilizer and Pesticide Industries in the Developing Countries Served by ECE, organized by the Joint UNIDO/Romania Centre for International Co-operation in the Chemical and Petrochemical Industries for the Benefit of the Developing Countries, was held at Bucharest from 10 to 14 July 1972. This report of the meeting, comprising an account of the discussions and the technical papers submitted to the meeting, is issued by the United Nations Industrial Development Organization as an internal document. The papers are reproduced in the form in which they were received ; only typographical errors and errors of fact or terminology have been corrected. The report was printed in Romania with the assistance of the Joint Centre. The United Nations Industrial Development Organization expresses its appreciation to the Centre for its co-operation in the issue of this document.

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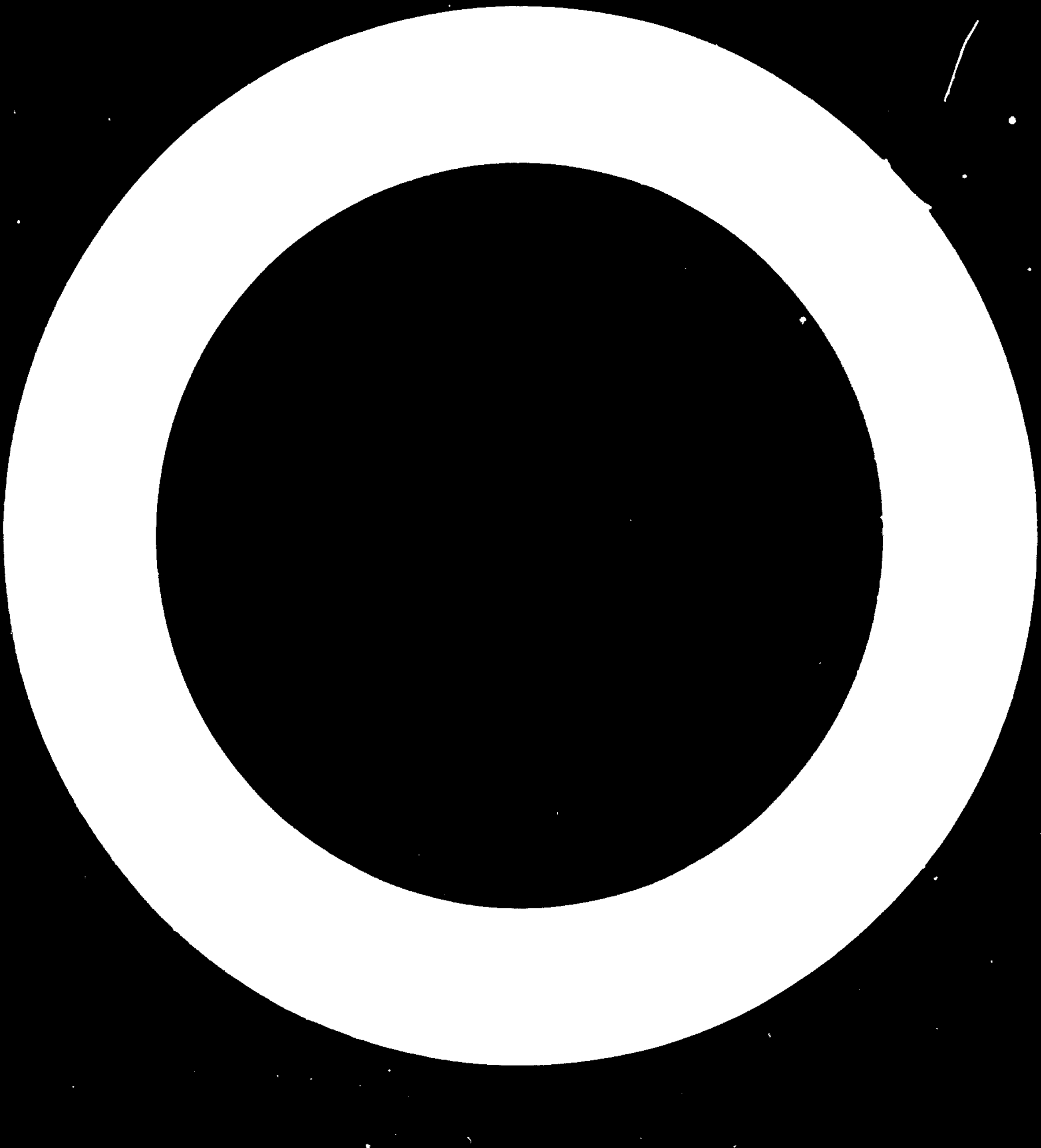


Part one

REPORT OF THE MEETING

I. ORGANIZATION OF THE MEETING

The technical and economic problems of the fertilizer and pesticide industries in the developing countries of Europe were discussed at a meeting held at Bucharest, Romania, from 10 to 14 July 1972. Organized by the United Nations Industrial Development Organization (UNIDO) in co-operation with the Economic Commission for Europe (ECE) and the Government of Romania, the Meeting was held under the auspices of the Joint UNIDO/Romania Centre for Co-operation in the Field of Chemical and Petrochemical Industries for the Developing Countries.

The main objectives of the Meeting were

To identify problems related to the production and use of fertilizers and pesticides in the developing countries served by ECE ;

To provide guidelines for the future work programme of UNIDO in this field.

Additional objectives were

To promote co-operation and encourage joint projects between the developing countries and between these and developed countries in the production of fertilizers and pesticides ;

To provide a forum for exchange of experiences in the manufacture of fertilizers and pesticides, particularly as related to problems of production technology, quality control, personnel training and environmental pollution

C. Keleti acted as Officer-in-Charge of the Meeting and K. Szabo as Technical Secretary. From the Romanian side of the Joint Centre and of the organizing committee, A. Lungu was the counterpart officer, V. Ioniţă was the liaison officer and M. Anghelescu was the administrative officer.

C. Hera and A. Constantinescu of Romania were elected Chairman and Vice Chairman respectively, and P. Markou of Cyprus and E. C. Little of the Food and Agriculture Organization of the United Nations (FAO) were elected Rapporteurs for the fertilizer and pesticide sections, respectively.

The inaugural address was given by the Romanian Deputy Minister for the Chemical Industry, Nicolae Ionescu. C. Keleti red a message from the Executive Director of UNIDO, I. H. Abdel-Rahman; A. Rotival, Resident Representative of the United Nations Development Programme (UNDP) in Romania, greeted the delegates, and C. Keleti presented the over-all programme for the Meeting.

There were 52 participants from 12 countries and 2 from FAO : 18 experts from 10 countries (Bulgaria, Cyprus, Hungary, Italy, Malta, Poland, Romania, Turkey, United States of America and Yugoslavia) and 1 from FAO ; 34 observers from 6 countries (Federal Republic of Germany, Hungary, Norway, Poland, Romania and United Kingdom of Great Britain and Northern Ireland) and 1 from FAO.

[illegible] papers and country reports were presented and discussed. There were also field trips to the Craiova Chemical Complex and the Fundulea Agricultural Research Institute.

The Meeting achieved its objectives: several countries defined specific sectors in which they could offer help to others or in which they needed assistance.

The various suggestions made on the questionnaire forms distributed at the Meeting are incorporated in Chapter III Conclusions and recommendations.

The Meeting closed with summary speeches and messages of thanks [illegible] A. [illegible], C. Kelet and C. Hera.

II. FIELD TRIPS

A. Visit to the Craiova Chemical Complex

The host country, Romania, arranged a trip to Craiova to visit the complex of chemical plants there.

The group of 31 participants was received by O. Popa, technical director of the complex. After a brief description of the plants to be visited, Mr. Popa invited questions from the participants.

The plants were then inspected; they included:

A 600 tons per day ammonia plant based on technology developed by the State Institute for the Nitrogen Industry (GIAP, Union of Soviet Socialist Republics), which uses oxygen reforming at atmospheric pressure, and a 925 tons per day ammonia plant, using the Imperial Chemical Industries (ICI) reforming process, delivered by Sybetra — (Belgium) as general contractor and licensed by Humphreys and Glasgow (United Kingdom of Great Britain and Northern Ireland). A project to install computer control in this plant is being studied. The raw material for both plants is natural gas.

An urea plant using CO_2 and NH_3 from an ammonia plant as raw materials. This plant was also delivered by Sybetra and is based on the Stamicarbon technology, but with licence and engineering from Evence Coppee-Rust of Belgium. The plant is producing urea with a biuret content of 0.7 to 0.9 per cent.

A nitric acid plant with a capacity of 750 tons per day (as 100 per cent HNO_3) also supplied by Sybetra, using Grande Paroisse technology with medium-pressure conversion and high-pressure absorption (Escher-Wyss compressor). The concentration of the nitric acid produced is 56 per cent. There is another, older plant (built in 1963) which uses technology from the Union of Soviet Socialist Republics and has a capacity of about 750 tons per day. This plant produces acid at 49 per cent concentration and operates at a pressure of 2.5 atm throughout.

An ammonium nitrate plant with capacity of 900 tons per day supplied by Sybetra, using Kaltenbach technology. The bagging and finished-product handling section was inspected. The ammonium nitrate was not coated before bagging. Apparently coating is done at the distribution end. There is also a plant built in 1963 according to GIAP technology, with a capacity of 900 tons per day.

The Craiova Complex employs about 6,000 people. It is very well maintained and operates under strict technical control. The new nitrogen fertilizer plants are up-to-date as any others in the world.

Management is attending to the pollution problems created by the fertilizer plant. Solutions to the problems of atmosphere pollution by dust from the ammonium nitrate plant and nitrogen oxides from the old nitric acid plant are under investigation. The new Grande Paroisse nitric acid plant operates with a vent gas containing 200 ppm nitrogen oxides and 2.5 per cent oxygen. This emission level, averaged over continuous operation would be acceptable anywhere in the world. It is apparently obtained without catalytic fume abatement systems.

The Craiova Complex can also produce prilled calcium ammonium nitrate with a concentration of 24–26 per cent N.

Construction has begun on a 2 700 tons per day NPK fertilizer prilling plant using Norsk Hydro technology.

B. Visit to the Fundulea Agricultural Research Institute

The Fundulea Agricultural Research Institute, the largest of the 18 agricultural and forestry research institutes in Romania, was visited during the Meeting by a group of seven participants. The staff of about 330 scientists, 60 of whom are Ph.D.s, investigate the genetics, agrotechniques, biochemistry and biology of cereals and industrial crops. These crops comprise about 85 per cent of the country's agricultural production.

The Institute has a distinguished scientific history marked by such achievements as the development of the first simple sunflower hybrid with high oil content and good resistance to mildew, and the breeding of Helminthosporium-resistant corn seed for the United States of America.

A new modern building for the Institute, to which FAO is contributing staff and equipment worth $ 2 million, is now under construction.

While the Institute takes an integrated approach to the problem of crop protection, chemical control receives top priority.

The visitors had an excellent opportunity to learn about the current programme of the chemistry and biochemistry departments. The small-plot herbicide tests on sunflowers and field corn, which aim at minimum tillage, were particularly interesting.

III. CONCLUSIONS AND RECOMMENDATIONS

1. The papers presented and the discussions generated by them provided a useful survey of the status of fertilizer and pesticide consumption, production and problems in the countries represented.

It is therefore recommended

a) That the papers presented at the meeting should be published and made available to all participants in their home countries as quickly as possible ;

b) That more meetings of this kind should be organized by UNIDO to provide for a regular exchange of ideas ;

c) That manufacturing and contract engineering companies should be encouraged by UNIDO to participate in such meetings ;

d) That similar meetings should be held biennially in future ;

e) That as far as possible, copies of papers to be presented at future meetings should be sent to participants well in advance, so that questions can be presented to the author early enough for him to prepare answers ;

f) That detailed papers should be presented in summary form to allow more time for productive discussion.

2. Each country was represented by separate delegations for the fertilizer and pesticide industries.

It is therefore recommended :

That the proceedings of the fertilizer and pesticide sections should run concurrently.

3. Data on fertilizer production and consumption were at times presented in the form of total tonnage of nutrients : $N + P_2O_5 + K_2O$.

It is therefore recommended :

That, at future meetings, fertilizer statistics should specify the nutrients N, P_2O_5 and K_2O separately.

4. Bulk distribution of fertilizers is expected to become increasingly mandatory, mainly because of the need to reduce agricultural manpower requirements in the coming years.

It is therefore recommended :

That, as soon as possible, UNIDO should study the bulk handling and distribution of fertilizers, at the same time taking into account the existence of small farms in some countries.

5. Some countries find it difficult to obtain supplies of raw materials and intermediates for their manufacturing industries.

It is therefore recommended :

That UNIDO should (a) collect information on the supply of raw materials and intermediates for the fertilizer and pesticide industries and (b) encourage joint ventures.

6. The disposal of waste gypsum is an important and growing problem.

It is therefore recommended :

That as a matter of urgency UNIDO should collect information on techniques for using gypsum as a sulphur source or in the manufacture of plaster board and on the economics of these techniques.

7. The caking of fertilizers is still a problem.

It is therefore recommended

That UNIDO should initiate a search for new anti-caking agents.

8. The agricultural application of micronutrients such as zinc, magnesium, manganese and boron is becoming increasingly necessary

It is therefore recommended

That UNIDO should initiate studies on effective methods for the incorporation of micronutrients into fertilizers.

9. The use of liquid fertilizers, including anhydrous ammonia, is of growing importance

It is therefore recommended

That UNIDO should arrange for an early meeting to study in detail problems connected with the use of liquid fertilizers.

10. A variety of different methods are now being used for the analysis of fertilizers and pesticides and for the determination of pesticide residues

It is therefore recommended

That UNIDO should assist in (a) standardizing analytical methods, (b) surveying the types of analytical instruments available and (c) training personnel in modern analytical techniques.

11. Several countries already at a certain stage of development could contribute from their own experience to help with the development of fertilizer production in other countries.

It is therefore recommended :

a) That countries should periodically inform the Joint UNIDO/Romania Centre, via UNIDO, of (I) new solutions to problems and (II) problems in which they still need technical assistance ;

b) That the Joint UNIDO/Romania Centre should act as a clearing-house by organizing meetings on specific subjects of interest to both developed and developing countries ;

c) That the Joint UNIDO/Romania Centre should promote feasibility studies and technical assistance in the formulation of recommendations for the development of national fertilizer industries ;

d) That the Joint UNIDO/Romania Centre should provide facilities for technical training of staff from interested developing countries in Romanian fertilizer plants.

12. Developing countries with limited local demand cannot afford to build a separate plant for each basic pesticide they need.

It is therefore recommended :

That UNIDO should study the feasibility of designing versatile multi-purpose pesticide plants.

13. The art of pesticide formulation is highly proprietary, and little published information on its principles and techniques is available.

It is therefore recommended :

a) That publication of the forthcoming UNIDO book on in-plant training programmes on the principles of formulation and production of pesticides in developing countries should be expedited ;

b) That UNIDO should convene a working group that brings together industrial representatives of both developed and developing countries to deal with this problem on a bilateral basis and to develop guidelines for more efficient operation in the mutual interest of both parties ;

c) That UNIDO should investigate the possibility of setting up a research and development centre to serve member countries in the solution of their research, manufacturing and training problems in pesticide formulation and application.

14. There is a growing public awareness of the environmental pollution that can be caused by the fertilizer and pesticide industries.

It is therefore recommended :

a) That efforts to prevent such pollution should be intensified ;

b) That UNIDO should study technological improvements in manufacture and packaging that can result in the reduction of industrial pollution. (It is good news that UNIDO has already started to plan a conference on this important subject).

15. Problems related to the use of pesticides, particularly hazards to the user and the persistence of harmful residues, have become quite important.

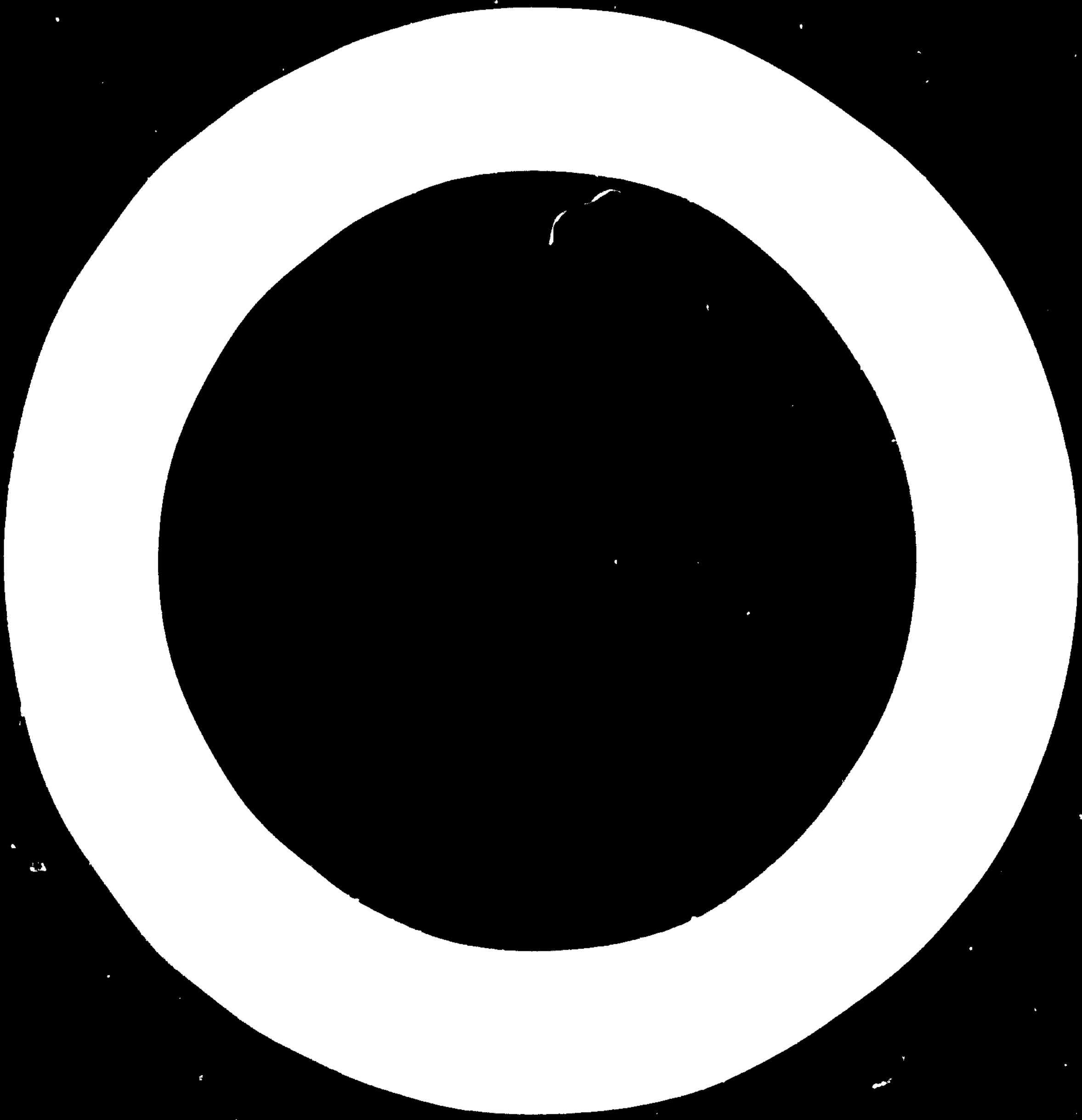
It is therefore recommended :

That UNIDO should solicit FAO and other interested bodies to establish without delay a research and co-ordinating centre which would undertake the following activities :

a) Study of compounds such as benzene hexachloride which are no longer covered by patents but are used in developing countries ;

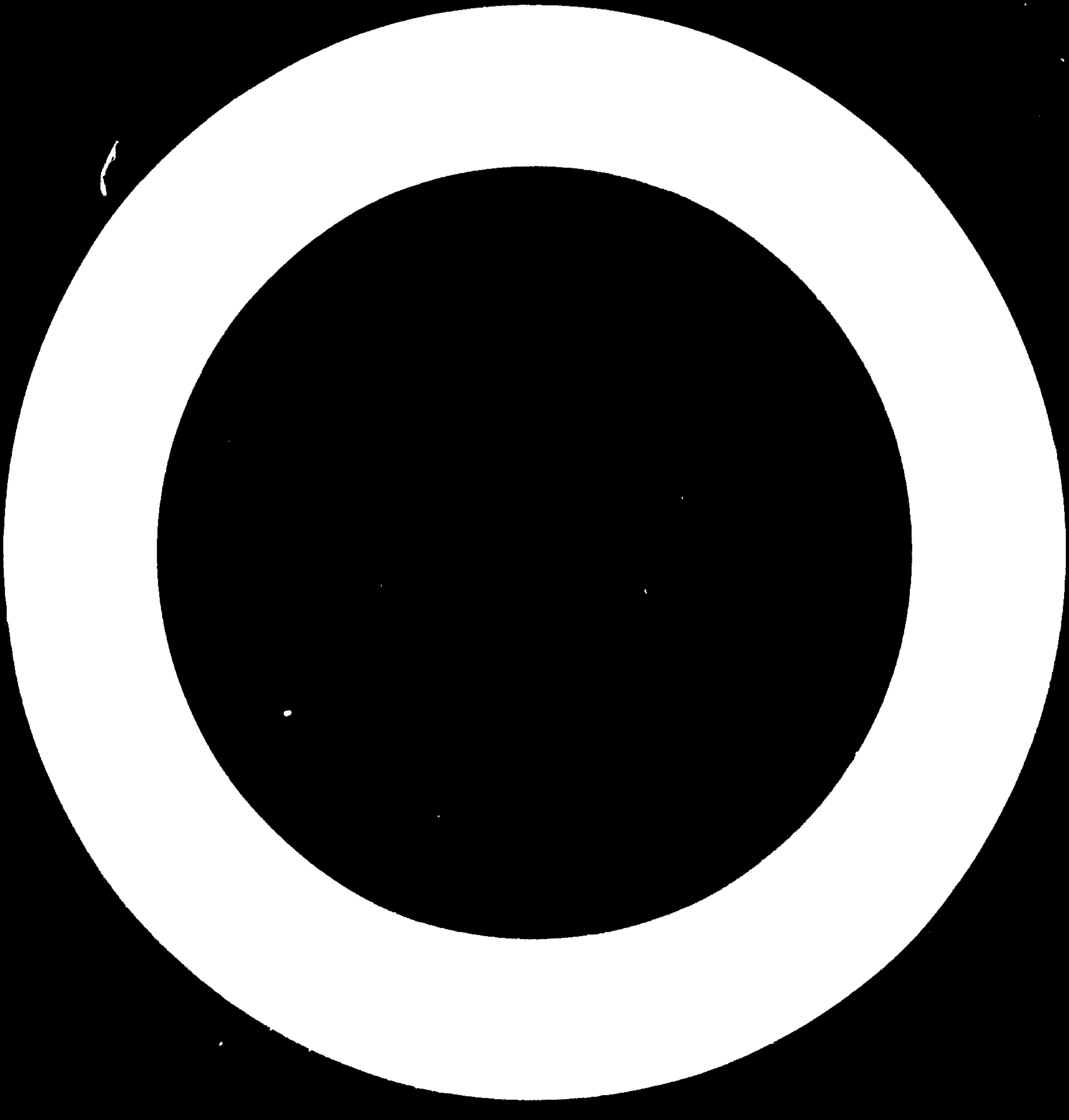
b) Investigation of chemical-technical problems related to the production of narrow-spectrum insecticides ;

c) Investigation of problems related to environmental pollution by agricultural chemicals and the occurrence of their residues in food.



Part two

PAPERS RELATING TO THE FERTILIZER INDUSTRY



IV. PAPERS SUBMITTED BY CONSULTANTS

TRENDS IN FERTILIZER PRODUCTION

Travis P. Hignett *)

The purpose of this paper is to examine current trends in fertilizer manufacturing, to analyse the reasons for these trends, and to project them into the future.

Increased use of fertilizer

The use of fertilizer has increased sharply in recent years. Figure I shows that world consumption of the three major nutrients (N + P_2O_5 + K_2O) reached 68 million tons in 1971, approximately double the amount consumed eight years before, and triple the amount consumed 14 years ago. In other words, more fertilizer tonnage were added in the last eight years than in all previous history, a trend that obviously cannot continue indefinitely. The use of nitrogen has increased more rapidly than that of the other elements ; it was doubled in the past six years and quadrupled in the past 14. The largest tonnage increases have been in the developed regions of Europe and North America, but the percentage increases have been greatest in the less developed regions of Africa, Asia and Latin America.

The latest projection of fertilizer consumption made by the Tennessee Valley Authority (TVA) (figure I) indicates that total consumption of the three major nutrients will reach 86 million tons in 1975 and 105 million tons in 1980.

The principal reason for the increased use of fertilizer is the need for more and better food for the world's growing population. A low to medium level of crop production can be maintained with little or no fertilizer by utilizing the native fertility of the soil, by returning crop residues and wastes, and by utilizing the small amount of nitrogen brought down with rainfall or fixed by legumes. Such levels of crop production, however, are no longer adequate to feed the growing population of the world.

A second reason for the increase in the use of fertilizer is one of economics. In contrast to the rising cost of labour and machinery, fertilizer costs in most countries have declined. Even in countries that have a surplus of food crops, farmers cannot afford to neglect the advantages of substantial fertilizer application. In the past, many farmers relied on growing legumes in a crop rotation to supply nitrogen, a sound practice when chemical nitrogen fertilizers were expensive and labour was cheap. The practice has now become uneconomical in many areas.

The latest TVA projection of fertilizer consumption indicates a slower rate of growth that its previous forecast [1], particularly in the developing countries of Africa, Asia and Latin America. Numerous problems are

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*) Director of Chemical Development, Tennessee Valley Authority, Muscle Shoals, Alabama, United States of America.

slowing the growth rate in these areas. Production facilities in some countries have operated at only about 60 per cent capacity, resulting in high production costs. Marketing and transportation of increased quantities of fertilizer have been difficult. High fertilizer costs in some countries and low prices for farm products have provided little incentive for

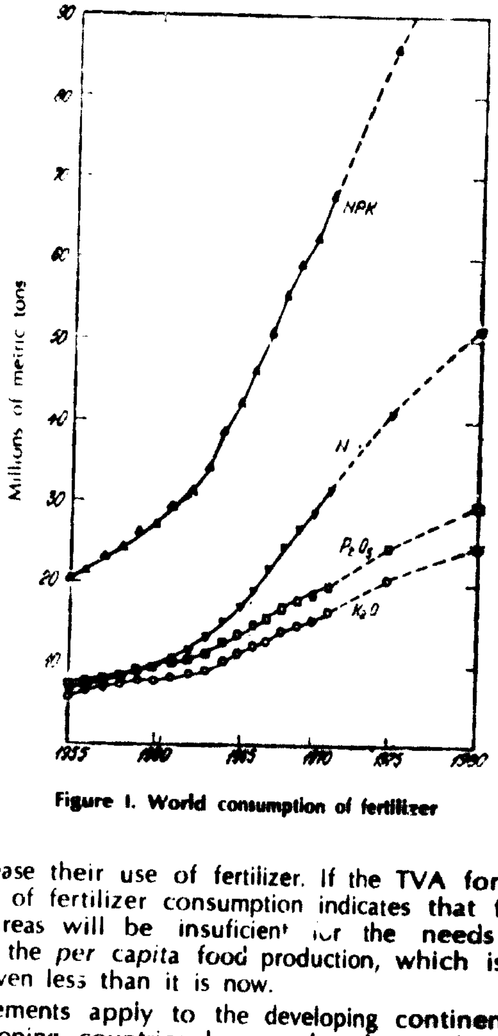

Figure I. World consumption of fertilizer

farmers to increase their use of fertilizer. If the TVA forecast is correct, the growth rate of fertilizer consumption indicates that food production in developing areas will be insuficient for the needs of the rising population, and the *per capita* food production, which is already inadequate, will be even less than it is now.

These statements apply to the developing continents as a whole, but some developing countries have made substantial progress towards improving the quantity and quality of their food supplies.

In the developed countries the rate of population growth has declined and the *per capita* food production has increased to the point that surpluses exist in several areas. This condition will tend to slow the growth of fertilizer use in such areas.

Concentration

An important trend in fertilizer technology is increase in concentration of N, P_2O_5, and K_2O. Figure II shows this trend for four countries where the concentration of compound fertilizers *) increased at rates ranging from 0.7 to 1 per cent per year during the last decade. Of the four countries, the United Kingdom of Great Britain and Northern

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*) The term "compound fertilizer" as used in this paper applies to all fertilizer containing more than one of the three primary nutrients, N, P_2O_5 and K_2O.

Ireland has attained the highest average concentration, nearly 42 per cent, while Japan shows the greatest rate of increase. The economics involved in fertilizer technology has brought about this trend. As bagging, storage, handling, and transportation often account for more that half of the cost of fertilizer delivered to the farmer, increa[illegible] [illegible]entration can markedly decrease the cost per [illegible]nit of nutrient content at the farm.

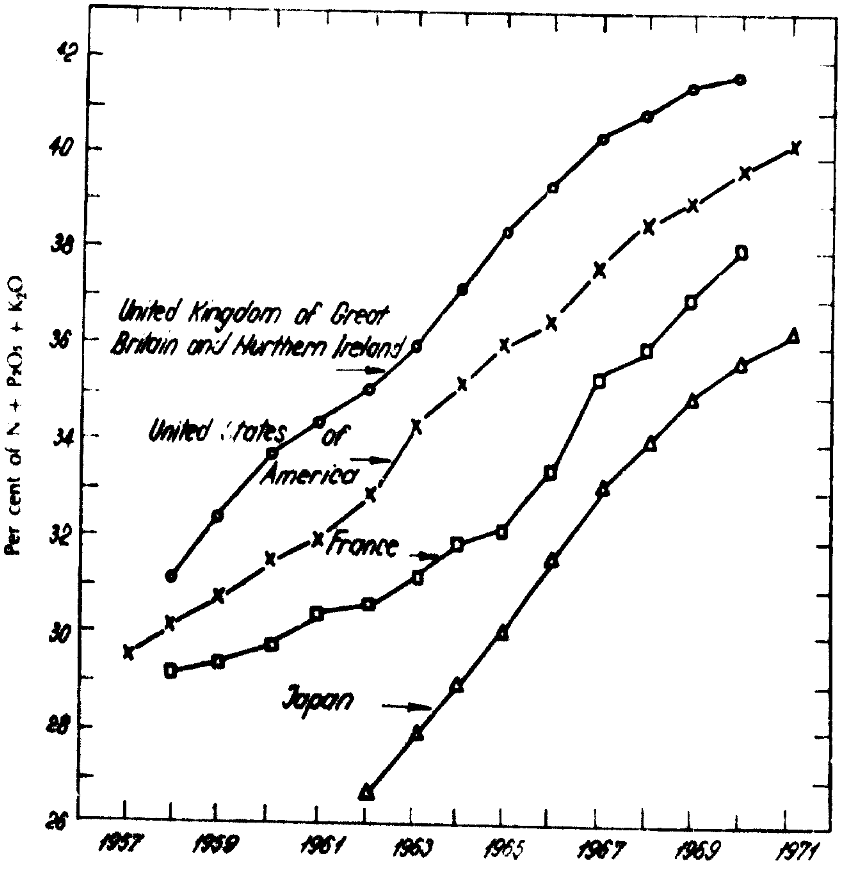

Figure II. Trends in concentration of compound fertilizers

Although precise data are lacking for many developing countries, the trend towards high concentration is evident in the increased emphasis on higher analysis materials. For instance, in the Republic of Korea, diammonium phosphate is granulated with potassium chloride to produce a 14—34—14 grade, which is blended with urea to make a variety of grades; 22—22—11 is typical. In India some new plants produce urea-ammonium phosphate compound fertilizers containing more than 50 per cent nutrients.

In the next decade the concentration of fertilizers will continue to increase and may reach an average (by weight) of 50 per cent in some countries. Planned facilities indicate that urea and diammonium phosphate will be favorite materials, with these materials and high-grade potassium chloride, compound fertilizers containing nearly 60 per cent N + P_2O_5 + K_2O are possible. However, a growing realization of the frequent importance of including secondary and micro-nutrient elements in fertilizers may slow the growth in concentration of the primary elements. Also, lower analysis materials are likely to be more economical for use in some areas.

Trend towards compound fertilizers

Another anticipated trend is towards greater use of compound fertilizers. Compound fertilizers have always been popular in the United States of America but in many European countries and in Japan straight fertilizers have been more popular. During the period 1958 to 1968, compound fertilizers in Western Europe increased from 35 to 52 per cent of all fertilizers. In Japan the increase was from 56 per cent in 1962 to [illegible] per cent in 1969. In the United Kingdom, 97 per cent of the P_2O_5 (other than basic slag), 92 per cent of the K_2O, and 63 per cent of the N are supplied in compound fertilizers. Comparable figures are not available for the United States partly because some of the materials sold as straight fertilizers are actually compounds or are subsequently mixed by blenders to form compounds. A rough estimate indicates that in 1963, 35 per cent of the N, 87 per cent of the P_2O_5, and 86 per cent of the K_2O were supplied to the farmer in compound fertilizers.

The increase in the use of compound fertilizers has occurred because farmers no longer have the time or inclination to apply several fertilizers separately, nor do they have the equipment to mix them. Supplemental dressings of nitrogen are often applied separately for economy reasons, but the preferred basic application is a compound fertilizer.

Larger factories

Another predictable trend is the concentration of manufacturing operations in large factories. Plants geared to turn out 1,000 or more tons per day of ammonia, urea, ammonium nitrate, phosphoric acid, ammonium phosphate, triple superphosphate, or potassium chloride are becoming common place. Some plants in Europe now produce as much as 2 million tons of fertilizer per year.

The average size of plants producing basic fertilizer materials will undoubtedly continue to increase during the next decade. It is doubtful whether there would be much advantage in increasing plant size beyond that of some of the largest existing plants because of the cost of transporting products long distances, and because any further increase in size would result in only a minor decrease in production cost. There is, however, a need for small plants, not to manufacture basic materials, but to combine them into compounds that will satisfy local needs.

The growing pressure to control pollution of the air, rivers, and lakes increases the complexities of manufacturing. These problems can be dealt with more economically in large plants than in small ones. Some small plants have closed because it was uneconomical for them to comply with pollution control regulations, and more will probably do so in the future. Pollution control regulations will, therefore, accelerate the trend towards larger factories.

Complexity of formulation

A rather wide range of $N : P_2O_5 : K_2O$ ratios is needed for various crops and soils. Moreover, it is known that ten other elements are equally necessary to plant growth ; the secondary elements, calcium, magnesium, and sulphur ; and the micronutrients, manganese, iron, boron, copper, zinc, molybdenum, and chlorine *). The time is approaching and has already arrived in many areas when the fertilizer industry can no longer limit its concern to the primary nutrients. The farmer has a right to expect that agronomists will prescribe and technologists will supply compound fertilizers for his crops containing the elements needed in the correct proportion

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*) Although chlorine was established as an essential micronutrient element in 1954, no incident of naturally occurring deficiency is known, perhaps because of the abundance of the element [2].

for economical production. A great many compound fertilizers in the United States already contain one or more of the "other ten" elements. In 1970, well over 100,000 tons of micronutrient materials were used in fertilizers plus unknown quantities of materials supplying secondary elements. In the same year in Japan 842,000 tons of fertilizer contained boron, magnesium, or manganese.

The trend towards more complex formulations is likely to continue because : more adequate fertilization with primary nutrients often results in one of the other ten elements becoming a limiting factor, increased crop yields rapidly exhaust the soil of these elements, improved diagnostic techniques and accelerated research help to identify specific needs, and increasing the concentration of the three primary plant nutrients in fertilizers has been attained at the expense of eliminating some of the other ten.

Some years ago in a lecture to the Fertilizer Society in London, Howard Cunningham [3] commented on the growing complexity of farmers' needs. He said :

> "N, P and K must always be the main preoccupation of the Fertilizer Society but their very success in producing bigger yields of crops and stock is taxing the supply of other elements and leading to problems for farmers. Fertilizer manufacturers should apply to the solution of these problems as much skill and determination as they have applied with such success to the three major ingredients".

At the same time he was aware that the size and complexity of a granulation plant imposed serious limitations on flexibility in formulation, for he said :

> "It is not easy to reconcile low cost production and special mixtures for a customer, a crop or even a district".

Farmers in many areas demand a combination of herbicides or other pesticides with fertilizer, which further increases the complexity of formulation. Such combinations are advantageous to the farmer as they save time and labour. Slow-release nitrogen is desirable in some situations and may be provided by incorporating slowly soluble nitrogen materials or nitrification inhibitors in compound fertilizers.

Increased use of intermediates

In order to profit from large-scale manufacture and still provide flexibility of formulation of compound fertilizer, various new systems are being developed. The general characteristics of these systems are : production of fertilizer intermediates in large plants where raw material costs are low, transportation of the intermediates in concentrated form to various market areas, and production of the final mixture in small local plants that may combine the functions of manufacturing and retailing.

The principal intermediates are ammonia, ammoniating solutions containing free ammonia and ammonium nitrate or urea, urea-ammonium nitrate solution, monoammonium or diammonium phosphate, ammonium polyphosphate solution, triple superphosphate, phosphoric acid, and potash salts.

The types of local plants using these intermediates fall into three categories : dry mixing, liquid mixing, and granulation. Dry mixing plants merely make mechanical mixtures from dry fertilizer materials. The materials may be either granular or pulverized ; most farmers prefer granular products because of superior storage and handling properties.

Dry mixing of granular materials is known as "bulk blending". Favorite materials for bulk blending are diammonium phosphate, triple superphosphate, potassium chloride, ammonium nitrate, and urea. All materials should be of about the same particle size, usually in the range of 1 to 3 mm. Materials are usually received in bulk by rail, barge, or ship. They are often stored in bulk and mixed to the farmer's specification in accordance with soil test data. The mixtures may be sold either in bulk or in bags according to the farmer's preference.

Bulk blending plants are often quite small and inexpensive to construct. A typical plant is shown in figure III. Frequently the output is marketed within a radius of 20 km. The average annual output of about 5000 such plants in the United States is about 2,000 tons per plant. Large

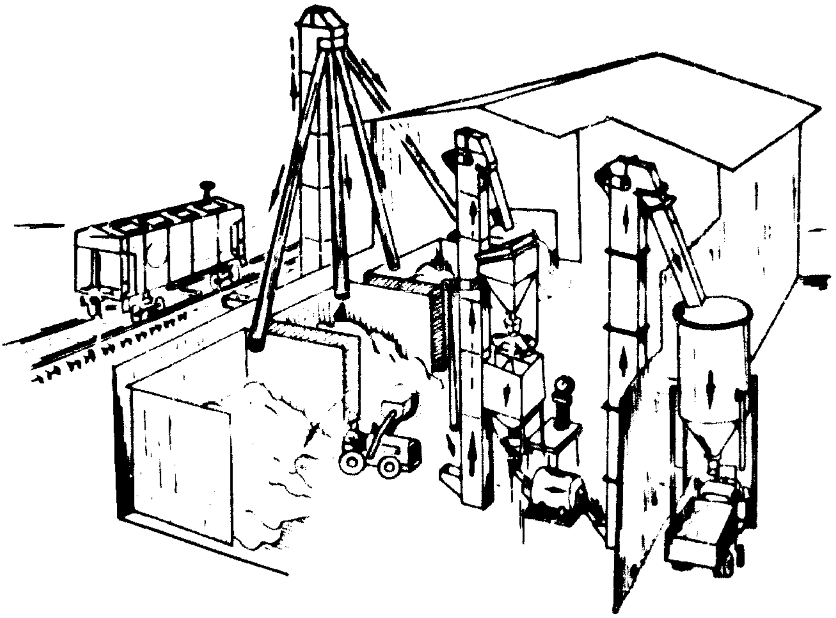

Figure III. Typical bulk blending plant

bulk blending plants, can be economical, however, particularly when they are located at, or near a port where materials may be received by ship or barge. One such plants in the United States has an annual output of over 200,000 tons.

One problem in bulk blending is the tendency of the materials to segregate during handling and application [4]. Segregation can best be prevented by having all materials of closely matched particle size. Particle shape and density are relatively unimportant. When the particle size is not closely matched, segregation can be minimized by careful distribution in filling bins, trucks, or hoppers [5]. Filling from one spot causes "coning" and promotes segregation.

Micronutrients may be added to bulk blends in several ways. Powdered micronutrient materials may be coated on the surface of the granules by using oil or other binder. Alternatively, granular micronutrient materials may be used in the blend. Addition of pesticide to blends may be in the form of a powder (with a binder) or in the form of a concentrated liquid.

Bulk blending is particularly popular in North America. In 1971 it was estimated that bulk blends accounted for 58 per cent of all dry compound fertilizers in the United States. Recently other countries have started bulk blending operations and the practice is expected to grow.

Successful use of bulk blending in local plants requires dependable transportation, such as a network of railroads and a supply of rail cars that will protect the bulk fertilizer from the weather. Covered, hopperbottom cars are preferred for ease in unloading. Many developing countries do not have rail cars suitable for transporting bulk fertilizer. If a blending operation is located at a port where bulk materials may be received by ship, there must be sufficient storage space at, or near the port to accommodate the size of the bulk shipments. Mechanized unloading of ships is desirable to minimize the time that ships must stay in port. The unloading equipment should prevent undue degradation of the granular material and should offer protection from the weather. In very humid climates dehumidified bulk storage is desirable. Several types of such blending facilities are in operation in developing and developed countries. The blends are usually bagged for inland transportation.

Flexibility of formulation in small local plants is also possible with liquid mixed fertilizers. Like bulk blending, the production of liquid mixed fertilizers requires only very simple inexpensive equipment and depends on shipped-in intermediates. The advantages of liquid fertilizers will be considered later.

A small granulation plant based mainly or entirely on shipped-in intermediates is another solution to the problem of maintaining flexibility of formulation. Although granulation plants do not have as much flexibility as bulk blend or liquid-mix plants, a small plant can produce formulations that are needed by local farmers for their crops and soils.

A typical small granulation plant may use superphosphate produced at the site. It may also use a higher analysis phosphatic intermediate — triple superphosphate, ammonium phosphate, or phosphoric acid. Nitrogen may be supplied by ammonia, ammoniating solutions, urea, or some combination of these materials. Potash is supplied as chloride or sulphate.

Most small granulation plants attempt to operate with a formulation in which drying is mainly accomplished by the heat generated in chemical reactions. Several small plants have operated successfully without any dryer at all.

Superphosphoric acid has been used in small batch granulation plants [6], and more recently in a small, continuous granulation plant without a dryer [7], to promote granulation at low moisture contents. Grades were 12—18—18—3 MgO and 15—15—15—4 MgO. Formulations containing about 200 lb. of superphosphoric acid and 70 to 100 lb. of sulphuric acid per ton of product gave good results. The acids were neutralized with ammonia-ammonium nitrate solutions. The granular products were hard and dry (less than 1 per cent moisture) and had good storage properties.

Another approach to a simplified granulation system is to use a powdered monoammonium phosphate with special properties that are well suited to granulation. Several low-cost processes are available for producing this material [8, 9, 10]. The monoammonium phosphate may be used to supplement and up-grade superphosphate or to replace it. Granulation may be promoted through use of steam, ammonia or ammoniating solution, or a combination of these practices. A typical grade of the powdered monoammonium phosphate is 10—50—0; it may be produced at low cost and shipped in bulk to granulation plants [11]. In most cases it may be preferable to manufacture monoammonium phosphate at the plant where posphoric acid is produced rather than to deal with the problems of shipping the acid.

Some granulation plants use only dry materials; the mixture is granulated by adding water or steam or both. In some cases, heating the mixture with a flame in the granulator may generate enough liquid phase for granulation. Granulation at elevated temperature is preferable to granulation by water addition alone, as the water added during granulation must be subsequently evaporated by drying, and the dried granules are likely to be porous and weak.

Granulation with formulations including urea and superphosphate in several small plants in the United Kingdom have been recorded [12]. Additional materials included in the formulation were ammonium sulphate, monoammonium phosphate, and potash. A granulation plant in Brazil recently started operation using urea-ammonia solution imported from Europe; its initial operation was quite satisfactory.

Many granulation plants use phosphoric acid as an intermediate, either to supply all the phosphorus or to supplement superphosphate. Ammonia may be supplied as such or as ammoniating solution.

As in blending, granulation with imported intermediates requires suitable, dependable transportation and storage facilities. Solid materials should be protected from the weather, although prevention of deterioration is less critical than in blending.

Granulation in large plants adjacent to the plants where basic intermediates are produced is sometimes the best arrangement even though large granulation plants cannot prepare small lots of special grades economically. In large granulation plants (20 to 50 tons per hour) the usual practice is to produce a limited number of grades, ordinarily three to six, as the time and expense involved in clearing the equipment of one grade before beginning the production of another make short runs or frequent changes uneconomical. Some companies that operate large granulation plants also have smaller plants (6 to 10 tons per hour) that granulate special grades. Also, special grades may be made by blending or by adding micronutrients as a coating after granulation.

Trends in types of nitrogen materials

A prominent feature of the world nitrogen industry is the rapid rise in popularity of urea, as shown in figure IV. Data for figure IV through 1969 are from FAO reports ; TVA projections to 1975 take into account planned capacity. Urea's share of the world nitrogen fertilizer market has risen from less than 5 per cent in 1955 to 16 per cent in 1969 and is expected to increase to about 26 per cent by 1975. These figures are for solid urea only, and do not include the urea content of solutions. In the United States about half of the urea used for fertilizer goes into solutions.

The largest group of nitrogen fertilizer materials consists of anhydrous ammonia, nitrogen solutions, the nitrogen content of ammonium phosphates and complex fertilizers, and miscellaneous other materials. Ammonium sulphate, once the dominant nitrogen material, supplied only 15 per cent of the world market in 1969 and may decline to 8 per cent by 1975. Other low-analysis materials include calcium nitrate, sodium nitrate, and calcium cyanamide — a group now supplying only 2 per cent of the market. Ammonium nitrate now supplies 27 per cent of the market ; in future years that percentage may decline slightly.

By 1975, nearly 40 per cent of the world fertilizer nitrogen capacity will be used for production of urea (including solutions and the urea content of complex fertilizers). In the developing countries of Africa, Asia and Latin America, urea is expected to constitute 62 per cent of nitrogen capacity.

The growing demand for urea is attributed to its high analysis and to improvements in technology that have lowered its cost. At present, urea is less expensive than ammonium nitrate per unit of nitrogen, both in capital and production costs. Manderson [13] estimates the production cost of urea to be about 12 per cent less than ammonium nitrate ; when distribution and application costs are included the cost advantage of urea is about 20 per cent under prevailing United States marketing conditions. In comparison with ammonium nitrate, which has been the leading form of nitrogen since about 1960, there are no fire or explosion hazards involved in using urea ; also, it is agronomically preferable for rice.

One of several disadvantages of ordinary commercial prilled urea is that the size of the particle is too small for use in bulk blends. The small-particle size increases the caking tendency and the rate of moisture absorption ; also, some types of broadcast spreaders operate less efficiently with small-particle size prilled urea. The usual prilled urea is weak ; it has a low crushing strenght and poor resistance to abrasion. This weakness may lead to excessive fine formation in bulk shipments and in some

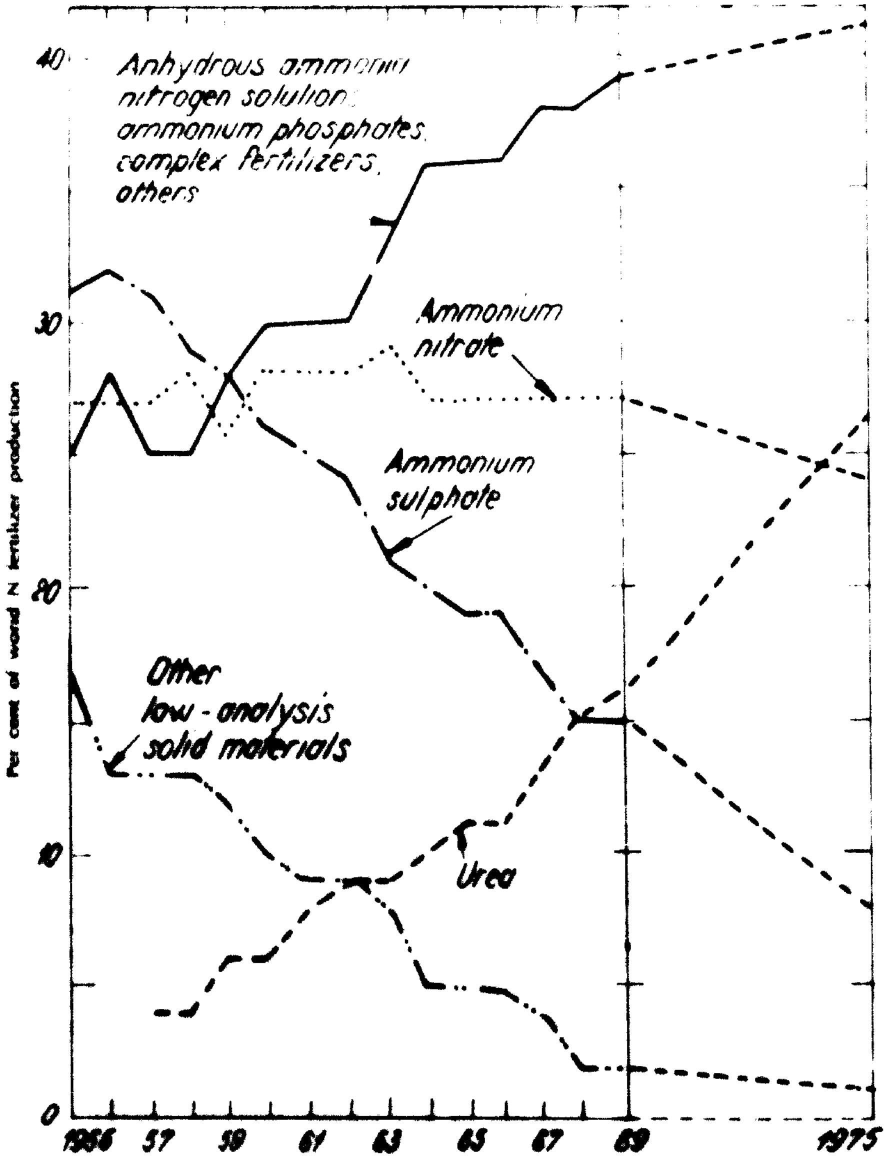

Figure IV. World trends in types of nitrogenous fertilizer materials

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Source: Food and Agriculture Organization of the United Nations; does not include data from the Union of Soviet Socialist Republics or from other countries of Asia with centrally planned economies. Projection to 1975 by Tennessee Valley Authority.

types of applicators. In view of the extensive development that has taken place in improving the efficiency and economy of the urea synthesis process, it is unfortunate that so little study has been given to improving the quality of the final product.

One company in Canada (Cominco Ltd.) is producing urea by a spray-drum granulation process in a plant located in Calgary. Two sizes are produced; one size, about 1.7 to 3.3 mm, is used for direct application and bulk blending; a larger size, 4 to 6 mm, is used for forest fertilization by aerial application. The granules are harder and more resistant to abrasion than prilled urea, and the cost of granulation is said to be about the same as prilling.

TVA has developed a pan granulation process for urea through the pilot-plant stage. The process has proved capable of producing closely sized well-rounded granules in any specified size range. Crushing strength and resistance to abrasion have been quite satisfactory and large-scale development is planned.

Although some urea is marketed without conditioner, most of it is now conditioned by a coating of inert material such as kaolin clay or by a treatment of formaldehyde or other organic chemicals. These treatments prevent urea from caking while stored in moisture-proof bags, but they do not retard the rate of moisture absorption when the material is in contact with air above the critical humidity which is 75 per cent relative humidity at 30°C. In many areas where the climate is hot and humid, there is a need for a conditioning treatment that will significantly retard moisture absorption. TVA is conducting research on this problem and some promising results have been obtained. In any conditioning treatment, it is advantageous to have larger granules to decrease the surface area.

In view of the plentiful supply and low cost of urea, consideration should be given to ways of using it. With the world trend towards farmer preference for mixed (compound) fertilizer, use of urea in granular mixtures is receiving attention in many countries. The high analysis of urea is useful in offsetting the low analysis of cheaper nitrogen sources in mixtures. A mixture of urea and ammonium sulphate in equal parts, for example, would contain 33.4 per cent nitrogen, nearly as much as ammonium nitrate. Substitution of urea-ammonium sulphate mixtures for ammonium nitrate therefore might be a good way to move low-cost by-product ammonium sulphate into a high-grade product.

The technology of using urea in granular compound fertilizers, with or without ammonium sulphate, is well advanced in Japan [14] and in the United Kingdom [15]. Although there are some technical problems, methods of handling them have been developed.

Compounds containing urea must be dried at a relatively low temperature to avoid hydrolysis of urea (forming ammonia and carbon dioxide) and to avoid softening or melting in the dryer. Rather large dryer capacity is required to attain adequate drying at low temperature.

When the compounds contain urea and single or triple superphosphate, an urea-monocalcium phosphate forms, releasing water of hydration and causing the mixture to become wet and sticky. Ammoniation of the superphosphate helps to prevent this condition, but reduces the water solubility of the P_2O_5. The addition of ammonium sulphate helps by reacting with the superphosphate preferentially. The most prevalent method of dealing with the problem requires very light ammoniation plus the inclusion of ammonium sulphate in the formulation and careful drying.

Granular compound fertilizers containing urea and superphosphate should be cooled to about 30°C before storage, as slow hydrolysis of urea releases ammonia which reacts with the superphosphate, causing a decrease in P_2O_5 water solubility. This reaction occurs to an appreciable extent even at temperatures as low as 40°C during several months of storage.

Trends in types of phosphate materials

Figure V shows world trends in types of phosphate fertilizer materials with projections to 1975. A striking feature is the decline in relative importance of single superphosphate from 63 per cent of the total P_2O_5 supply in 1955 to 35 per cent in 1969. A further decline to 22 per cent in 1975 is forecast. The decline in actual tonnage has been small. In fact, in 1966 the largest tonnage of single superphosphate was produced, and the 1970 tonnage exceeded that of 1960. However, most of the expansion industry has been in higher analysis products, particularly triple superphosphate, ammonium phosphate, and other complex fertilizers. Concentrated superphosphate has maintained a nearly steady level of 15 per cent

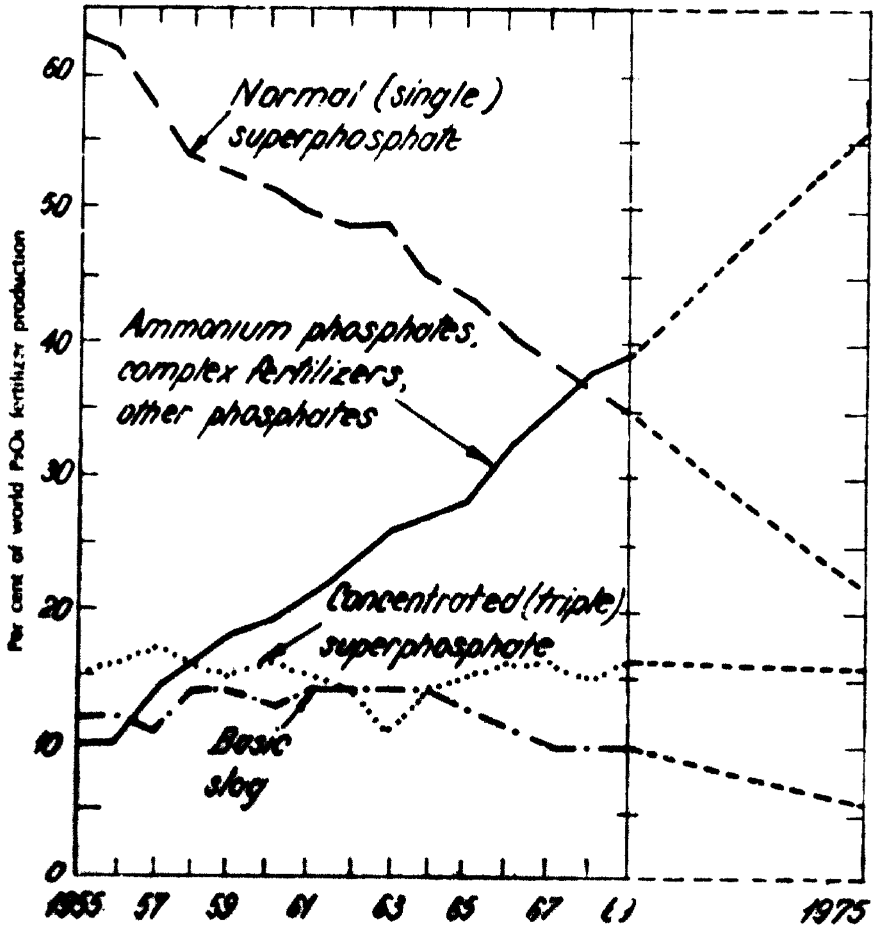

Figure V. World trends in types of phosphatic fertilizer materials

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Source: Food and Agriculture Organization of the United Nations; does not include data from the Union of Soviet Socialist Republics or from other countries of Asia with centrally planned economies. Projection to 1975 by Tennessee Valley Authority.

of the total. The group, ammonium phosphates, complex fertilizers, and other phosphates, has risen from 10 per cent in 1955 to 39 per cent in 1969; further increase to 56 per cent in 1975 is predicted. Probably as much as three quarters of this group consists of ammonium phosphate, including straight ammonium phosphate and that formed in complex fertilizers. Most of the remainder is the P_2O_5 content of nitric phosphates. Basic slag is expected to supply a declining percentage of fertilizer P_2O_5 in the future.

Decline in the use of single superphosphate (and ammonium sulphate) may bring about a need for alternative sources of sulphur. Substantial responses to sulphur have been noted in some parts of nearly all states of the United States and in at least 47 other countries, including many developing countries (16). Most soils in tropical and subtropical regions are inherently deficient in sulphur. Sulphur-deficient areas become more widespread when heavy rates of nitrogen and other primary nutrients are applied. Much sulphur is supplied by rainfall in highly industrialized areas where it originates from burning coal and oil. In these areas, sulphur is [illegible]. However, as plans for preventing atmospheric pollution materialize, a greater need for sulphur in fertilizers can be expected.

Ideally, sulphur should be supplied in fertilizers only when it is needed. To attain this ideal, an alert, efficient agricultural advisory service should be available to every farmer, but even in the most developed phosphate countries this service is not always available to all farmers. In developing countries where little is known about the need for sulphur, deficiencies may become evident only after several years of cropping with sulphur-free fertilizers.

In some circumstances, single superphosphate may be the most economical source of sulphur; however, elemental sulphur has, frequently proved to be economical and effective. Elemental sulphur can be incorporated in granular fertilizer by spraying it in liquid form in the granulator.

There is a trend towards using phosphoric acid as an intermediate rather than converting it to finished fertilizer at the point of manufacture. In the United States approximately 1 million tons of P_2O_5 is shipped as phosphoric acid from the point of manufacture (near phosphate mines) to market areas for conversion to fertilizer. "Superphosphoric" acid (70 to 72 per cent P_2O_5) may comprise about half of the shipments; the remainder is usually shipped at a concentration of 54 per cent P_2O_5. The acid is used at the destination in granulation plants, in liquid mixed fertilizer plants, or for direct application.

Because of the long distances between phosphate mines and market areas in the United States, the shipment of phosphoric acid is feasible. Several phosphoric acid plants are either in operation, under construction, or planned which are intended primarily to supply phosphoric acid to international trade because such shipments are deemed economic.

There is some interest in partial purification of phosphoric acid, especially in areas where the phosphate rock contains more than the usual amount of impurities. The impurities form a sludge that is troublesome in shipping, and some types of impurities detract from the quality of liquid fertilizer. Calcining the phosphate rock removes organic impurities. Concentration of the acid followed by settling or centrifuging removes some of the sludge. Concentration to superphosphoric acid volatilizes most of the fluorine and silicon. Some companies remove part of the magnesia from superphosphoric acid for liquid fertilizer production. One company in Mexico practices partial purification by solvent extraction. Phosphoric acid produced by the hydrochloric acid route, as in the Israel Mining Industries process, has a low impurity content.

Liquid fertilizers

Consumption of liquid fertilizers has grown rapidly in the United States, as shown below.

Liquid fertilizers

	Millions of tons			
	1965	1967	1969	1971
Anhydrous ammonia	1.4	2.2	2.8	3.4
Aqua ammonia	0.7	0.8	0.6	0.7
Nitrogen solutions	1.7	2.3	2.5	3.2
Liquid mixed fertilizers	0.9	1.7	2.0	4.0 a)

a) Estimated.

In addition to these materials, direct application of phosphoric acid (50 to 60 per cent P_2O_5) amounted from 50,000 to 70,000 tons per year.

Including anhydrous ammonia, liquids comprised 26 per cent of all fertilizers in 1971. The data for liquid mixed fertilizer in use between 1965 and 1969 may be incomplete due to incomplete reporting; a recent survey by TVA in co-operation with the National Fertilizer Solutions Association indicated a 1971 consumption of about 4 million tons, or about 20 per cent of allcompound fertilizers [17].

Growth in use of anhydrous ammonia is mainly attributable to its low cost, which more than offsets higher costs for storage, transportation, and application. The average prices paid by farmers in the United States in 1970 for various nitrogen fertilizers are shown below [18].

	US $/kg of N
Anhydrous ammonia	0.10
Urea	0.20
Ammonium nitrate	0.20
Nitrogen solution	0.19
Ammonium sulphate	0.28

Liquid mixed fertilizers are more expensive than bulk blends, but are comparable in cost to granular compound fertilizers. Their popularity is due to advantages other than price.

Liquid fertilizers are dependably free-flowing, are free from dust or caking problems, and are unaffected by humidity. They are convenient to handle and easy to apply; and because they save labour and are easily adapted to mechanical handling, they are of great advantage to the farmer.

Even distribution and precise placement are easier with liquids than with solids. Liquid mixing is readily adapted to prescription formulation and herbicides or pesticides may easily be mixed with liquid fertilizers. For irrigated crops liquid fertilizers are especially popular as the fertilizers may be added to the irrigation water.

From a manufacturing standpoint, a primary advantage of liquid fertilizers is the simplicity and low cost of production, storage, handling, and transportation. Manufacture does not require large plants, dust and fume problems are practically non-existent and losses are very small. Controll of composition is simple and there are no problems of hygroscopicity or caking. The costs of storage, loading, and handling are not high because pumps and piping are cheaper than conveyors, elevators, power shovels, and cranes, both in capital cost and in operating cost.

The usual nitrogen materials for liquid mixed fertilizers are urea-ammonium nitrate solutions (28 to 32 per cent N) and solid urea. Urea-ammonium nitrate solutions are preferred because they are cheaper, more convenient, and give high solubility in grades containing little or no potash. Solid urea gives higher solubility in most NPK grades.

Ammonium polyphosphate solution is the most popular phosphatic material. Solid ammonium polyphosphate may also be used. The ammonium polyphosphate materials are prepared by reaction of superphosphoric acid with ammonia. The superphosphoric acid may be made from elemental phosphorus (thermal process) or by concentrating wet-process phosphoric acid. At present, most of the liquid products are made from wet-process superphosphoric acid. The usual solution grade is 10—34—0 or 11—37—0. At present, only the Tennessee Valley Authority produces the solid material. Its grade is 15—62—0 (made from thermal acid). "Soluble" refined potassium chloride (62 to 63 per cent K_2O) is the usual potash source.

Use of liquid fertilizer is increasing rapidly in some European countries, including Belgium, France and the United Kingdom; use in France is the most advanced.

While convenience and labour-saving may not be very important in developing countries, there are other advantages that should be considered. Manufacturing facilities for liquids are generally less complex and less expensive to construct and to operate than those for granular solids. Liquids lend themselves well to production of homogeneous mixtures in distribution centres to meet local needs in developing countries a segment of the fertilizer production and marketing system that has been sadly neglected. Application equipment for liquids need not be expensive and can even be very simple. Many developing countries are located in humid, tropical areas where even relatively non-hygroscopic solids present problems. Hygroscopicity is never a problem with liquids.

Foreseeable improvements in liquid fertilizer manufacture include production of ammonium polyphosphate solution directly from orthophosphoric acid without the intermediate production of superphosphoric acid. This has been accomplished in France [19] and in the United States and should help to reduce cost.

Agronomic advantages of liquid fertilizers have been reported which may result from more precise placement or from the presence of polyphosphate, as discussed below.

Suspension fertilizers

A disadvantage of clear liquids is the low analysis of grades that contain a substantial proportion of K_2O. For instance, the average analysis of liquid mixed fertilizers (including a small proportion of suspensions) in the United States in 1970 was 8.4—16.4—7.6 as compared with 9.2—17.7—12.7 for all mixed fertilizers. This disadvantage is minimized by the marketing system: the final mix is seldom transported far distances. Nevertheless, the relatively low analysis often has a significant effect on the cost of transportation and application.

The use of suspension fertilizers provides a means for overcoming the disadvantage of low analysis. They are liquids containing solids, usually soluble salts in their saturated solution. The mixtures are treated to minimize settling by inclusion of 1 to 3 per cent of a gelling-type clay in their formulation. In 1971, about one-third of all liquid mixed fertilizers were suspensions.

With suspensions, the analysis can be on a level comparable with granular solid or bulk blended fertilizers. Popular grades of suspension fertilizers are 7—21—21, 3—10—30, 10—20—20, and 15—15—15, about twice the nutrient content obtainable in clear liquids with these ratios.

Another advantage of suspensions is greater flexibility in formulation; the materials need not all be soluble. This is a particular advantage when secondary elements or certain micronutrients must be supplied; magnesium and manganese compounds, for example, are only slightly soluble in liquid mixed fertilizer.

Handling and application of suspensions, in their present state of development however, are not as simple, convenient, and trouble-free as for clear liquids.

Ammonium polyphosphate

The term "ammonium polyphosphate" is used in fertilizer parlance to denote materials containing condensed phosphates. As discussed previously, solutions or solids produced by ammoniation of superphosphoric acid are favorite intermediates for compounding liquid fertilizers. Typical composition of the three most popular polyphosphate materials are given below.

Phosphate species in ammonium polyphosphate	Percentage of total P_2O_5		
	10—34—0 solution	11—37—0 solution	15—62—0 solid [a]
Ortho	49	20	41
Pyro	42	37	54
Tripoly	8	23	4
Tetrapoly and higher	1	16	1

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[a] Made from electric-furnace phosphoric acid.

Ammonium polyphosphates may also be made directly from orthophosphoric acid by a process that utilizes the heat of reaction of the acid with ammonia to dehydrate the ammonium phosphate. This process is in an advanced stage of pilot-plant study.

Chemically, ammonium polyphosphates are the ammonium salts of polyphosphoric acids. The general formula for polyphosphoric acid is $H_{n+2}P_nO_{3n+1}$. The specific ammonium polyphosphates most abundant in fertilizers are triammonium and tetraammonium pyrophosphate, $(NH_4)_3HP_2O_7$ and $(NH_4)_4P_2O_7$, and pentaammonium tripolyphosphate, $(NH_4)_5P_3O_{10}$.

Ammonium polyphosphates are particularly useful in liquid fertilizers because they sequester the impurities normally present in wet-process phosphoric acid, thus avoiding precipitation of insoluble iron, aluminum, and other compounds when the acid is ammoniated. Also, the ammonium polyphosphates are more soluble than the orthophosphates, permitting production of higher analysis solutions.

Terman and Engelstad [20] summarizing studies in the United States concluded that ammonium polyphosphate usually was equal or slightly superior to monoammonium phosphate. Both were usually superior to concentrated superphosphate for early growth response. Fourcassie and Gadet [21] concluded from experiments in France that ammonium polyphosphate supplied as liquid fertilizer was consistently superior to other phosphorus sources as the result of better phosphorus utilization. Most of these tests were made on calcareous soil. Field tests at six locations in Japan indicated that response to solid ammonium polyphosphate was generally greater than to ammonium orthophosphate, although early growth was sometimes slightly delayed. There was some suggestion that better utilization of native or applied micronutrients may have been a factor in the favourable results with polyphosphates.

Gourny and Conesa [22] reported that liquid fertilizer containing 34 to 82 per cent of its phosphate as nonorthophosphate was slightly inferior to ammonium orthophosphate on acid soil, but markedly superior on calcareous soil.

Conesa [23] demonstrated that plants can take up polyphosphate without previous hydrolysis.

Singh and Dartigues [24] reported that polyphosphate was superior to ammonium orthophosphate on two zinc-deficient calcareous soils.

Soubies and Baratier [25] emphasize the advantage of band placement of ammonium polyphosphate solution near the seed as compared with broadcast solid orthophosphate. They claimed that the band placement used with liquids was not possible with solids.

Mortvedt and Giordano [26] reported that liquid polyphosphate fertilizers were effective carriers of iron sulphate in greenhouse tests for crops grown on iron-deficient soils, whereas application of iron sulphate alone or in several granular fertilizers was ineffective.

In a recent series of field tests in the United States [27] ammonium polyphosphate solution gave higher yields of maize and wheat, than orthophosphate fertilizer in either liquid or solid form.

Nitric phosphates

Nitric phosphate-type processes are particularly attractive for countries with limited raw material resources for fertilizer manufacture. The only feed materials required are ammonia and phosphate rock, either or both of which can be imported. Nitric phosphates are economically preferable when sulphur prices are high.

About sixty plants are believed to be producing solid nitric phosphates, two thirds of them are in Europe.

Recent process improvements have made the nitric phosphate process more versatile and have removed some of the earlier objections to these products. It is now possible to produce high-analysis grades such as 20—30—0 and 23—23—0 with over 80 per cent of the P_2O_5 water soluble in large, efficient plants [29].

Estimates usually indicate that nitric phosphate processes are more economical than production of equivalent amounts of nitrogen and phosphate fertilizers as ammonium phosphate and ammonium nitrate or urea. When compared with the urea plus ammonium phosphate, the cost advantage is small and may be offset by higher transportation costs if the products are shipped very far [28].

The principal disadvantages of nitric phosphates are that only about 2 tons of nitrogen are produced for each ton of P_2O_5, and that most of the nitrogen is in the form of ammonium nitrate. Also, it is not easy to produce a wide range of grades.

Potassium phosphates

There has been much interest in potassium phosphates because of their very high analysis and good agronomic properties. The potassium phosphates under consideration include the orthophosphates, KH_2PO_4 and K_2HPO_4, and the polyphosphates ranging from pyro and tripoly to long-chain polyphosphates commonly called "metaphosphate". The orthophosphate and short-chain polyphosphates are quite soluble, whereas the metaphosphates may be either soluble or insoluble, depending on their method of preparation and impurity content.

Potassium orthophosphate is used to a limited extent in special fertilizers such as water-soluble mixes for foliar application or transplanting solutions, there is also some use of liquid fertilizers for farm application. One company in the United States produces a 0—26—27 potassium polyphosphate solution for use in liquid mixed fertilizers. All of these materials are produced from potassium hydroxide or carbonate, and hence are too costly for general use.

Many research projects have been aimed at producing potassium phosphates from potassium chloride, the cheapest source. Most of these projects have not proved economic because of the difficulty of utilizing or disposing of the by-product hydrochloric acid. Even if the hydrochloric acid is used to react with phosphate rock, calcium chloride becomes a by-product which is difficult to dispose of in many locations.

Recently a process was developed in Ireland by Goulding Fertilizers on a pilot-plant scale that produces KH_2PO_4 and anhydrous HCl gas [30]. A similar process was developed in the United States by Pennzoil, and the two companies have agreed to pool their information. It is claimed that anhydrous HCl can be used in certain organic oxychlorination processes where its value will be comparable with that of elemental chlorine. It was recently announced that a small plant in California would be adapted for production of potassium phosphates by the Goulding-Pennzoil process.

Controlled-release fertilizers

Fertilizers that release plant nutrients slowly throughout the growing season or even several growing seasons continue to attract the attention of technologists and agronomists. Potential advantages claimed for controlled-release fertilizers are increased efficiency of uptake by plants ; minimization of losses by leaching, fixation, or decomposition ; reduction in application costs through reduction in number of applications ; elimination of luxury consumption ; and avoidance of burning of vegetation or damage to seedlings.

The term "controlled-release fertilizers", as used in the following discussion, refers to any fertilizers that release their nutrient content over an extended period. Even a simple choice among materials inherently slow to dissolve is viewed as a measure of control.

Controlled-release phosphate fertilizers

Of the numerous controlled-release phosphorus compounds that have been tested, those in frequent use are : ground phosphate rock, calcined aluminium phosphate ore, basic slag, defluorinated phosphate rock (tri-calcium phosphate), fused calcium magnesium phosphate, Rhenania phosphate, bone meal, dicalcium phosphate, magnesium ammonium phosphate, calcium metaphosphate, and potassium metaphosphate (The so-called metaphosphates are more properly designated as polyphosphates).

Ground phosphate rock containing about 1.8 million tons of P_2O_5 was applied to the soil in 1969—1970 [31]. This probably represented some 6 million tons of rock ; about half of this amount was used in the Union of Soviet Socialist Republics and the remainder was widely distributed among other countries.

The effectiveness of ground phosphate rock varies widely with variation in its reactivity. A good indication of reactivity is solubility in neutral ammonium citrate. The effectiveness of the most reactive rocks, such as those from Gafsa and North Carolina, may approach the effectiveness of water-soluble phosphates on some soils and with certain crops. The least reactive rocks, such as igneous apatite and Udaipur (India) rock, are quite ineffective on all soils. Effectiveness depends on soil pH and is greatest on acid soils ; on high-pH soils, even highly reactive rocks are quite ineffective. As an exception, calcined aluminium phosphate ores, such as those from Senegal or Christmas Island are more effective on neutral or alkaline soils.

Basic slag containing about 1.3 million tons of P_2O_5 was applied in 1969—1970 [31]. Gross weight of the slag probably was about 8 million tons. Basic slag is generally regarded as quite effective except on calcareous soils. It is also valued for its content of the secondary nutrients calcium and magnesium and for its micronutrient content.

Calcined aluminium phosphate ore is used mainly in France. It tends to be more effective on high-pH than acid soils. The main source of aluminium phosphate ore is Senegal, but several other occurrences are known, and some is now being mined on Christmas Island. Its effectiveness depends on the calcination temperature and on fine grinding, and may be indicated by solubility in neutral or alkaline ammonium citrate. It is more soluble in the alkaline reagent.

Straight dicalcium phosphate is manufactured for fertilizer use in relatively small quantities in France and Belgium. Substantial amounts however are present in nitric phosphates and ammoniated superphosphates. It is fully soluble in neutral ammonium citrate and is generally considered to be an effective fertilizer, particularly on acid soils when broadcast in fine particle size and incorporated with the soil.

Fused calcium magnesium phosphate is manufactured mainly in Japan. it is effective on acid soils when finely ground. it supplies magnesium and silica, which may be quite helpful in some soil-crop combinations.

Most of the insoluble or slightly soluble phosphate materials are used either because they are less expensive than soluble phosphates or because they supply other elements. Very seldom if ever can any agronomic superiority be attributed to their slow release of nutrient in the soil. In fact, the slightly soluble materials often give inferior results, particularly in the first year of application. However, some of them are valued for specially uses because they may be safely placed in contact with seeds or roots, whereas soluble phosphates might damage seedlings or roots in some situations.

Soluble phosphates react rapidly with the soil to form relatively insoluble products [32], so even fully soluble phosphates become slow-release fertilizers in the soil. The main effort has been to find ways to increase the release rate. When soluble phosphates are applied in granular form, the reaction with the soil is delayed, and pockets of relatively soluble phosphate may persist at the granule sites for several weeks. Thus, good results usually are obtained by placement of soluble granular phosphate fertilizers near the seed.

Controlled-release nitrogen fertilizers

Slightly soluble materials. One group of controlled-release nitrogen fertilizers comprises chemical compounds that are only slightly soluble. It may be noted that the rate of release of nutrient from most of these slightly soluble compounds is not directly related to water solubility. Instead, the release rate is related to microbiological attack which converts the nitrogen to forms that can be used by plants. However, the rate of attack is related to the rate of solution, which depends, in turn, on solubility, particle size, and other factors.

Urea-aldehyde compounds are the principal representatives of this group that are produced commercially. Isobutylidene diurea (IBDU) is produced in Japan through the reaction of urea with isobutyraldehyde in 2 : 1 mole ratio. When pure, it contains 32.18 per cent N. Hamamoto [33] reported methods for its preparation and discussed its usefulness as a fertilizer. Crotonylidene diurea (CDU), also called cyclodiurea, is produced in Federal Republic of Germany and Japan through the reaction of urea with crotonaldehyde or acetaldehyde. The pure compound contains about 32 per cent N.

According to Ando [15] the consumption in Japan in 1968 was 1,800 tons of N as IBDU and 1,400 as CDU, a total of 3,200 tons of N or 10,000 tons of the two slow-release materials, more than double the amount of 1966. The materials were used to prepare compound fertilizers in which about half of the nitrogen was in slow-release form.

Hamamoto [33] discussed agronomic studies made in Japan with IBDU and other slow-acting nitrogen materials. The release rate from these slightly soluble materials is a function of the particle size. Under conditions in Japan, the use of these materials often improved yields and saved labour by decreasing the number of applications required. Hamamoto stated that the cost of IBDU to farmers was over twice that of conventional nitrogen fertilizers per unit of nitrogen. Compound fertilizers of 1:1:1 ratio with half of the nitrogen supplied as IBDU cost about 20 per cent more than conventional fertilizers. For this reason they were used mainly on vegetables and cash crops and not very much on grains.

Urea-formaldehyde reaction products, usually called "ureaform", are produced by about six manufacturers in the United States and in several other countries. Unlike IBDU and CDU, ureaform, which usually contains about 38 per cent N, is not a definite chemical compound. It contains methylene ureas of different chain lengths ; the solubility increases with decrease in chain length.

Perhaps the most useful component of ureaform as a slowrelease nitrogen material is trimethylene tetraurea ; shorter chain lengths are too rapidly decomposed, and longer chains are highly resistant to decomposition. Unfortunately it is very difficult to produce commercially a pure trimethylene tetraurea ; ureaform contains both shorter and longer chains.

A typical ureaform may contain 30 per cent of its nitrogen in forms that are soluble in cold water (25°C). The quality of the remaining 70 per cent is judged by the percentage that is soluble in boilling water as determined by prescribed analytical procedures. At least 40 per cent of the nitrogen insoluble in cold water should be soluble in hot water for acceptable agronomic response ; typical values are 50 to 55 per cent.

The consumption of ureaform in the United States is approximately 50,000 tons per year. Most of the production goes into mixed fertilizer for special uses, such as for lawns, flower gardens, and golf courses. The wholesale price of ureaform per unit of nitrogen is about three times that of urea, ammonium nitrate, or ammonium sulphate.

In TVA tests of many other organic nitrogen-containing compounds as fertilizers, some proved readily available, some slowly available, some inert, and some toxic. Among those that showed promise as slow-release fertilizers were oxamide, glycouril, cyanuric acid, ammeline, and ammelide. For lack of a practical process, none of these materials has been manufactured commercially as fertilizer.

Coated soluble materials. A wide range of materials and techniques have been explored with the object of making controlled-release fertilizers by coating soluble fertilizer materials with plastic films, resins, waxes, asphaltic materials, or other barriers. The only known commercial production of coated controlled-release fertilizer uses a process developed by Archer Daniels Midland Company (ADM). The main component of the coating is a copolymer of dicyclopentadiene with a glycerol ester [34]. Applied in several layers that vary in composition, the coating releases fertilizer solution by osmotic exchange with moisture from the soil. The coated granular fertilizer was manufactured by ADM under the trade name Osmocote starting in 1964. It is now produced and marketed by Sierra Chemical Company under exclusive license from ADM. Three grades of Osmocote are available: 14—14—14, 18—9—9, and 36—0—0. The nitrogen in the first two grades is supplied by ammonium nitrate and ammonium phosphate; the third grade is coated urea. The weight of the coating ranges from 10 to 15 per cent of the gross weight.

Osmocote products are recommended for turf, floriculture, nursery stock, and high-value row crops. The retail price in 1965 was reported to be about $ 0.55 per kg.

Sulphur-coated urea (SCU) is a controlled-release material that has been under development by TVA for ten years. Sulphur was selected as the coating material on the basis of economy and efficiency after several coating materials were tried. Urea was selected as the material to be coated because of its high nitrogen content, low cost, and commercial availability.

Initial studies indicated that sulphur alone was not adequately resistant to moisture penetration. The discovery that an oily wax sealant was required with the sulphur provided the breakthrough to a successful coating. The wax, however, was subject to microbial attack in the soil resulting in deterioration of its sealing properties. This problem was solved by adding 0.2 per cent of coal tar as a microbicide.

In early laboratory work, 2 to 15 pound batches of urea were coated in small drums. The development then was shifted to a small continuous pilot plant with a production rate of about 300 pounds per hour. The process is now being developed further in a large pilot plant with a capacity of about 1 ton per hour.

A flow diagram of the pilot plant is shown in figure VI. Granular urea is preheated in the first rotating drum to 80°C with electric radiants heaters to prevent the sulphur from freezing too rapidly on the granules. The molten sulphur is air-atomized and sprayed onto the rolling

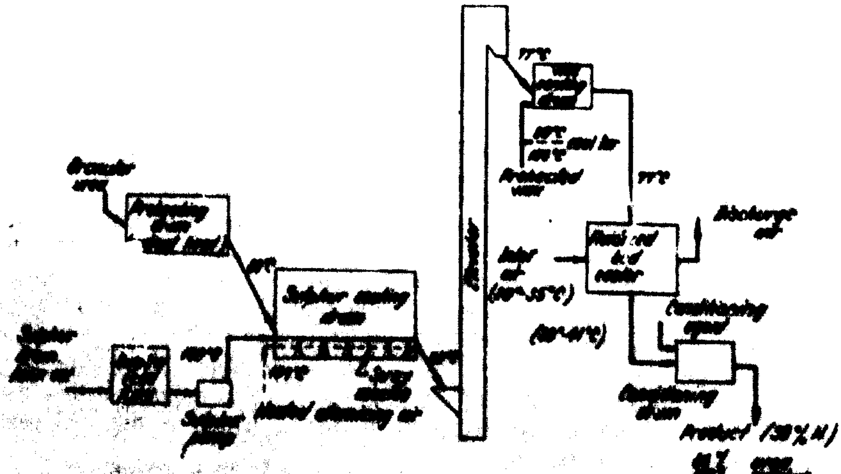

Figure VI. Flow diagram for sulphur-coated urea pilot plant bed of granules in the second drum. Wax and coal tar are applied in the third drum. The coated granules are then cooled in a fluidized bed cooler, and a powdery conditioner is applied in a fourth drum to eliminate the tacky condition of the wax.

Most of the work was done with commercial granular urea (1.7 to 3.3 mm) produced by the spray-drum granulation process. Some tests were made with prilled urea, but its smaller particle size results in greater surface area per unit weight of urea ; this greater surface requires a coating that is higher in percentage by weight of the product for a given coating thickness. For this reason, large, well-rounded granules are preferred for coating.

The rate of dissolution of coated urea can be governed by varying the thickness of the coating. To determine the dissolution rate, a laboratory test is made which measures the percentage of urea that dissolves in seven days in water at 38°C. Current agronomic information indicates that in general the best results are obtained with materials that have a seven day dissolution of 20 to 30 per cent. Such material can be produced with a total coating weight of as little as 15 per cent (10% sulphur, 2% wax and coal tar oil, and 3% conditioner).

Typical dissolution patterns in water are shown in figure VII. These tests were made with early products ; in subsequent work, improved coating technique provided similar dissolution patterns with lighter coatings. However, the figure illustrates the relative effect of coating weight and the effect of water temperature on dissolution. It also shows that the dissolution rate decreases with time of immersion. Soil dissolution rates are not necessarily the same as dissolution rates in water. Allen et al. [35] have published data on the rate of dissolution in the soil as affected by coating weight, temperature, placement, and inclusion of microbicide in the coating.

In addition to the controlled-release characteristics, coated urea has excellent storage and handling characteristics and might even be handled in bulk in humid climates. Also, it may be blended with triple or single superphosphates, which are incompatible with uncoated urea.

Agronomic tests have been completed or are in progress in 29 countries and in 36 states of the United States. Some results of TVA tests have been reported [36, 37, 38].

Coated urea was advantageous for sugarcane, pineapple and rice grown with delayed or intermittent flooding, and in general for long-season crops or for conditions conducive to heavy leaching or decomposition.

The sulphur-coating technique may be applied to fertilizers other than urea. Experimental work has included coating of diammonium phosphate, potassium chloride, potassium sulphate and various compound fertilizers.

Nitrification inhibitors : Nitrogen fertilizers in the ammonium form are immobilized in the soil by sorption on clay particles and hence are resistant to leaching. The ammonium form, however is rapidly converted to the nitrate form in most soils by microbiological processes called nitrification. The nitrate form is more readily available to most plants, although some plants (e.g., rice) can readly use the ammonium form. Thus, some of the purposes of controlled release (resistance to leaching and delayed availability) mai be attained by delaying nitrification of ammonium nitrogen.

Numerous organic chemicals have been identified as nitrification inhibitors. The inhibition is due to the toxicity of these chemicals to organisms that convert ammonium nitrogen to nitrite, which is the first step of the nitrification process.

One of the nitrification inhibitors that has received attention in the United States is 2-chloro-6-(trichloromethyl) pyridine. Dow Chemical Company is promoting it under the trade name N-Serve and is aiming at a price level per hectare for growers of about $ 6.20 to $ 7.40. The mini-

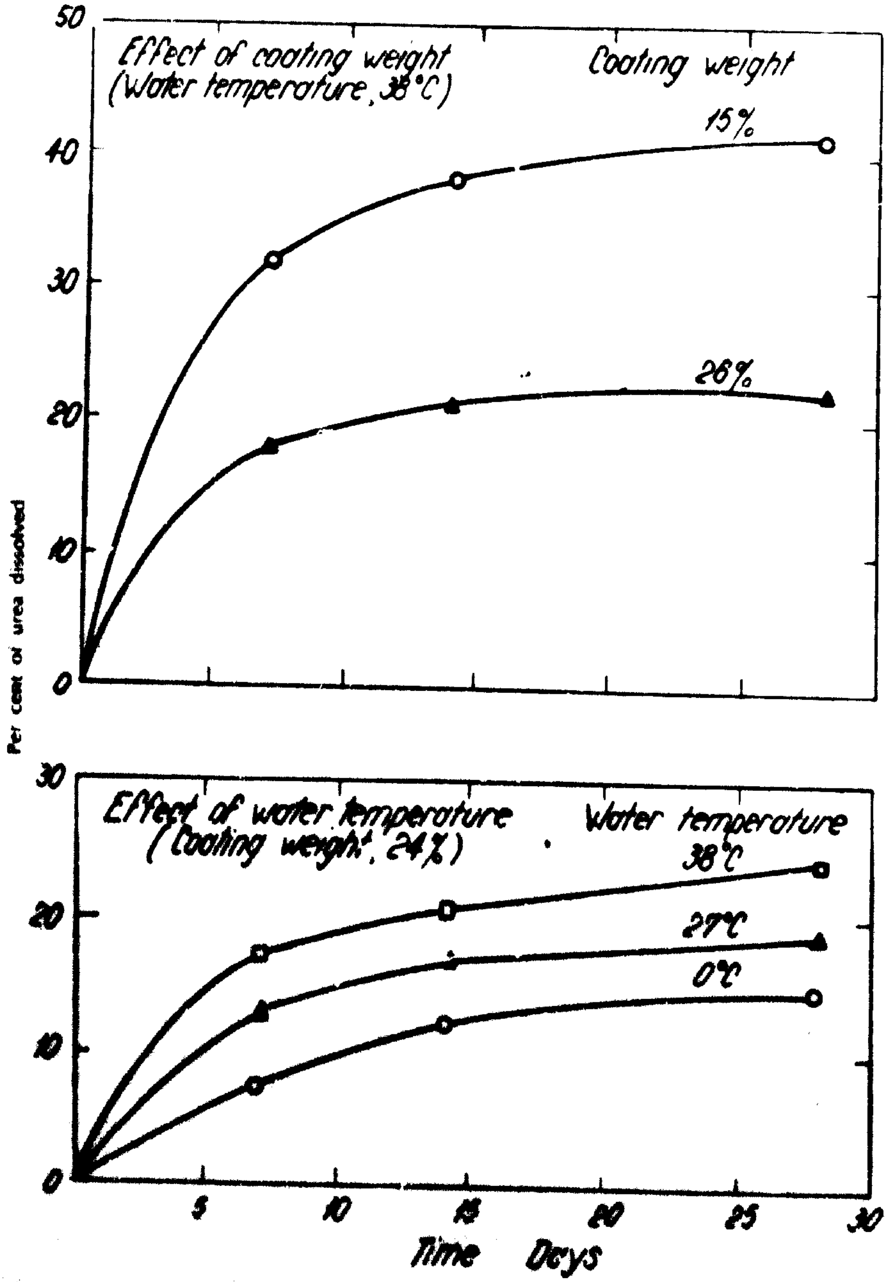

Figure VII. Rate of dissolution in water of coated urea (1.7—3.4 mm)

mum concentration of N-Serve in the soil for delaying nitrification at least six weeks is said to range from 0.5 to 10 parts per million.

Dow points out that a nitrification inhibitor is needed only when the soil suffers from high nitrogen loss because of heavy rainfall or heavy irrigation, or when the soil is coarse textured, or is in the pH range where nitrification occurs readily, or for anaerobic soil.

Potassium azide (2 to 6 per cent KN_3) dissolved in anhydrous ammonia was effective in lowering the rate of nitrification in tests conducted by the United States Department of Agriculture in cooperation with agricultural experiment stations in the states of Louisiana [illegible] and Washington [illegible]. PPG Industries, Inc., is exploring this and other agricultural uses e.g. as a herbicide in rice culture) for the azide. A commercial production unit is anticipated in about three years.

Another nitrification inhibitor that has received much attention in Japan is 2-amino-4-chloro-6-methyl pyrimidine. It is manufactured by Mitsui Toatsu Chemicals Inc. (formerly Toyo Koatsu Industries Inc.) under the trade name AM. Japanese companies produced 15,400 tons of NPK fertilizers containing AM in 1968.

Controlled-release potassium fertilizers

Some interest has been shown in controlled-release potassium fertilizers. TVA conducted tests with potassium polyphosphates and potassium calcium pyrophosphates. Some of the materials were found to be only slightly soluble in water by the AOAC procedure. Agronomic evaluation of the materials was reported by Engelstad [41] and their only advantage was that they helped to reduce injury to germinating seeds. Most of the materials, however, were determined readily available as soluble potash salts. Some of the least soluble materials showed slow-release characteristics when applied as large particles (about 7 mm) but there was no conclusive evidence of increased efficiency.

More recently, sulphur-coated potassium chloride has been prepared by TVA for agronomic tests. Some of these tests were promising in that yields were increased in comparison with uncoated potassium chloride [42]. More information is needed for agronomic and economic evaluation. The low cost of soluble potassium fertilizers tends to discourage efforts to increase their efficiency.

Conclusions about controlled-release fertilizers

Controlled-release nitrogen fertilizers will probably prove useful for some field crops in some situations, but much more study is required to determine the place of controlled-release nitrogen fertilizers in the farm economy.

Controlled-release fertilizers are most likely to prove profitable where labour is scarce and expensive. In developing countries where labour is plentiful, multiple applications of soluble fertilizers can be used to increase crop yields. Prospects for improvement of phosphate and potassium fertilizers through controlled release seem remote.

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SULPHURIC ACID: PRODUCTION, TECHNOLOGY AND PLANT CONSTRUCTION IN POLAND

Jan Wozniakowski *)

Introduction

Sulphuric acid is a very important intermediate for the manufacture of a wide range of chemical products which include fertilizers, dyes, inorganic compounds and synthetic fibres. Its production is used as a measure of the economic and industrial development of a country.

The fertilizer industry is the largest consumer of sulphuric acid. The world trend is towards phosphate fertilizers, which are produced by treating phosphate rock with sulphuric acid (the wet method).

Considering today's low sulphur prices and the rising costs of mining and extracting, there would seem to be good reason for the development of phosphate production on a phosphoric acid base as this yields fertilizers analysing 18—46—0 and even higher, based on superphosphoric acid. A part from this application, NP-granulated phosphates can be mixed mechanically with other monocomponent granules, or macro-grain phosphates to produce a series of tri-component fertilizers complete with micro-elements, according to the demands of agriculture. This is the direction in which Polish phosphate production is developing: the production of sulphuric acid has gained in importance and the proper technology and raw material have became very significant.

Raw materials for sulphuric acid production

Poland is fortunate in having at its disposal a number of raw materials containing sulphur of a very high purity. The country also uses the following raw materials in the production of sulphuric acid:

Anhydrite and gypsum
Sulphur-refining wastes (cake)
Sulphur dioxide (SO_2) containing gases from non-ferrous ores calcination (zinc, lead, copper)
Hydrogen sulphide and off-gases

The installations that used pyrites up to 1970 have been converted to sulphur as the high cost of mining pyrites had resulted in the closing down of the mines.

Polish sulphur which is supplied mainly in liquid form contains 99.9 per cent pure elemental sulphur. Thus, no additional preparation is needed before it is used in production. The installation itself is relatively simple and investment costs are very low.

Anhydrite and natural gypsum, which are still being used in one plant are to be replaced by phospho-gypsum waste from phosphoric acid production. The results of semi-technical pilot-plant tests, and tests on

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the industrial scale have indicated the possibility of producing sulphuric acid of a high standard on this base. The following are the average analyses of sulphur-refining wastes rich in elemental sulphur :

Percentage	
35 —40	Sulphur (S)
1.2— 1.8	Gypsum ($CaSO_4$)
52 —58	Calcium carbonate ($CaCO_3$)
4 — 6	Water (H_2O)

These are very suitable for sulphuric acid production and have waste-calcines that may be used as calcium fertilizers. The average composition of these residues is :

Percentage	
84 —90	Calcium carbonate ($CaCO_3$)
9 —16	Gypsum ($CaSO_4$)
0.1— 0.5	Calcium sulphide (CaS)
0.1— 0.5	Elementary sulphur (S)

Gases which contain 4—12 per cent of sulphur dioxide (SO_2 e.g. smelter gases) may now be used only in sulphuric acid production, as a result of the raising of pollution control standards.

Hydrogen sulphide (H_2S), extracted from gas-purification masses finds a small application in some Polish plants and the sulphuric acid produced from it is used in ammonium sulphate production, which makes the whole process economical.

Sulphuric acid technology

METHODS USED IN POLAND

Over 90 per cent of the sulphuric acid plants in Poland operate on the contact process.

The remainder, which work on the chamber process, will be phased out gradually, up to complete liquidation in 1980—85.

Production of sulphuric acid is increasing rapidly. In 1946 it was as low as 190,000 tons per year ; in 1965 it passed the 1 million tons per year and in 1970 it reached 2 million tons per year. The national raw material base changed over the same period as may be seen from the table below :

Percentage 1965	1970	
40	60	Sulphur
18	—	Pyrites
17	18	Metallurgy waste gases
14	13	Sulphur refinery wastes
9	6	Anhydrite-gypsum
2	1	Others

In the years immediately following the Second World War, there was a tendency to build plants of comparatively low capacity, e.g. [illegible] tons per year. Nowadays much larger units are erected : the largest units now in operation in Poland have a capacity of 230,000 tons per year while the smallest has [illegible] tons per year. Units of up to [illegible] tons per year will be built in the coming years, either for use in Poland or for export. The largest unit built so far by Polish designers and contractors is a [illegible] tons per year plant located in the Federal Republic of Germany.

Most plants are based on single conversion and absorption. Since [illegible] however sulphuric acid units in Poland have been using double conversion and absorption.

It is expected that the remaining single contact units working on a base of sulphur-refining wastes or natural sulphur will be re-designed and converted to the double-contact process. Sulphuric acid plants based on sulphur dioxide (SO_2) in smelter gases use single contact. The SO_2 content in the flue gases is diminished by ammonia absorption, ammonium sulphate being the by-product.

As the production of sulphuric acid using a sulphur base is expected to increase in the years to come, this process will receive most attention in this paper; other methods which are less attractive and seldom applied, will be described superficially only. The following table shows clearly the shift of the world raw material base in the direction of sulphur:

Raw materials consumed in sulphuric acid production

(percentage)

Raw material	World		West Europe		United States	
	1952	1969	1952	1969	1946	1970
Sulphur	43.8	58.2	18.0	35.7	79.1	77.9
Metallic sulphides	51.4	26.6	78.8	47.0	13.3	8.4
Others	4.8	15.2	3.2	17.3	7.6	13.7

SULPHURIC ACID PRODUCTION ON SULPHUR BASE (FIGURE 1)

Raw material (sulphur). Poland has rich deposits of sulphur and this fact has naturally influenced sulphuric acid production in the country.

In 1965 production on this base amounted to 40 per cent; in 1970 it was 64 per cent; now it is more than 70 per cent of the total country capacity.

The composition of Polish sulphur is as follows:

	Percentage	
	Liquid	Solid
Elemental sulphur, over	99.95	99.85
Impurities (total), below	0.05	0.15
Arsenic	0.000	0.000
Selenium	0.000	0.000
Acids (as H_2SO_4), below	0.007	0.01
Organic compounds, below	0.015	0.02
Ash	0.04	0.1

Sulphur transport and storage. Sulphur is transported mainly (up to 90 per cent) in the liquid state. It is transported in special 50 tons railway tanks equipped with steam-heating coils that may be used to prevent it from becoming solidified. This heating system is not used during transportation however.

At the plant, the tanks, before they are cleaned, are heated by means of 5—6 ata saturated steam. The melting period varies from 5 to 10 hours, depending on weather conditions and period of transportation. Tank clearing is carried out by means of pipe connections in the bottom of the tank. Alternatively, they may be cleared by pumping the liquid sulphur out through an upper hatch, by means of a special moveable pipe-arm with on elastic joint, either directly into a main storage tank or into an intermediate tank from which it is later transferred, using submerged pumps, into the main tank. The clearing takes from a half to two hours, depending on the method used.

The storage tanks, which are of steel, are also steam-heated. In order to keep steam consumption to a minimum, the tanks and pipings are insulated and covered with aluminium sheet, which in addition, provides protection against damage and weather.

The capacity of the tanks ranges from 500 to 3,000 m^3. Their design enables periodic clearing of residues (mostly impurities) to be carried out.

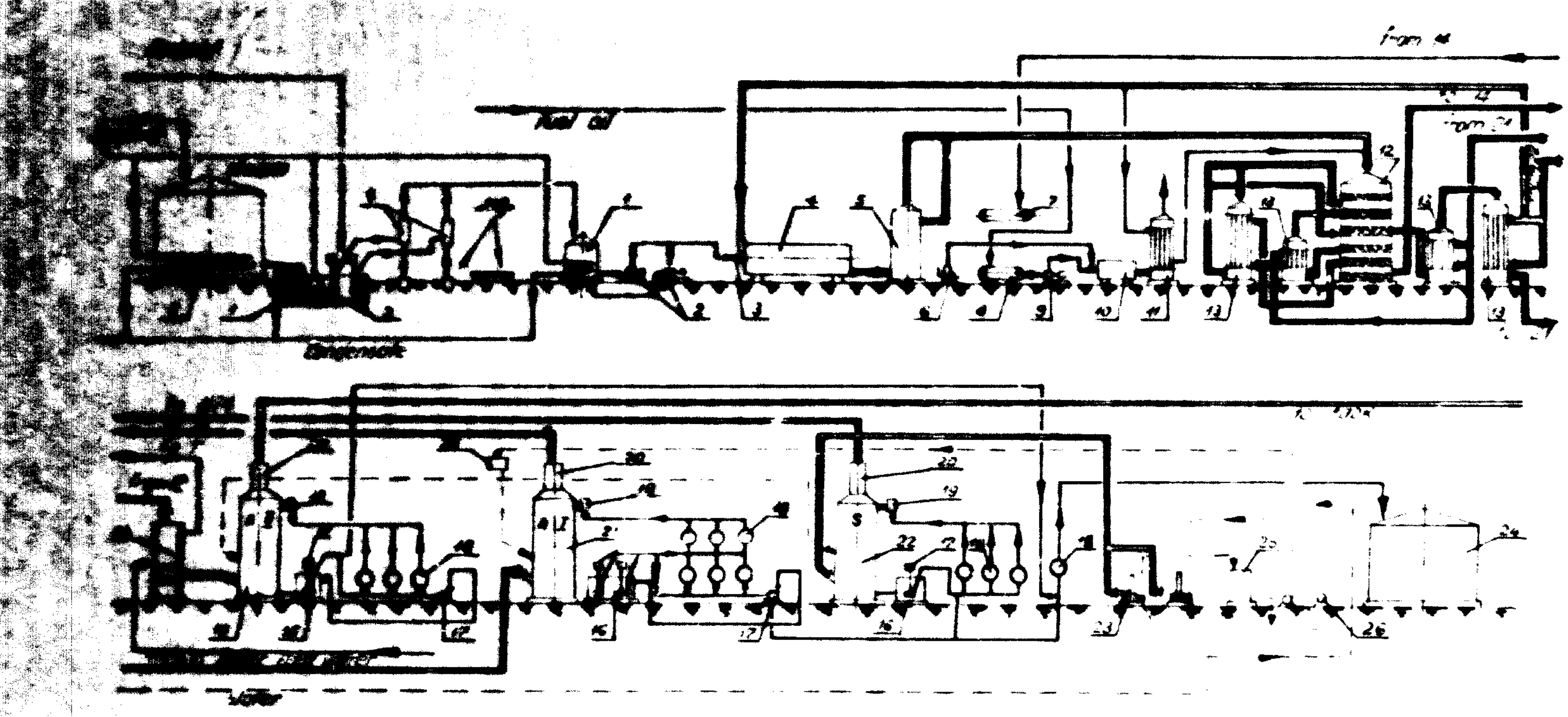

Figure I. Sulphuric acid plant by double contact sulphur-burning process

1. Sulphur storage tank
2. Sulphur pump
3. Sulphur burner
4. Sulphur furnace
5. Boiler
6. Air fan
7. Boiler feedwater tank
8. Oil tank
9. Oil pump
10. Start-up furnace
11. Heat exchanger
12. Convertor
13. Heat exchanger
14. Economizer
15. Absorption tower I
16. Pump tank
17. Acid pump
18. Spiral cooler
19. Acid filter
20. Demister
21. Absorption tower II
22. Drying tower
23. Blower
24. Acid storage tank
25. Water tank
26. Water pump

Subsequent filtering prevents the solidification of dirty sulphur in the tank bottom and permits the bottom steam coils to be dispensed with. The total steam consumption including railway tanks, storage tanks, filtering equipment pumps and piping, amounts to 80 - 100 kg per ton of sulphuric acid produced. This of course, depends on the period of transportation. For solid sulphur, the total consumption is 100 - 120 kg per ton of sulphuric acid.

Solid sulphur is transported mainly in open railway cars, which are covered with canvas to protect the sulphur against atmospheric influence and spilling. The cars are unloaded by means of a holder gantry or a mechanical shovel. Solid sulphur is stored in covered warehouses surrounded by 3 m/high retaining walls or in open stacking yards.

Sulphur preparation. Solid sulphur, which is used only in some of the older plants is transferred from storage to the melting tanks by means of a grab or on a conveyor belt, the belt scales registering the quantity to be transported.

The melting tank is equipped with steel pipe roasts, which serve as melting elements heating coils to keep the sulphur liquid, and special mixer to speed up the melting process. The molten sulphur feeds, into the dirty- sulphur storage tank, after it has been filtered in the primary network filter.

The dirty sulphur is shoved in an underground tank made of concrete, lined with acid-proof bricks and equipped with steam-heating coils and compartments for diatomaceous earth precoat feeding of candle filters. Several pumps are installed in this tank : one is part of the filtering system, the others are used in the unloading of railway-tanks, eventually pumping into the storage tanks.

When a diatomaceous earth precoat has formed, the suplhur is filtered again by pumping it through a filter cake.

In the case of liquid sulphur, the underground storage tank serves as a railway-car clearing tank ; to speed up the clearing activities additional pumps of greater capacity must be installed.

The capacity and pressure of unloading and filtering pumps depends on the solid sulphur size, distance to storage tanks und type of filter. Graphite candle filters are normally used. For a 100,000 tons per year sulphuric acid unit only two are needed, each with a filtering surface of about 206 m^2.

For larger units, larger candle filters or pressure filters with a special stainless steel network are used. Under normal conditions, pure sulphur containing 99.999 per cent elemental sulphur can be obtained. The filtration process is controlled according to the sulphur pressure indications on the manometer. In the case of graphite candles, the pumps are stopped and the process is finished when the pressure reaches 3.5 ata. A reverse flow of steam strips off the filter cake with all its impurities. This cake, which is immediately solidified in cold water, contains about 50 per cent elemental sulphur and serves as raw material in another plant. Similar waste material obtained during sulphur refining is also used later. Approximately 0.16 kg of a special kind of diatomaceous earth is used per ton of H_2SO_4.

Filtered sulphur is fed into the pure-sulphur tank, from which it is pumped, by means of gear pumps, through the flow-meter into the burner in the furnace.

The pure sulphur tank is designed either as an underground tank, with a construction similar to that of the dirty sulphur tank, or as a steel surface tank. The sulphur furnace feed pumps have different capacities according to the productivity of the unit, the pressure ranging between 12 and 16 ata to permit fine sulphur atomizing in the furnace. Output of the pumps is regulated by either rotation speed or needle valve control. In all cases the sulphur pump output control is automatically guided by the sulphur dioxide (SO_2) concentration in the boiler flue gases.

Sulphur combustion and heat utilization. The sulphur combustion process releases a large amount of heat. The combustion reaction to SO_2

is a highly exothermic process ; one kg of burned sulphur emits 2211 kcal. Theoretically, combustion of sulphur in air will give a concentration of SO_2 in the gases of up to 21 per cent, and a considerable concentration of sulphur vapour. Practically, sulphur-vapour-free gases up to an SO_2 concentration of 18 per cent can be obtained by using an extended combustion surface and additional ceramic grates after-burners. The specific heat loading of this assembly is obviously lower. This kind of combustion is used in the case of by-production of liquefied SO_2, by partial SO_2 condensation out of cooled gases, where the remaining SO_2-containing gases are processed into sulphuric acid.

In conventional sulphuric acid plants, the sulphur combustion process is operated so as to give an SO_2 concentration of 8—14 per cent.

In Poland there are two kinds of sulphur-burning installations : low capacity and high capacity. In low capacity units (about 150,000 tons per year of sulphuric acid) sulphur combustion of up to 12—13 per cent SO_2 content is desirable. Gases of such concentration are further processed by cooling down, beginning from the second converter shelf and by direct air blending ; in this way the proper conversion of SO_2 into SO_3 is obtained.

In high capacity units (200,000—500,000 tons per year) sulphur combustion of up to 9—10 per cent SO_2 content is preferable. A concentration of 10 per cent is mostly used.

Filtered sulphur is burned with dry air warmed to 250—260°C by post-contact gases. A temperature of 1,140°C is then reached in the furnace exhaust side. After the gases passing through the boiler have been cooled down to 430—440°C, they may be fed over the first contact shelf.

In smaller units, a horizontal furnace which works at the same time as boiler is used, its construction being such that in the axial part of it, the combustion takes place, and the emitted heat is radially given to the boiler elements forming the external walls. In large units, where the furnace and boiler are separate, the furnace is used first.

In sulphur combustion furnaces a specific heat load of 180,000—200,000 kcal/m^3.h is obtained.

In newer models, with specially designed combustion chambers, a specific heat load of 600,000 kcal/m^3.h is reached. The combustion process and its intensivity depend on the degree of sulphur atomizing and air feeding ; the main furnace elements are the burner and the air-inlet nozzle arrangement. Burning is started by means of fuel gas or oil.

In Poland there are horizontal and vertical sulphur furnaces, the former being preferred for construction reasons.

Boilers, which utilize the heat produced by sulphuric gases, are of both designs, with natural and forced circulation. Steam utilization conditions for the boilers are : pressure, 20—40 ata ; temperature, 350—450°C. Steam generation output varies between 1.1 and 1.0 tons of steam per ton of sulphuric acid, depending on whether it is a single or double contact unit. Boilers are fed with warm water, which passes first through an economizer in which it is degased by warming up to 250°C, by means of hot contact exhaust-and-tower-in-coming gases. Circulating and water-feed pumps are driven either by electric motors, fed by two independent sources, or by both electric and steam drives. Boiler flue gases, which have a temperature of 430—440°C, are not filtered in new installations as the sulphur filtration is sufficient to keep them clean.

Contact. In a sulphuric acid single contact unit with a capacity of 150,000 tons per year five-shelf contact apparatus is used. The reaction heat of gases that have passed the first shelf is taken away in an exchanger by the combustion air ; gases that have passed three shelves are cooled by the intake of cold air.

Intake gases on the first shelf have an SO_2 concentration of 12 per cent ; in the exhaust an SO_2 concentration of 0.5 per cent is obtained. The conversion ratio in this case amounts to [illegible]—98.5 per cent. Catalyst requirement amounts to 200—220 l/t day of sulphuric acid.

In sulphuric acid single contact units of larger capacities, reaction gases, after passing each shelf are cooled with sulphur combustion air in heat exchangers. In this case four-shelf contact apparatus is used, together with three pipe exchangers. Conversion ratios and catalyst requirements remain on the previously cited levels. On the first shelf the conversion ratio reaches 60—70 per cent, on the second it is 20—32 per cent.

In double contact units, one four shelf contact and a number of heat exchangers are used. The first conversion stage consists of three contact shelves, the second one is formed by the fourth shelf. The gases leaving the first shelf attain a conversion of 60 per cent, then they pass through the first exchanger warming up the gases destined for the second stage. Gases passing the second shelf reach a total conversion ratio of 85 per cent and after the third shelf it becoms 92—92.5 per cent. Gases leaving each shelf are cooled by fresh gases passing to the second stage, those leaving the third shelf being additionally cooled by air taken in for sulphur burning. This helps to keep the temperature of gases being guided to the first absorption tower at the 200 C level. Gases leaving this tower pass through heat exchangers, where they are warmed up to 430°C before being guided into the second conversion stage. After this stage the total conversion ratio amounts to 99.8 per cent (In new designs a total conversion ratio of 99.9 per cent is expected).

Gases leaving the second stage pass through the economizer where they are cooled down to 220 C while the boiler water is being warmed up to 260 C. When they leave this stage, the gases enter the second absorption tower. As a result of this catalytic action, the intake gases over the respective shelves have the following temperatures :

Shelf	Temperature (°C)	Conversion ratio (percentage)
I	430—440	60—70
II	440—450	85—88
III	430—440	92—94
IV	430—440	99.8—99.9

The catalyst requirement in a double-contact unit amounts to 180—200 l/t day. The satisfactory working period lasts over 10 years, provided the layer on the first shelf is screened or reactivated every 2—5 years the length of time depending on the condition of the sulphur-filtration assembly.

In Polish designed units, insulating brick-lined contact apparatus is used. The elements in contact with SO_2 or SO_3 gases are made from or covered with, aluminium. Shelf supports and plates are made of heat-resisting cast iron ; screens are made of heat-resisting steel that is SO_2 and SO_3 proof. Specially designed systems for the distribution of the gas over the shelves provide a uniform flow through the total contact-mass surface, thus reaching high conversion ratios. The most difficult problem is to keep the SO_2 concentration of effluent gases as low as 0.8 g SO_2/Nm^3 of gas at the highest possible conversion ratios. Heat exchangers are aluminium sprayed, and the working period of the unit lasts as long as 350 days in a year. The economizer of a single-conversion unit is made of brick-lined steel, and the pipes, which are finned, are of coated cast iron.

In double-conversion units the economizer may also be steel ; as the SO_3 concentration in the second conversion stage is very small, finned pipes must be used to keep its dimensions within proper limits. All equipment, ducts and pipings in contact units are externally insulated. The unit is started up (warmed up) with the help of furnace heat. The catalyst may be formed either by burning small quantities of sulphur in the furnace, or by feeding 100 per cent SO_2 to the hot air pumped into the contact apparatus.

Drying and absorption. Air for the drying tower is usually pumped by the blower into the sulphur furnace, through the tower and heat exchanger.

In Polish designs, blowers are outside the drying tower. This means that steel blowers can be used, which is a definite advantage. Special oil filters, air filters, and a damper for silencing noise above 85 dB, are installed on the blower. The air from the tower exhaust contains less than 0.1 g/Nm³ moisture. For air drying 94—96 per cent sulphuric acid is used. The towers are packed with ceramic rings of 50 mm or 80 mm in diameter. Demisters are installed on top of these to catch mist or rain droplets. This lengthens the life period of the exchanger. Specially designed units assure the proper distribution of sprayed acid. The bottom part serves as a pump sump, while the submerged pumps are used for circulating acid, spraying and cooling. Acid is pumped through the exchangers and the cast iron drip coolers, which have recently been replaced by acid-proof steel spiral coolers. Air coolers are used in regions where the water supply is low.

The tower cycle is fully automated for the production of a given acid concentration.

The temperature at the tower inlet is kept at 40—45°C. The absorption assembly of a single-contact unit consists either of an absorption tower or an oleum tower plus an absorption tower. For double contact the assembly is enlarged by a second tower with circulation equipment. The circulation cycle of the absorption tower is similar to that of the drying tower with the exception that the former has a more intensive spray system, the acid concentration being 98.5—99.0 per cent and the temperature 60—70°C. The absorption tower inlet gas temperature is kept at 200—220°C and a quenching intensity of 20—36 m³/m².h is maintained.

For oleum production, the same capacity is possible, provided that low air-humidity and a concentration less than 25 per cent of free SO_3 is maintained. In Polish designs the production of 37 per cent free-SO_3 oleum is possible. The cycle of the oleum tower, which is made of steel, is identical to that of the absorption and drying towers. To keep the oleum tower in proper working condition, it is by-passed on the gas side, as the first absorption tower is ; thus, the absorption inlet gas temperature is high, the absorption itself is very complete, and the 99.98 per cent ratio guaranteed.

The demisters reduce the moisture content in the flue gases. The SO_3 concentration in the tower exhaust gases is as low as 0.1 g/Nm³. The acid and oleum produced are directed into the storage tanks and, according to the concentration desired, are drained out, either from drying or in the case of double contact, in the second absorption tower. The absorption and drying tower cycles are automatically coupled together to give the required concentrations of the product.

Acid and oleum storage. The oleum tank is heated by means of water coils installed on the outside wall, the whole being insulated. Acid and oleum storage tanks are drained from the bottom, with the help of small submerged pumps. There are double valves on the draining flanges.

The total acid and oleum production is cooled down to 40°C and is metered with the help of the flow-meters.

Sulphuric acid double-contact unit. The sulphuric acid unit is built in the open air. Only the blowers and control desk are housed. The whole unit is automated to a large degree, which automatically secures the main working parameters. The following data are representative of this unit :

332 kg/ton H_2SO_4	Sulphur consumption
40 kWh/ton H_2SO_4	Electrical energy consumption
30—40 m³/ton H_2SO_4	Cooling water consumption
99.8—99.9 per cent	Conversion ratio
99.98 per cent	Absorption ratio
1.0 ton/ton H_2SO_4	Steam generation
80—120 kg/ton H_2SO_4	Steam consumption
3 shift	Crew

Sulphuric acid production based on anhydrite and phosphogypsum

Poland has anhydrite-based sulphuric acid plants with capacity of 70,000 tons per year. The erection of new plants based on this raw material is not planned, because of high capital costs, but conversion to phosphogypsum base may be a reasonable alternative. Industrial tests have revealed that cement of "350" quality and sulphuric acid may be produced in this way. The production process consists of four phases :

Raw material preparation
Calcination of process mixture
Sulphuric acid production (from SO_2-containing gases)
Clinker fabrication for cement.

The raw materials are dried, ground and finally made into a mixture of phosphogypsum, coke, lime, sand and calcines. The most difficult parts of this process are drying with simultaneous degasification and removing the considerable quantities of fluorine. The calcination is carried on in rotary kilns 70—100 m long, the standard size in the cement industry. Gas, oil or coal-dust are burned to produce an inside temperature of 1,250° C. The exhaust SO_2 containing gases, after they have been de-dusted in dry electroprecipitators, cooled and washed in quench towers and wet precipitators and dried in a drying tower, constitute together with air an SO_2 concentration of 5.5—6.0 per cent, the base of sulphuric acid production. A strict washing discipline must be observed in order to remove fluorine, which is a contact-mass poison. The clinker is fabricated in the same way as for cement. The following are data for the raw materials consumption :

1,700 kg	Phosphogypsum (recalculated as 100 per cent calcium sulphate $CaSO_4$)
110 kg	Coke (80 per cent elemental carbon)
250—300 kg	Lime, sand, pyrites calcines (recalculated on dry mass)
240 kWh	Electric energy
50 m³	Cooling water (20°C)
360 kg	Fuel oil $\left(\text{heating volume } 9{,}000 \ \frac{\text{kcal}}{\text{kg}}\right)$

The installation can produce small quantities of 25 per cent oleum, as well as sulphuric acid.

This process is unprofitable in times of low sulphur prices, but it is interesting in terms of the utilization of wastes from future phosphoric acid production.

Cement of "350" quality is characterized by the following :

	After 3 days	After 7 days	After 28 days
Bending strength	25	40	60
Compressive strength	130	225	350

Before use, the phosphogypsum is washed on the final filter to reduce its P_2O_5 content to 0.2—0.3 per cent. Fluorine-containing waste waters are treated with lime and then filtered. Discharge into the sewers of water containing fluorine is forbidden in Poland.

Sulphuric acid production on cake base

Poland uses its large quantities of sulphur-refining wastes (cake) as raw material for sulphuric acid production. The calcination process is carried out in a fluidized-bed calciner with a bed surface loading of 10 ton/m^2/day. The fluidized bed, which is made of 2—4 mm grain sand, is artificial. Boiler pipe elements, protected against abrasion, are installed inside the bed. The calciner exhaust gases with a SO_2 concentration of 13 per cent and temperature of 550 C pass through the boiler, where they are cooled down to 400—450 C and further processed in normal sulphuric acid units furnished with cooling and washing systems, wet electrostatic precipitators, drying tower, blowers and contact and absorption assemblies. A conversion ratio of 98 per cent is achieved in single contact and one of 99.5 per cent in double contact.

The wash waters of the scrubbing system, after the SO_2 has been desorbed and neutralized, are fed into the sewage system.

The calcines, the wastes of the method, are used in agriculture as lime fertilizers.

A very important element of this process is the proper collecting of dust. Special, large, dry precipitators are installed to clean the gases to the maximum possible degree before they are washed. These precipitators, which work on 60 kV voltage must have 99 per cent efficiency, otherwise great losses of SO_2 occur and the calcines represented in large amount by the calcium carbonates become contaminated with SO_2 and SO_3 gases.

Sulphuric acid production on SO_2 containing gas base

In non-ferrous metallurgy, particularly in copper smelting, gases containing 4—12 per cent SO_2 are produced. The composition of the gases changes in the course of time, depending on the copper converter operation used. In Poland there are two large copper metallurgy plants. Each of them has installed several converters but they do not work continuously. Their working time should be ideally settled in a manner that would secure the most uniform gas concentration, but this is difficult to achieve. Therefore, in order to prevent contact cooling or low conversion ratio, additional sulphur-burning furnaces have been built, which stabilize SO_2 content and keep SO_2 conversion ratios high.

The gas temperature during the converter working period fluctuates between 1,200 and 350°C ; this is the cause of sulphuric acid condensation in coolers and in the electrostatic precipitator. By means of sulphur, after burning, the gas temperature is elevated, the corrosion possibility is diminished and the conversion ratio reaches 96 per cent, which is satisfactory in this sort of installation. The resulting SO_2 gas is captured by ammonia absorption ; SO_2 conversion ratios of 80—90 per cent and a SO_3 ratio of 50 per cent are obtained. As the water for cooling and washing contains large amounts of dissolved SO_2, it must, before its discharge as sewage, be desorbed in a tower by an air stream and neutralized. The rest of equipment, from washing tower assembly to storage, is similar to that needed for a cake-based unit.

Sulphuric acid production on pyrites base

At present, although Poland has no pyrite-based sulphuric acid units of its own, builds complete plants of this type for export. Moreover, Polish experience with similar units based on zinc blend and filter cake has made it possible to further improve and modernize these units. At present, the double-contact principle is being introduced, and this ensures a considerable drop in the SO_2 content of flue gases.

Export of sulphuric acid and means of transportation

In summer time, in Poland, sulphuric acid concentrated up to 98 per cent is produced, in winter, because of low temperatures and freezing possibilities it is 93—95 per cent. Oleum of great purity (25—35 per cent or 65 per cent of free SO_3) and a reagent of special purity for analysis are also steadily produced.

Deliveries are made by the producers, as sulphuric acid plants have their own railway transportation equipment and cars. Very large quantities are shipped by train, or, as it is frequently the case now, by special ocean-going tankers. In 1971 over 150,000 tons of sulphuric acid, were exported.

Poland has a large surplus of sulphuric acid, and in case of urgency, 250,000—300,000 tons per year may be exported. In the harbours, bases for loading tankers up to 10,000 DWT have been extended and storage parks and other necessary equipment make it possible to load or discharge rapidly.

However, sulphuric acid is difficult to transport because of its corrosive character. It is much more economical and practical to transport the raw material, i.e. sulphur, as only one ton of this is needed to produce three tons of acid. Transportation of acid is recommended only if the receiver wants to avoid troubles connected with the flue gases (although the SO_2 quantities in these cases are very small), to avoid poisoning sewage, or in the case of break-downs.

Oleum export is of little significance as there is only small demand for it, nevertheless, the necessary quantities may be delivered in railway cars or steel containers.

Economics of sulphuric acid production. The erection of a sulphuric acid unit requires considerable capital, the amount depending mainly on the kind of raw material to be used. Costs of an unit comprised within "battery limits" on a base of sulphur, pyrites, or calcium sulphates (anhydrite, gypsum) the world's main raw materials — are approximately in the proportion of 1:3:9. When, anhydrite or gypsum are used, clinker (cement) is also produced, which is reflected in the capital and operating costs.

Erection costs of SO_2-containing gas base units are not taken into account, as generally speaking these are only used when it is necessary to avoid air-pollution, and their cost is higher than pyrite-based units.

The most economic, therefore, is the sulphur-based unit. The actual cost of unit of this kind, with a capacity of about 300,000 tons per year double conversion and absorption, within "battery limits", amounts to $ 4 million whereas a pyrite-based unit with the same capacity and adequate "battery limits" would cost some $ 13 million. The total cost is, of course, much greater when energy, transport, administration and other costs are taken into account. Capital requirements and capacity will depend on local needs, as the sulphuric acid units as a rule comprise part of larger plants or are integrated in factories, where the acid serves as a semiproduct to final product fabrication.

Operating costs vary greatly, those of sulphur-based units being the lowest. In large units, as a rule, direct operating costs are approximately covered by income from steam generation as the sulphur combustion heat is utilized. Accordingly, in these units operating costs are defined as sulphur preparation costs and indirect costs such as amortization, capital lock-up, and over-all unit, plant or factory costs. As all other bases have much higher fabrication costs their raw material prices must be much lower than the price of elemental sulphur if they are to be competitive, hence the tendency of pyrites sulphuric acid producers to keep pyrite prices down. For example, in 1971 the cost of 48 per cent S pyrites (f.o.b. export harbours), was $ 9—10 per ton, i.e. $ 19—21 per ton S, whereas imported sulphur prices in Europe ranged from $ 23—26 per ton, depending on location. Thus, to be competitive, pyrite prices should be as low as $ 7—9 per ton, which is impossible in view of the higher mining and separation costs and steadily falling sulphur prices.

Many pyrites sulphuric acid plants have already been converted to sulphur base, and it would seem obvious that many more will follow suit.

Newly built sulphuric acid plants will be based mainly on sulphur and only countries possessing very cheap pyrite supplies will be interested in pyrite plant development. Prices of sulphuric acid delivered by train range from $ 20—30 per ton and show a tendency to drop, because of the steady dropping of sulphur prices and the utilization of larger means of transport such as tankers. The cost of transporting raw material plays a considerable role in the economics of sulphuric acid production, which depends mainly on the specific quantity of the raw material needed to produce one ton of acid. In sulphur-based production, 332—340 kg of raw material is sufficient to produce one ton of acid. Thus, sulphur-based plants need not to be located near sulphur sources, as the weight of the transported raw material is only one third that of the product itself. In the case of pyrites, the total weight of the raw material is up to 75—80 per cent that of the acid produced and may equal it if low-grade pyrites are used. Sulphur — or pyrite-based plants are generally located near the consumption centres, which are usually the components of large phosphates plants. Anhydrite — or gypsum-based fabrication presents a different situation. In this case consumption of raw material amounts to 1.8—2.0 ton/ton of acid produced ; additional large quantities of sand, lime, pyrites, calcines and other materials amount to 0.25 ton/ton and, together with fuel — 0.4 ton/ton — bring the total weight of materials to 2.5—2.6 times that of the acid produced.

Although they produce a great quantity of cement, the location of these plants does not depend on the demand for cement but on the sources of anhydrite or phosphogypsum.

Unit capacity is another factor in the economics of sulphuric acid. The larger the producing unit, the lower are the operating costs and consequently, the lower the prime costs. The optimal unit capacity is expected to be high. The largest units may be erected only on a sulphur base, where the highest SO_2 concentrations are available in the combustion process and the necessary oxygen concentration is of such degree that the conversion ratio reaches 99.9 per cent. Some acid plants nowadays have a capacity as high as 700,000 tons per year, which brings the prime cost down to less than 10 $/ton. Foreign trade, an important factor in the development of sulphuric acid production, shows a tendency to increase, though its present share in total world consumption is only 1.2—1.6 per cent. An increase in foreign trade is foreseen for the coming years for the following main reasons :

a) Production costs vary greatly. In the case of non-ferrous metallurgy the acid is only the by-product and manufacturers may fix its price very low ; other producers may compete by using very cheap raw materials or large production units.

b) Transportation costs are inversely proportional to the trade increase: as long-distance supplying is profitable, the receivers are not obliged to start their own production. Under certain conditions, these factors may induce an increase in trade rather than the development of production.

Research, design and executing possibilities for the Polish sulphuric acid industry

Among the countries of the Council for Mutual Economic Assistance (CMEA), Poland is the leader in sulphuric acid technology and its exports in this industry are considerable. Over 30 complete sulphuric acid plants or installations, on both sulphur and pyrites bases, single and double-contact principle, have been exported. Most of the units exported to CMEA countries, varied in capacity from 100,000 to 360,000 tons per year H_2SO_4. In Poland itself over 30 plants, on different raw material bases have been built. The specialized equipment and machines needed are produced by Polish industrial firms.

At present the import of equipment from Western countries is confined to several types of control instruments and fittings. Of course, special equipment may be imported to comply with the wish of a client or when delivery periods are limited. Polish catalyst production being insufficient to the demand created by the newly erected units it relies on imports from the German Democratic Republic or Western Europe.

In order to maintain its strong position in sulphuric acid technology, Poland has established a research institute, design office, experimental base and executing forces and bought licences for the production of special equipment. Under the guidance of the Study, Design and Executing Office "Biprokwas" in Gliwice and with the aid of the Inorganic Chemistry Institute, over all progress has been made.

As a result of this technology developed in Poland with the co-operation of specialized firms abroad "battery limits" sulphuric acid plants with capacity of 500 000 tons per year based on pyrites feedstock have been delivered to clients in other countries under "turn-key" contract basis. One of these plants was exported to the Federal Republic of Germany under such conditions.

SUMMARY OF THE REPORT ON THE CHEMICAL FERTILIZER PRODUCTION AND CONSUMPTION IN ALBANIA, BULGARIA, CYPRUS, CZECHOSLOVAKIA, GREECE, HUNGARY, MALTA, POLAND, ROMANIA, SPAIN, TURKEY AND YUGOSLAVIA

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A preliminary research of the chemical fertilizer problem, on the whole, in the countries that are the analysis purpose of this survey, has indicated that, generally, there is an important base for developing the consumption and the fertilizer output in these countries.

Under these conditions, the chemical fertilizer state in the countries under research was presented in point of the two main features, consumption and output.

The paper has three chapters.

Chapter I. As for the chemical fertilizer consumption, there are analyzed aspects regarding the present consumptions, provisions, knowledge degree, etc.

Chapter II. In point of fertilizer output, there are presented the present state and trends as regards the raw material base, processes, fertilizer grades, developing conditions, etc.

Chapter III. Trends regarding the chemical fertilizers in the countries under research, as compared to the general trends at a world scale — there is pointed out the way the most advanced trends all over the world are reflected in the specific development of each country.

* * *

We mention that the report has been worked out on the basis of the data and publications in the branch literature, to the extent they have been available to us. Under such circumstances it is possible that the data shown herein should contain some lacks or should reflect only partially the state in a certain country. In this respect, we kindly ask the representatives of the countries under research to excuse the possible omissions and to contribute, as much as possible, to the completion or accuracy of data.

The basic report represents a detailed analysis of the chemical fertilizer problem, in the twelve countries under research.

The summary presents very briefly only the main problems dealt with.

To facilitate the simultaneous consulting of the abstract and of the paper, the notations in the paper, for titles of chapters, tables and bibliographical indications are maintained.

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Chapter I

CHEMICAL FERTILIZER CONSUMPTION

1.1 Fertilizer consumption at the level of 1970/1971

The fertilizer consumption in a country depends on several factors, among which the most important are the soil and climate conditions, the sort of cultures, demographic conditions, etc.

In the specialized statistics, the fertilizer consumption is presented as related to the agricultural soils or to the inhabitant number.

Table 1 presents the chemical fertilizer consumption in thousands of tons of NPK active substance at the level of the agricultural year 1970/1971, related to arable soil, pastures and totally cultivated land.

It is possible to group the countries under consideration on the basis of the values in table 1, in the classification proposed by UNIDO [1].

1.2 Fertilizer consumption expressed in NPK ratio

Under the present developing conditions, the three unanimously accepted main nutritive elements are : nitrogen, phosphorus, potassium.

At present, as well as in the future there is a more striking preference for the nitrogen element, in the developing countries ; there is also an obvious trend towards a higher consumption of phosphorus, than of potassium.

Table 4 shows the NPK ratio through 1968—1970 included in the countries under study.

Analysing the values shown in table 4, the following features can be underlined :

— in all the countries that are the subject of this survey — except Cyprus — the nitrogen element is the main one ;

— in Albania, Bulgaria, Cyprus, Greece, Romania and Turkey, the potassium element is by far less used than phosphorus (10 to 20%) ;

— the potassium consumption in Czechoslovakia and Poland is 50% higher than the phosphorus one ;

— in Hungary and Yugoslavia the potassium consumption represents 80—90 per cent out of the phosphorus one, and in Spain it is of about 50 per cent out of the phosphorus consumption ;

It is foreseen that the value of the ratio NPK, dependent on the pedo-climatic conditions in each country, will change its structure in the future, by means of increasing the participation of potassium, whose importance is generally less known by the agricultural customers [2].

Concluding this subchapter, we mention only that the importance of a fourth fertilizing macro-element, that is sulphur, shall not be disregarded since it seems to be necessary for plants, in equal quantities, to those of potassium [3, 4].

Table 1. Fertilizers consumption (in active substance)

Countries under study	Total area, km² [a]	Cultivated land, 1000 ha [b]			Ratio, per cent		Consumption 1970—1971 [c]		
		arable	pastures	total	col. 5 / col. 2	col. 3 / col. 5	Total, 1000 t	kg/ha cultivated land	kg/ha arable land
1	2	3	4	5	6	7	8	9	10
1. Albania	28,748	488	736	1,224	42.6	39.9	58	47.4	118.0
2. Bulgaria	110,912	4,538	1,147	5,685	51.2	79.8	786.3	138.3	173.2
3. Cyprus	9,251	434	80	514	55.6	84.4	27.7	53.8	63.8
4. Czechoslovakia	127,870	5,412	1,825	7,237	56.6	74.8	1,283	177.3	237.1
5. Greece	131,944	3,702	5,200	8,902	67.5	41.9	338	35.0	91.3
6. Hungary	93,030	5,622	1,390	7,012	75.4	80.2	786	112.1	150.0
7. Malta [d]	316				No available data				
8. Poland	312,677	15,000	4,104 [b]	19,104	61.4	78.2	2,780	191.8	180.0
9. Romania	237,500	9,733 [e]	4,418 [e]	14,151	62.5	70.8	594	41.9	61.0
10. Spain	504,750	20,730	14,361	35,091	69.5	59.1	1,264	36.0	61.0
11. Turkey	780,576	25,348	28,666	54,014	69.2	46.9	462	8.55	18.2
12. Yugoslavia	255,804	8,363	6,566	14,929	58.4	56.0	678	45.5	81.

Note: [a] Data taken from Statistics about Romania, 1971, pp 737, 738, 742, 744.

[b] Columns 3 and 4, [illegible] A., Small geographical Atlas, Bucharest, 1967, with the exception of item 8 Poland — according to the data presented to Bucharest Symposium, July 1972).

[c] Col. 8 — excerpt from the British Sulphur Corp. Ltd., Statistical Supplement no. 4, Nov.—Dec 1971, pp. 10, 12, 14

[d] Group of islands — Malta (246 sq. km), Gozo (67 sq. km), Comino (2.6 sq. km).

[e] From the Statistics about Romania, 1971, pp. 272—273.

Table 2. Classification according to the fertilizer consumption (NPK) in kg/ha of cultivated land

(arable + pastures + hayfields)

kg/ha	Countries under study
<25	Turkey
25 to 50	Albania, Greece, Romania, Spain, Yugoslavia
50 to 100	Cyprus
100 to 150	Bulgaria, Hungary, Poland
150 to 200	Czechoslovakia
>200	—

Table 3. Classification according to the fertilizer consumption (NPK) in kg/ha of arable land

Kg/ha	Countries under study
<25 (very low)	Turkey
25 to 50 (low)	—
50 to 100 (moderate)	Cyprus, Greece, Romania, Spain, Yugoslavia
100 to 200 (high)	Albania, Bulgaria, Hungary, Poland
>200 (very high)	Czechoslovakia

Table 4. Ratio between fertilizing elements, in the fertilizer consumption *)

Countries under study	Fertilizer consumption				1000 t	Ratio		
	Year	N_2	P_2O_5	K_2O	Total	N	P	K
1. Albania	1968	19	9	2	30	2.11 :	1 :	0.22
	1969	32	18	2	52	1.78 :	1 :	0.11
	1970	36	20	2	58	1.80	1	0.10
2. Bulgaria	1968	367	367	40	774	1.00	1	0.11
	1969	430	256	27	713	1.68	1	0.11
	1970	500	260	26	786	1.92	1	0.10
3. Cyprus	1968	10	12	2	24	0.33	1	0.17
	1969	11	11	2	24	1.00	1	0.18
	1970	12	12	2	26	1.00	1	0.17
4. Czechoslovakia	1968	302	310	463	1,075	0.97 :	1 :	1.49
	1969	400	312	476	1,188	1.28 :	1 :	1.53
	1970	419	350	514	1,283	1.20 :	1 :	1.46
5. Greece	1968	182	116	17	315	1.57 :	1 :	0.15
	1969	195	125	18	338	1.56 :	1 :	0.14
	1970	201	119	18	338	1.69 :	1 :	0.14
6. Hungary	1968	299	159	125	583	1.88 :	1 :	0.79
	1969	346	181	167	694	1.91 :	1 :	0.92
	1970	472	180	134	786	2.62 :	1 :	0.74
7. Malta				No available data				
8. Poland	1968	680	540	790	2,010	1.26 :	1 :	1.46
	1969	785	595	1,036	2,416	1.32 :	1 :	1.74
	1970	850	650	1,200	2,700	1.31 :	1 :	1.85
9. Romania	1968	330	140	14	484	2.36 :	1 :	0.10
	1969	350	169	19	538	2.07 :	1 :	0.11
	1970	367	203	24	594	1.81 :	1 :	0.12
10. Spain	1968	564	369	162	1,095	1.53 :	1 :	0.44
	1969	617	423	224	1,264	1.46 :	1 :	0.53
	1970	574	430	260	1,264	1.33 :	1 :	0.60
11. Turkey	1968	176	182	26	384	0.97 :	1 :	0.14
	1969	168	214	27	409	0.79 :	1 :	0.13
	1970	205	170	20	435	1.44 :	1 :	0.12
12. Yugoslavia	1968	270	195	182	547	1.38 :	1 :	0.93
	1969	287	143	117	547	2.01 :	1 :	0.82
	1970	303	200	175	678	1.52 :	1 :	0.88

*) *Worked out on The British Sulphur Statistical Supplement, no. 4, Nov.—Dec. 1971, pp. 10, 12, 14, except it. 9, Romania, based on Statistics about Romania, 1971, pp. 328—329.*

1.3. Fertilizer consumption, having in view the period 1971—1980

As well as all over the world, in the studied countries there can be noticed a steady increase of fertilizer consumption, as shown in table 5.

The increase is greater in the countries where no high consumption has been attained as evaluated by international organizations at the level of 100—200 A.S./ha [1]. Bulgaria, Czechoslovakia, Hungary, Poland, Romania and Spain could be quoted in this respect (table 6).

Table 5. Fertilizer consumption increase *)

Countries under study	Arable area, 1000 ha	Consumption A.S. 1000 t			Consumption A.S. kg/ha		Dynamics 1963 = 100	
		1968	1969	1970	1968	1970	1969	1970
1	2	3	4	5	6	7	8	9
1. Albania	488	30	52	58	61.5	118.9	173	193
2. Bulgaria	4,538	774	713	786	170.6	173.2	92	102
3. Cyprus	434	24	24	26	55.3	59.9	100	108
4. Czechoslovakia	5,412	1,075	1,188	1,283	198.6	237.1	111	119
5. Greece	3,702	315	338	338	85.1	91.3	107	107
6. Hungary	5,622	583	694	786	103.7	139.8	119	135
7. Malta				no available data				
8. Poland	16,068	2,010	2,416	2,700	125.1	168.0	120	134
9. Romania	9,733	484	538	594	48.7	61.0	111	123
10. Spain	20,730	1,095	1,264	1,264	52.8	61.0	115	115
11. Turkey	25,348	384	409	435	15.1	17.2	107	113
12. Yugoslavia	8,363	547	547	678	65.4	81.1	100	124

**) Out-worked col. 2 in table 1, col. 3*

col. 3, 4 and 5 in The British Sulphur Corp. Ltd. Statistical Supplement no. 4, p. 10, 12, 14 except rt. 9 — Romania according to Statistics about Romania, 1971, p. 328—329.

Among the respects raised by the fertilizer consumption both at a world scale and in the countries under study, there are obvious some preferences for certain grades. From this point of view, there are known the following: the preponderance of ammonium sulphate, of ammonium nitrate and of 16% ordinary superphosphate, during the first period of using fertilizers; the decrease of their importance, by replacing them with fertilizers more concentrated in fertilizing substances — urea and double and triple superphosphate; the further use of complex and mixed fertilizers, having the advantage of the shipping and inclusion cost decrease; the penetration, nowadays, of the liquid fertilizers in the consumers' usage, these being efficient especially with irrigated areas — and of the fertilizers containing micro-elements.

The agricultural consumers' orientation towards certain grades has been the main factor for re-profiling fertilizer plants in all the fertilizer manufacturing countries.

There is to point out that in the basic paper, out of the available data, a detailed analysis has been done, for the fertilizer consumption in all the countries under study, except Malta, for which no information was available.

Table 6. Provisions for the A.S. fertilizer consumption *)

Countries under study	Arable area 1000 ha	Year	Fertilizer consumption A.S. kg/ha			
			1000 t	cultivated	arable	no indication
1	2	3	4	5	6	7
1. Bulgaria	4,538	1970	786	138.3	173.2	—
		1975				217
		1980				247
		1990				279
2. Czechoslovakia	5,412	1970	1,283	177.3	237.1	—
		1975				229
		1980				252
		1990				296
3. Hungary	5,622	1970	786	112.1	139.8	—
		1975				217
		1980				295
		1990				467
4. Poland	16,069	1970	2,700	133.3	168.0	—
		1975				200
		1980				235
		1990				339
5. Romania	9,733	1970	594	41.9	61.0	—
		1975	2,115		217.3	—
6. Spain	20,700	1970	1,264	36.0	61.0	—
		1975	1,560		75.2	—

* *Taken from col. 2 in table 1, col. 3*

col. 4 — year 1970, in table 1, col. 8

col. 5 and col. 6 in table 1, col. 9 and 10

col. 7 — Bulgaria, Czechoslovakia, Poland, Hungary — in "Chemical Age", no. [illegible] 34, 10.12.1971

col. 4 — Romania 1975, taken from the "Law for undertaking the Five year plan of economic and social development in Romania, through 1971—1975", Political Publishing House, Bucharest, 1972, p. 14

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Chapter II

FERTILIZER PRODUCTION

II 1. General information

As for most ot the countries under consideration, the ever-increasing fertilizer demands have determined the investment policy in the fertilizer industry.

An analysis of the relation between production and consumption, through 1968—1971, points out the following aspects (table 7).

— all the analyzed countries except Cyprus and Malta are fertilizer manufacturers, some of them have positive differences between production and consumption at the level of 1970/1971, differences which were meant for export.

— the greatest fertilizer shortage is to be found in Turkey which is the greatest chemical fertilizer importer.

— all the countries except Spain, are importing potash salts and phosphorus raw materials.

It is to be mentioned that the image resulting from the figures shown in table 7 has a limited value as regards the period 1968—1971 included ; during the very next years, the production development in most of the countries under consideration, is characterized by sensible increases, which modify the state shown in table 7.

II. 2. Specifical features, for the countries under study

In the basic paper, within the available information, there has been done a thorough analysis of the fertilizer output state, in the countries under study.

This survey is presenting very briefly only some aspects, characteristic of each country.

II.2.1. *Albania*

Albania has a nitrogen fertilizer industry, at Fleri [1], as well as an ammonia and ammonium nitrate one. In the present five-year planning, there are provisions for a super-phosphate plant at Laci [2], as well as new nitrogen and phosphorus fertilizer plants [3].

On the basis of the known data, it is estimated that the internal output can cover the inside chemical fertilizer consumption.

II.2.2. *Bulgaria*

Bulgaria is a mainly nitrogen fertilizer producer, using as raw materials natural gas from inside supplies and petroleum from import [4, 5, 6]. The nitrogen fertilizer output in Bulgaria has been directed, initially, towards ammonium nitrate of high concentration, and only later an importance has been paid to the urea output ; now, special care is given to complex fertilizers.

Table 2. Ratio between fertilizer output and consumption, in the countries under study *)

Country		1968/1969				1969/1970				1970/1971			
		Prod. 1000 t	Cons. 1000 t	Dif. 1000 t	%	Prod. 1000 t	Cons. 1000 t	Dif. 1000 t	%	Prod. 1000 t	Cons. 1000 t	Dif. 1000 t	%
1		2	3	4	5	6	7	8	9	10	11	12	13
1. Albania													
	N	29	19	+ 10	+ 34.5	36	32	+ 4	+ 11.1	36	36	0	0
	P_2O_5	10	9	+ 1	+ 10.0	19	18	+ 1	+ 5.3	20	20	0	0
	K_2O	...	2	—	—	...	2	—	—	...	2	—	—
Total	S.A.	...	30	—	—	...	52	—	—		58	—	—
2. Bulgaria													
	N	504	367	+ 137	+ 27.2	586	430	+ 156	+ 26.6	602	500	+ 102	+ 16.9
	P_2O_5	135	367	— 232	— 63.2	139	256	— 117	— 45.7	148	260	— 112	— 43.1
	K_2O	...	40	—	—	...	27	—	...		26	—	—
Total	S.A.	...	774	—	—	...	713	—	—		786	—	—
3. Cyprus													
	N	—	10	— 10	— 100.0	—	— 11	— 11	— 100.0	—	12	— 12	— 100.0
	P_2O_5	—	12	— 12	— 100.0	—	— 11	— 11	— 100.0	—	12	— 12	— 100.0
	K_2O	—	2	— 2	—	—	— 2	— 2	— 2	—	2	— 2	—
Total	S.A.	—	24	— 24	-	—	— 24	— 24	—	—	26	— 26	—
4. Czechoslovakia													
	N	262	302	— 40	— 13.2	299	400	— 101	— 25.5	324	419	— 95	— 22.7
	P_2O_5	264	310	— 46	— 14.8	289	312	— 23	— 7.4	322	350	— 28	— 8.0
	K_2O	...	463	—	—	...	476	—	—		514	—	—
Total	S.A.	...	1,075	—	—	...	1,188	—	—	...	1,283		—
5. Greece													
	N	127	182	— 55	— 30.2	151	195	— 44	— 22.6	165	201	— 36	— 17.9
	P_2O_5	130	116	+ 14	+ 10.8	120	125	— 5	— 4.0	114	119	— 5	— 4.2
	K_2O	...	17	—	—	...	18	—	—		18	—	—
Total	S.A.	...	315	—	—	...	338	—	—	...	338	—	—

1		2	3	4	5	6	7	8	9	10	11	12	13
6. Hungary	N_2	253	299	— 46	— 15.4	300	346	— 46	— 13.3	348	472	124	26.3
	P_2O_5	152	159	— 7	— 4.4	170	181	— 11	— 6.1	167	180	13	7.2
	K_2O	...	125	—	—		167	—	...		134		—
Total	S.A.	...	583	—	—	...	694	...	—		786		
7. Malta							No available data						
8. Poland	N_2	799	680	+ 79	+ 10.4	958	785	+ 173	+ 18.1	1,031	850	+ 181	+ 17.6
	P_2O_5	474	540	— 66	— 12.2	521	595	— 74	— 12.4	600	650	— 50	— 7.7
	K_2O		790	—	—	...	1,036	—	—		1,200		—
Total	S.A.		2,010	—	—	...	2,416	—	—		2,700	—	—
9. Romania	N_2	421	330	+ 91	+ 21.6	494	350	+ 144	+ 29.1	647	367	+ 280	+ 43.3
	P_2O_5	182	140	+ 42	+ 23.1	221	169	+ 52	+ 24.0	244	203	+ 41	+ 16.8
	K_2O	...	14	—	—	...	18	—	—		24		—
Total	S.A.	...	484	—	—	...	537	—	—		594		—
10. Spain	N_2	487	564	— 77	+ 13.6	563	617	— 54	— 8.8	584	574	+ 10	+ 1.7
	P_2O_5	361	369	— 8	— 2.2	375	423	— 48	— 11.3	380	430	— 50	— 11.6
	K_2O	543	162	+ 381	—	351	224	+ 327	—	521	260	+ 261	—
Total	S.A.	1,391	1,095	—	—	1,489	1,264	—	—	1,485	1,264		—
11. Turkey	N_2	36	176	— 140	— 79.5	96	168	— 72	— 42.9	81	245	— 164	— 66.9
	P_2O_5	60	182	— 113	— 62.1	48	214	— 166	— 77.6	54	170	— 116	— 68.2
	K_2O	...	25	—	—	...	27	—	—		20		—
Total	S.A.	...	383	—	—	...	409	—	—		435	—	—
12. Yugoslavia	N_2	148	270	— 122	— 45.2	183	287	— 104	— 36.2	290	303	— 13	— 4.3
	P_2O_5	182	195	— 13	— 6.7	180	143	+ 46	+ 24.3	208	200	+ 8	+ 3.8
	K_2O	...	182	—	—	..	117	—	—		175	—	—
Total	S.A.	...	647	—	—	...	547	—	—	...	678	—	—

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*) Taken from: The British Sulphur Corp. Ltd. Supplement, no. 4, Nov.—Dec. 1971, pp. 10, 12, 14, excep t 9 (Romania according to Statistics about Romania 1971, pp. 280—281 and pp. 328—329).

Bulgaria is importing phosphate rock and potash salts [7]. To produce N.P.K. fertilizers, Bulgaria has made use of nitric process.

The main industrial combinates, for chemical fertilizer production, are at Dimitrovgrad, Stara Zagora, Vrața, and one of the most large and up-to-date is planned to be made during the 6th developing planning, at Povelyanovo [5].

The existence and the ensuring of a raw material potential, and the great development of the fertilizer industry in Bulgaria enable the estimation that there are proper conditions for both covering the internal consumption predicted at the level of 1980 and maintaning the state of a chemical fertilizer exporter.

II.2.3. *Cyprus*

Cyprus is interesting in point of the chemical fertilizer industry, on the basis of pyrite rocks. The European market imports large quantities of pyrite from Cyprus [8].

Considering that the total maximum consumption of fertilizers that can be reached by Cyprus is of about 100,000 A.S. per year and considering the increase output cost of the fertilizer plants, depending on their capacity decrease, the achievement of a Cyprus national production seems reasonable only when natural pyrite supplies are to be highly and competitively recovered.

Cyprus favourable position, as related to the main fertilizer markets, could yield a series of favourable solutions.

II.2.4. *Czechoslovakia*

According to the specialized statistics, the fertilizer output in Czechoslovakia, and especially the nitrogen fertilizers, are through 1955—1970, on the top of the basic chemical product lists in point of increase dynamics.

The nitrogen fertilizer output is partially achieved on the basis of the native raw materials, lignite, (there is a tendency of being re-placed, with petrochemical products) refinery products and partially, imported natural gas [9]. As for the complex fertilizer output, Czechoslovakia has to import natural phosphates, potash and sulphur salts, or intermediate products, i.e. phosphoric acid and ammonium mono-phosphate [10, 11].

At the beginning of the decade, the fertilizer industry comprised the main grade types; in the future the fertilizer development is centred round urea and complex fertilizers, most of them on the basis of the phosphatic rock attack with nitric acid.

The main industrial plants are located at Sala Nad Vahom, Strazka, Zaluzi, Mostu, Lovosice. The present state and the provisions for 1970—1980, of the fertilizer industry in Czechoslovakia show that the internal output will be able to cover the consumption of the inside agricultural department and will supply an surplus amount for export.

II.2.5. Greece

Greece is somehow differently directed as against the generally accepted principle of giving priority to gaseous or liquid hydrocarbon as raw materials for the ammonia output, continuing to develop its coal ammonia output, on the basis of its own sources, since it has not available petrochemical raw materials [21]; the reason of this policy leads to the achievement of a nitrogen industry, not depending on outside factors [18, 19, 20].

Having available domestic pyrite sources, Greece is developing at present a strong sulphuric acid industry [12, 13, 14].

On the basis of phosphatic rock and imported potash salts, Greece is also producing complex and mixed fertilizers [15, 16, 17].

The main industrial plants for intermediate products and fertilizers are located at Drapetsona, Ptolemais, Thessaloniki, Nea Karvali, etc.

On the whole at the level of 1970–1971 it is to be seen that consumption is about equal to the output at the same time taking place a foreign trade action of fertilizer import and export.

The present economical development conditions in Greece enables the predictment of an increase of consumption [illegible] of the fertilizer output, in the near future both in point of the classical grades (superphosphate, ammonium nitrate) as well as complex fertilizers.

II.2.6. *Hungary*

In contrast with the previous period the present and the future stage are characterized by an important development of the fertilizer industry in Hungary.

The raw materials used for the nitrogen fertilizer industry were lignite and coke (oven) gases till 1964, when they passed to the natural gas.

The phosphoric rock [53] and the potash salts are imported.

The nitrogen industry of Hungary was centered on calcium ammonium nitrate and only during the more recent period urea was introduced in the production profile.

As well, until recently, the phosphorus fertilizer industry was dominated by ordinary superphosphate production.

The general tendency to produce complex and concentrated fertilizers was adopted and developed now on a large scale in Hungary too [55, 56, 58, 59, 60].

It was adopted the nitric process to desintegrate the phosphatic rock [54].

Among the important chemical fertilizer complexes we mention Kazinbarcika, Varpalata, Tiszapalkonya, Peremarton, Szolnok, Budapest, etc.

The special development, in the last period, of the fertilizer production in Hungary will enable to cover the internal consumption (without an important available quantity for export).

As a result, Hungary will no longer be a commodity market for the great fertilizer producers.

II.2.7. *Poland*

The chemical fertilizer industry in Poland has many years of experience, producing a large range of grades even before the second world war.

The raw material for the ammonia production is natural gas, coke gases or coke (with the tendency to be replaced, up to 1975, by natural gas).

The phosphatic fertilizer production is based on imported phosphatic rock.

The sulphuric acid output is based on sulphur from native supplies.

The potassium fertilizers are based on imported potasium salts.

Nowadays, the fertilizer industry of Poland produces: ammonium nitrate, calcium ammonium nitrate, urea, calcium nitrate, calcium cyanamide, ammonium sulphate, ammoniac waters, ordinary superphosphate, calcined phosphate, ammonium phosphate, phosphatic rock concentrate.

In the future, the fertilizer production in Poland will extend to cover concentrated fertilizers and to fertilizers with many components [25].

It is to be mentioned the importance given in Poland to studies regarding the production and use of fertilizers containing micro-elements and liquid fertilizers.

Among the important industrial complexes are those at Pulawy [26], Gdansk, Police, etc.

Poland is an important producer of chemical fertilizers, although the use of fertilizers is intensive, in Poland it still remains an excess of production for export.

II.2.8. *Romania*

Starting with 1955, the fertilizer production in Romania is characterized by a continuous increase.

This industrial branch became important within economy in Romania only after 1960, when the development has been really substantial.

Romania has important natural gas deposits, fact that allowed for the development of a strong nitrogen fertilizer industry [34].

The phosphatic rock and the potash salts are imported.

Nowadays, the fertilizer industry in Romania produces : ammonium nitrate and calcium ammonium nitrate, urea, ordinary superphosphate, triple superphosphate, complex fertilizers.

Among the most characteristic aspects of Romanian's fertilizer production development, there are [27, 28, 29] :

— the extension of concentrated fertilizer, urea and triple superphosphate production ;

— the extension of complex fertilizer production ;

— the production of phosphatic fertilizers in grades that ensure a maximum phosphorus solubility in water ;

— the improvement of fertilizer physical qualities, in order to obtain products with as small a caking tendency as possible.

The limited available amounts of sulphur raw materials and the parallel development of the nitrogen fertilizer industry have determined, lately, the passage from phosphatic rock attack by sulphuric acid to the nitric process [30, 31, 32, 33].

Important chemical fertilizer industrial complexes in operation are at Făgăraş, Piatra-Neamţ, Craiova, Tîrgu Mureş, Turnu Măgurele, Năvodari, Valea Călugărească and in course of building at Slobozia and in Arad.

The future development of chemical fertilizer production has in view not only to ensure the internal requirements, but also to create some nitrogen fertilizer available amounts for export.

As for the fertilizer quality, special care is given to varying the fertilizers and microelement fertilizer production.

II.2.9. *Spain*

The fertilizer industry development in Spain is characterized by large resources of phosphatic rock [40, 41, 42] as well as of important internal reserves of pyrite [43, 44, 45, 46] and potassium [47].

Lignite and naphtha [36] are used to produce ammonia (with the tendency to be replaced by hydrocarbons).

The systematic exploitation of the pyrite mines at Huelva has created favourable conditions for complete and integrated phosphorus fertilizer industry. In this respect the sensible increase of phosphoric and sulphuric acid is to be mentioned.

In Spain a varied range of fertilizers is produced : ammonium sulphate, ammonium nitrate, urea, calcium cyanamide, ordinary superphosphate, triple superphosphate, ammonium phosphate, dicalcium phosphate, complex mixed and liquid fertilizers.

The tendency for concentrated, complex and liquid fertilizers is also noticed in the qualitative development of fertilizer production in Spain.

Among the analyzed countries, Spain is the only one which has got potash salt ores, exporting great quantities in many countries of Europe, Africa, America [48].

An improvement will be also achieved in the potassium fertilizers production by introducing the potassium sulphate production [49].

Among the important fertilizer plants there are to be mentioned the following : Barros, Cartagena, Puertollano, Tarragona, Huelva, etc.

The great development of the fertilizer industry in Spain, has practically excluded the import, internal consumption being counter-balanced by the native production.

II.2.10. Turkey

In Turkey it is noticed a developing action of the native chemical fertilizer production in order to decrease the import which is now increasing due to the fact that the production did not increase at the same rate as the consumption.

One of the important problems which condition the nitrogen fertilizer industry development in Turkey is the dependance of ammonia on import. In the future the ammonia production in Turkey is foreseen to be based on petrochemical raw materials at Izmir and Gemlik [50].

Turkey has sulphur raw materials, which enabled the development of a sulphuric acid production [51, 52].

The phosphatic rock is imported.

The chemical fertilizer grades produced in Turkey at present are: ammonium sulphate, calcium ammonium nitrate, ordinary superphosphate, triple superphosphate, diammonium phosphate.

II.2.11. Yugoslavia

After 1966 the fertilizer industry in Yugoslavia has registered a substantial development [22]. The raw materials used for the ammonia output are: coal (with a tendency to be replaced by petrochemical products), natural gases, coke gases, petroleum refinery products.

For phosphorus fertilizers, imported phosphatic rocks are used; nowadays there are phosphatic rock prospections, foreseeing the partial covering of phosphatic rock need, on the basis of indigenous sources.

The potassium fertilizers are entirely made by means of potash salt import.

The sulphuric acid fabrication is based on waste gases from non-ferrous metallurgy and on native sulphur raw materials.

Yugoslavia's fertilizer output initially based on calcium ammonium nitrate and ordinary superphosphate, is continuing its development, on the basis of concentrated fertilizers, urea, and triple superphosphate and complex fertilizers.

To produce N. P. K. fertilizers, two processes are used, attack (desintegration) by sulphuric acid and nitric desintegration as well.

Amoung the modern industrial complexes, the Kutina Combinate is mentioned [24].

After 1971, together with the achievement of the new industrial units, as planned, the fertilizer balance will become positive and Yugoslavia will come to be a fertilizer exporter, instead of an importer, as it was before 1966.

In the future it is estimated that the fertilizer production will cover the whole internal consumption at the level of 1975 while the further development of the fertilizer production will be achieved only in keeping with agriculture demands [22, 23].

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Chapter III

TENDENCIES REGARDING CHEMICAL FERTILIZERS IN THE COUNTRIES UNDER STUDY AS COMPARED TO OVERALL WORLD TENDENCIES

The state of fertilizers consumption and production in the countries this report deals with, in most cases reflects the application of the most advanced tendencies at a world scale to each country particular conditions.

These countries possess or get from outside the raw materials required for chemical fertilizer industry.

Except Cyprus and Malta, that have not yet a chemical fertilizer industry of their own, all these countries we studied have developed strong fertilizer industries based on inner or imported raw materials and intermediate products, including large size plants, based on advanced processes from a technical point of view.

The latest achievements introduced in the manufacturing processes at a world scale have been obtained by most of the mentioned countries.

Thus, large ammonia plants of 600—1000 tons per day, with a single production line, provided with steam drive centrifugal compressors, minimum electrical power consumption and thermal power generators are under construction or in operation in countries such as : Bulgaria, Czechoslovakia, Hungary, Poland, Romania and Spain.

Modern urea large sized plants, with total circulation, based both on conventional urea manufacturing processes and on modern "stripping"-type processes are under construction or in operation in : Bulgaria, Czechoslovakia, Hungary, Poland, Romania and Spain. Nitric acid, ammonium nitrate, sulphuric acid, phosphoric acid, ammonium phosphates, nitrophosphates etc. process plants are also characterized by large sizes, being based on equipments and process among the most up-to-date ones.

The modernizing of the manufacturing processes and the growth of production lines capacity enable the use of computers to operate the chemical fertilizer plants to increase the efficiency.

The efficiency of such large-sized units based on up-to-date processes is embodied by the production cost decrease of final products and intermediate products.

These industrial complexes achievement enabled the manufacturing of new modern fertilizer grades and — at the same time — contributed to the economical national system consolidation in the respective countries.

The problem of pollution, much debated at international level lately, also constitutes a steady preoccupation for the analysed countries, having an advanced fertilizer industry.

We quote Czechoslovakia's and Romania's processes for sulphur dioxide recovery in the waste gases that, besides avoiding the pollution effect, also obtains the sulphur dioxide recovery with outstanding economical results [4].

Most of the analysed countries acknowledge the advantages of concentrated fertilizers and the importance of a correct ratio between the three basic nutrients : nitrogen, phosphorus, potassium.

In this respect, the fertilizer industries in most of the analysed countries record qualitative transformations, thus the production of high grade concentrated and complex fertilizers acquiring a particular value.

As regards liquid fertilizers, we can conclude that their use is so far restricted in the analysed countries, both to radicle and extraradicle nutrition.

The advantages of the liquid fertilizers (the possibility of accurate uniform fertilizer spreading, the possibility of introducing them into the irrigation water, the absence of caking and dusting, and of mixed fertilizer segregation, lower costs for their storage and handling than for solids, the possibility of mixing them with insecticides and herbicides) plead for the expansion of their use. Czechoslovakia, Poland, Spain and Yugoslavia are particularly preoccupied by the use of liquid fertilizers.

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From the aspects analysed herein, we come to the conclusion that the countries this report refers to, are in full developing quantitative and qualitative progress in the fertilizer production and consumption evolution.

We appreciate that the moment chosen for working out this analysis is one of the most acute in the fertilizer history of these countries.

It is to underline the fact that the experience of the countries with strong industries and intensive use of chemical fertilizers is well-known, and the results thus obtained are applied in many of the countries under study.

Countries that developed more recently the fertilizer industry have overlooked the stages of looking for efficient technical solutions, enjoying the most up-to-date progress reached by advanced countries in the production and the use of fertilizers.

The concentration of production in large industrial complexes, the efficient transport of raw materials, intermediate products and final products, yield the premises for stimulating and developing the inter-countries co-operation.

In the future, one can foresee technical progresses in the fertilizer industry, that should lead to the continuous decrease of investments and production costs and that should enable the production of such grades that meet to the greatest extent the plant nutrition requirements.

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ACTIVITIES OF THE FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS IN THE DEVELOPMENT OF THE USE OF FERTILIZERS

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Within the organizational framework of the Food and Agriculture Organization of the United Nations, the Land and Water Development Division, as a part of the Agriculture Department, is responsible not only for work in water resources and use but also for soil surveys and related fields (including the Soil Map of the World) and for all aspects of soil development, soil conservation and the use of fertilizers. More specifically the Division, in co-operation with other Divisions (Plant Production and Protection Division, Economic Analysis Division, Statistics Division, Rural Institutions Division, etc. assists States members of Food and Agriculture Organization in

a) Promoting the use of fertilizers through soil appraisal and fertility programmes, to determine application rates and other cultural requirements for particular crops and kinds of soils, aiming not only at higher yields but also at optimum economic returns and farm profit ;

b) Assessing the needs member States for fertilizers and analysing (with UNIDO as appropriate) problems of supplies and production on a global, regional and country basis.

The rapid developments in the use of fertilizers have led and are leading to local fertilizer production facilities in the more advanced and larger developing countries. Already at an early stage, FAO and UNIDO have found it essential to co-ordinate activities dealing with the development of fertilizers. FAO dealing with the problems of the use and supply of fertilizers and UNIDO with the production of fertilizers and connected fields. The logical interrelation between the two activities led to the agreement between FAO and UNIDO in 1969 on the co-ordination and synchronization of activities of mutual interest. Experience has shown that this co-operation can lead to developments that help to avoid mistakes and that are in the interest of the countries concerned. Some fertilizer projects in which UNIDO co-operates with FAO have been or are being carried out or are planned for the foreseeble future, for example a project in Pakistan carried out with the assistance of the United Nations Development Programme entitled "Pre-investment Studies for the Promotion of Fertilizer and Petrochemical Industries" and the pilot-plant project in Togo.

Regular consultations on the policy and the technical level have led to a mutual approach to the problems of the development of fertilizers and to a better understanding on both sides, thus improving the quality of the assistance to the countries.

Both organizations are also co-operating in conferences and meetings of different types ; as for instance, at the Second Interregional Fertilizer Symposium held at Kiev and New Delhi in September — October 1971. The co-operation has also led to joint field missions relating to pre-investment studies on the use and production of fertilizers, which provide the

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countries and the organizations with the necessary information to enable them to take decisions on the production of fertilizers.

The Joint UNIDO/FAO/IBRD Working Group on Fertilizer Development Planning, a follow-up activity from the Kiev – New-Delhi Symposium, has already established the reputation of approaching fertilizer development problems in a most realistic way. The results of the Working Group Sessions are expected to be seen in a number of countries in the near future.

In the development of the use of fertilizers, FAO co-operates with other United Nations agencies, for example the International Atomic Energy Agency (IAEA) and the International Bank for Reconstruction and Development (IBRD) and with multilateral organizations, such as the Organization for Economic Co-operation and Development (OECD), the Fund for European Development (FED) and the Organization of American States. FAO also co-operates through different types of programmes, agreements and arrangements, with a considerable number of bilateral development aid organizations and with non-governmental organizations.

The following considerations influence FAO's approach:

a) In line with the requirements of the rapidly growing population in the developing countries during the Second United Nations Development Decade (1971—1980), the increased target per year in agricultural output is 4 per cent. This is considerably higher than it has been achieved during the last 10 to 15 years, when the average growth rate was only 2.7 per cent. Although most developing countries are essentially agrarian countries, more than 20 per cent of their imports still consist of food ;

b) It is generally accepted that most of the future production increases have to come from higher yields per unit area ;

c) Experience in countries with highly developed agricultural systems over the last 120 years has shown that approximately 60 per cent and more of yield increases are due to the use of mineral fertilizers and manures. The available figures indicate that this percentage might be even higher in developing countries ;

d) More than 60 countries are still in need of assistance in one way or another in developing the use of fertilizers. The real problems in this respect are the introduction of the use of fertilizers to the large number of economically weak farmers with small and often remote holdings who produce the bulk of the food crops, and the limited economic possibilities of the countries as a whole.

Development of the use of fertilizers

Although the introduction of the use of fertilizers is a matter for the countries concerned, the development of the use of fertilizers has become one of the most welcome forms of development aid. In the FAO programme, assistance of various forms in the development of the use of fertilizers has become increasingly important during the last 15 years. It consists essentially of the field programme and the activities under the regular programme.

Field programme

The main object of the field projects is to introduce the technically and economically right types and quantities of fertilizers into practical agriculture on a large scale and in accordance with the needs of the individual countries.

Because of the great variation in the needs of the countries and their degree of development, FAO together with the United Nations Development Programme (UNDP), Governments, and non-governmental organizations has developed a number of project types and methods for carrying out this work. The most important of them are the UNDP (small scale), the UNDP (large scale) and the FAO fertilizer programme.

This is the type of assistance that usually provides one or two experts as advisers to governments for special fields of technical activities. The programme also provides some equipment and one or two fellowships and has a duration per project from two to six years. Within the framework of this programme the use and promotion projects of fertilizers were started in the early 1950's and have operated in 24 countries.

These projects are intended to provide pre-investment assistance to governments. They primarly concern applied research and investigation, but for some years in Special Fund projects on soil fertility and the use of fertilizers, strong promotion components have been included. UNDP's contribution to these relatively large projects includes mainly a team of five to seven international experts, equipment and supply for the field and laboratory work including vehicles and for projects with the distribution of fertilizers, adequate quantities of fertilizers, and finally about ten or more fellowships for the training of local staff. The minimum duration of large-scale projects of this type is three years, but in most cases the duration is five years or more. Such projects have been or are executed, for example in Argentina, Ghana, Iran, Pakistan, Philippines, Republic of Korea and Thailand. Besides field experimentation and demonstration, special attention has been given to the establishment or strengthening of services required for the use of fertilizers and the development of sound fertilizer recommendations. Governments are also assisted in developing policies for fertilizer supply, and assistance is given to pilot schemes for the distribution of fertilizers. Emphasis has been placed on combining the use of fertilizers with the use of improved high yielding varieties and with better methods of cultivation, irrigation and pest control. These intensive projects have considerably contributed to an extraordinary increase of the use of fertilizers. For instance in the Philippines a large-scale project carried out jointly by the staff of the Philippine Bureau of Soils and the international team of FAO, layed out 5,500 fertilizer trials on all the major food and cash crops, with special emphasis on rice, maize and coconuts. Detailed recommendations on fertilizers for each province and main soil series and for the high yielding and traditional varieties have been worked out, at the range of 40—30—0 or 40—30—30 for local varieties, 60—40—30 for improved varieties and 90—40—30 for high yielding varieties. The project has assisted in re-equipping and upgrading eight regional soil laboratories. A plant nutrition laboratory and a greenhouse were completed, research has been organized on the nutrient requirements of rice, maize and coconuts, and tests of various strains of Rhizobium spp. on legumes have been carried out. A field check of 33 benchmark soils was carried out and suggestions were made for the improvement of soil mapping techniques. The marketing of fertilizers and credit situation were studied and proposals for improvement were presented. The project reviewed the organization and staffing of the Bureau of Soils and recommended its reorganization to improve the planning, co-ordination and practical orientation of research. A detailed proposal for a Division of Fertilizer Promotion to be created in the Department of Agriculture was worked out; it is to be responsible for the co-ordination of all activities in the development of the use of fertilizers, including dissemination of recommendations to farmers, fertilizer legislation, co-ordination of imports, local production, marketing, warehousing, pricing and long-term developments. The project in the Philippines has not only provided a sound technical and economic basis for the use of fertilizers but has also contributed to increase it. The consumption of fertilizers was 97,000 tons (N,P_2O_5, K_2O) in 1964, when the project started and reached 226,000 tons in 1970/71. Under the UNDP financing, FAO is at present executing 28 small-and large-scale projects related to soil fertility and the use of fertilizers.

The FAO fertilizer programme was initiated in 1960 under the Freedom from Hunger Campaign. It has turned out to be one of the most effective FAO field programmes ; it is oriented towards practical needs and should lead to short-term results. The fertilizer industry was the first contributor to this programme and in fact made its initiation, but increasingly voluntary contributions by governments and non-governmental organizations and by the recipient countries have helped towards the considerable expansion of the programme. The programme has up to now worked in 34 countries and is at present operational in 22 countries. In principle, the FAO fertilizer programme uses the following approach in its activities :

a) The first stage is to ascertain the most profitable treatments of fertilizers and to create a demand for these treatments among small-scale farmers through trials and demonstrations ;

b) The second stage is to identify the distribution of fertilizers, credit problems and test different answers. In fact, in our case, fertilizers can be properly sold directly to informal „natural" groups, directly through formal co-operatives, or indirectly through local dealers ;

c) The fertilizer programme is carried one step beyond the existing procedures on a pilot basis ; if the test proves successful, the programme helps institutionalize the new procedure in the whole country.

Results obtained

The following is a short summary of the results of the programme achieved from 1961/62 to 1968/69 on all crops in all regions and all participating countries ;

a) Out of a total of 55,861 demonstrations (3 to 5 plots), virtually all (99.9 per cent) showed positive responses and the weighted average response of the best treatments was 59 per cent ; 94.7 per cent showed positive economic returns to at least one treatment ; the average value/cost ratio *) of the best treatment was 4 ;

b) Out of a total of 6,158 trials (9 to 16 plots), 99.5 per cent showed positive responses ; 95.7 per cent of the 5,987, for which price data were reported, showed positive economic returns to at least one treatment. The average response and value/cost ratio of the best treatments were 81 per cent and 9.1 respectively ;

c) During the first seven years of the fertilizer programme, the annual consumption of plant nutrients (N, P_2O_5, K_2O) in the countries taking part rose from 273,000 tons in 1960/61 to over 875,000 tons in 1967/68, which is an increase of over 600,000 tons. This represents a gain of 220 per cent, or 31 per cent per year (linear). The value of this increase, at wholesale prices, was some $ 40 million per year.

Regular programme

The main purpose of the regular programme activities is to give technical support to the field projects and additional advice and assistance as requested by member States. These activities are carried out by the expert staff in FAO headquarters, in co-operation with the regional and project staff, with other organizations and with the help of consultants. Such activities include conferences, symposia, seminars, training courses, sessions of specialized commissions ; consultations, panels of experts, working groups (for instance, on fertilizer marketing and credit and on fertilizer economics) ; publications of different types ; soil data bank, consultation missions ; liaison and co-operation with other organizations.

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*) The value/cost ratio (VCR) is the value of the yield increase divided by the cost of the fertilizer dressing used to obtain the yield increase. A ratio of 2 indicates a net return of 100 per cent.

The Expert Panel on the Effects of Intensive Fertilizer Use on the Human Environment organized with the financial support of the Swedish International Development Authority (SIDA), brought together for the first time leading experts in this field on a word-wide basis. The following sentences from the summary and conclusions of the panel are of particular interest:

"Clearly, fertilizers have done much toward making this world a better place in which to live. They are presently and will become increasingly indispensable for providing food for those now living and the generations to come. The long-term evidence that is available, far from proving that fertilizers are damaging to soils and their organic reserves, shows the contrary. Less apparent but genuine benefits derived from proper fertilizer use are an enhanced water use efficiency and a cleaner atmosphere from the better crop growth achieved. Abuses to the environment have been induced by excessive fertilizer use in certain localities and it is important that correction be effected in these cases. On a world-wide basis, however, it seems reasonable to predict there would be a strong backlash to the environmental crusade if food became more dear through restrictions on fertilizer use."

The United Nations Conference on the Human Environment held at Stockholm from 5 to 16 June 1972, presented a number of recommendations concerning the use of fertilizers. In Recommendation 21 research is recommended on the environmental effects of pesticides and fertilizers and on the dose and timing of the application of fertilizers and their effects on soil productivity and the environment. Recommendation 20 includes items dealing with the maintenance of soil productivity. FAO is at present preparing its action plan related to the Stockholm recommendations that concern this organization *).

Situation concerning the development of the use of fertilizers

After more than a decade of intensive work on the development of the use of fertilizers by a large number of countries with the assistance of FAO and other organizations, the countries can be classified as follows as regards the stage they have reached in the use of fertilizers and the need for further assistance:

a) Countries that are still in need of basic technical and economic information on the use of fertilizers. For these, assistance would concentrate on experimental and demonstration work, followed by pilot schemes for the distribution of fertilizers. There are 49 countries in this category, most of them in Africa;

b) Countries that (I) have recognized the importance of fertilizers for the development of agriculture, (II) have information on the rational use of fertilizers, and (III) have developed a sizable demand for fertilizers among farmers, but that mainly because of inadequate infrastructure and deficiency of foreign exchange, cannot build up the use of fertilizers on their own as quickly as it would be desirable. This category includes 67 countries, distributed almost evenly in Africa, Asia and Latin America;

c) Countries with an already relatively efficient infrastructure but where (I) the lack of sufficient foreign exchange for the purchase of fertilizers represents a major bottle-neck in further development, (II) the infrastructure for distribution of fertilizers and other inputs needs further improvement either in the country as a whole or in parts of it. There are 16 countries in this category, mainly in Asia and Latin America;

d) Countries (I) that do not need any more foreign assistance in the development of the use of fertilizers, or (II) that need assistance in the development of the use of fertilizers only in parts of the country, or (III)

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*\) *With reference to the attitude of FAO to fertilizer hazards, an action programme based on the recommendations of the Stockholm Conference is being planned. It includes research on the ecological effects of fertilizers, under which more specific studies will probably be initiated.*

that need assistance only for solving specific problems, for instance, building up a soil testing service, establishing a fertilizer unit in the Ministry of Agriculture, introducing fertilizer legislation, preparing an overall plan for long-term development of the use of fertilizers and eventually for the production of fertilizers. There are at present 17 countries in this category.

FAO's activities in soil fertility and the use of fertilizers in Europe

As the major problems of the use of fertilizers have been solved in most European countries, the experience collected in this part of the world and the know-how available are often used as a basis for solving fertilizer problems in developing countries. Direct assistance to European countries is relatively limited, usually only to specific fields, for instance, in soil chemistry, complex experimentation with organic manure, mineral fertilizers and adequate crop rotations, management of heavy clay soils, specialized equipment in the use of fertilizers. Some projects include also classification of soils for irrigation and related soil fertility problems.

Matters of primary interest in Europe at present are problems arising from increasing concern for the protection of natural resources and the human environment. FAO, in connection with the UNDP, organized in June 1971 a consultation on soil degradation and measures to curb it. FAO is following up the work on these problems also in close co-operation with the European institutions concerned.

Identification of fertilizer projects

On dealing with the development of the use of fertilizers and with fertilizer requirements, FAO is giving assistance, in co-operation with UNIDO, through field projects, consultations, publications, missions in the identification of the projects for the production of fertilizers with the aim of providing for them a sound economic basis. FAO's activities include :

a) Obtaining information on the most rational use of fertilizers on a variety of crops under different soil and climatic conditions by experimental work with fertilizers in combination with other inputs under normal farming conditions. The experimental results obtained are also used as a realistic basis for the overall planning of the development of fertilizers and long-term estimates ;

b) Extending the information obtained through experiments to the advisory services to enable them to demonstrate the value of the use of fertilizers and of the related improved practices to cultivators ;

c) Studying the economic factors affecting the use of fertilizers and of improved practices and finding ways and means to overcome obstacles to their wide application. These economic studies are related to the farmer's level and the aconomic aspects of the country as a whole ;

d) Distributing fertilizers to farmers : pilot schemes for the distribution of fertilizers as examples and incentives in such countries or areas where the supply facilities are not adequate ;

e) Infrastructure for the long-term development of the use of fertilizers : infrastructure development to promote the use of fertilizers and other inputs by improving the marketing, organization, credit, storage and transport facilities ;

f) Easying foreign exchange problems through the supply of relatively large quantities of fertilizers (and possibly other inputs) free or on easy terms. FAO's role in this undertaking is mainly to mediate between potential donors and recipient countries and to advise on problems of distribution and use ;

g) Assisting in long-term planning the development of the use of fertilizers that might eventually lead to the identification of the projects for the production of fertilizers. This type of activity is being carried out jointly with UNIDO and IBRD.

h) Training in soil fertility and fertilizer work: the training of local personnel is related to field activities and consists of on-the-job training, training courses, fellowships and study trips outside the country. Additional assistance is required for national and regional seminars for extension staff and high level officers, responsible for the long-term over all planning and execution of the development of the use of fertilizers.

In a number of countries, the elements listed here have already led to the identification of needs for the local production of fertilizers and serve as a basis for discussion with UNIDO and other organizations interested in the production of fertilizers. The Joint UNIDO/FAO/IBRD Working Group on Fertilizer Development can be considered a competent organization to clear the related ideas for the identification of projects. The advantage of this Working Group is also that all elements of the use of fertilizers, the production of fertilizers and their financing have been brought together for the first time on a world-wide basis.

Conclusions

On the basis of data received from the Indicative World Plan for Agricultural Development the use of fertilizers during the Second Development Decade (1970—1980) should materialize (as shown in the following paragraph) in line with the requirements of the rapidly increasing population.

World consumption should increase from 68.2 million tons of plant nutrients (N, P_2O_5, K_2O) in 1970/71 to 126.5 million tons in 1980/81. Within these totals the increase of the use of fertilizers in developing countries will be more rapid. The consumption in 1970/71 was 10 million tons of plant nutrients and is estimated to be 22.4 million tons in 1980/81.

The experience of FAO shows that, particularly in the developing countries, these figures will not be reached without an extraordinary effort on the part of the countries and aid-giving organizations. This calls for even closer co-operation from all concerned : those producing fertilizers should provide the best possible fertilizer materials and those using fertilizers should make certain that the fertilizer is used in the most effective and economical way.

V. COUNTRY PAPERS

BULGARIA

Ştefan N Lazarov

The intensive agriculture of Bulgaria requires the application of various forms of fertilizer.

The production of fertilizers currently forms an important sector of the chemical industry and the demand for more and improved fertilizers is increasing.

Bulgaria produces ammonium nitrate, urea and phosphates. The production of nitrogen fertilizers nearly meets the needs of the country, but the production of phosphates is limited and potassium fertilizers are not produced at all.

Granulated ammonium nitrate is manufactured according to a process developed by the Union of Soviet Socialist Republics. In recent years the plant has been remodelled and the quality of this product is now much improved.

The ammonium nitrate produced in Bulgaria contains :

- Nitrogen, 33.5—34.5 per cent.
- Humidity, 0.2—0.3 per cent
- Dissolved additions, about 1 per cent
- Inert additions, about 0.5 per cent

The dimensions of granules are :

- Size 1—2 mm, about 75 per cent
- Under 1 mm, 5—8 per cent
- Over 2 mm, about 20 per cent

Granulated urea is produced by the Stamicarbon process of the Netherlands and contains :

- Nitrogen, 46 per cent
- Biuret, 0.8—1.2 per cent
- Humidity, 0.4—0.6 per cent

Bulgaria also produces crystalline urea.

The basic raw materials for the fertilizer industry are oil products.

The principal problems facing the industry in Bulgaria concern the production of a satisfactory product and the modernization of plants.

With regard to the production of ammonium nitrate, while attempts to improve the quality of the product have been partially successful, more improvement is needed, to achieve the right dimensions for the granules and the optimal temperature for packing the product. The increased adhesion of inert materials, used as powder coating to the particles of ammonium nitrate also presents a problem. The country hopes to produce an ammonium nitrate suitable for transport without packing.

In recent years agriculture has registered complaints of humidity and biuret in urea, a problem that is very difficult to solve ; at present, the biuret content in urea is 0.8 to 1.2 per cent. Moreover, agriculturalists avoid the use of urea, preferring ammonium nitrate because of its quicker action.

A general problem in the future will be remodelling plants and changing the raw material base of the Bulgarian fertilizer industry. The country expects to receive natural gas from the Union of Soviet Socialist Republics and this will be an important problem.

Another important problem concerns the automation of the fertilizer industry to improve the quality of the product and to lower the cost of production.

Other problems concern corrosion and work safety in the production of ammonium nitrate and urea.

Liquid fertilizers are not widely used because they are difficult to apply.

CYPRUS

Petrakis Markou
Anastasios M. Papakyriakou
John P. Zyngas

Cyprus is the third largest island in the Mediterranean, with a population of about 650,000. Agriculture is still the backbone of the economy and consequently, fertilizers are of primary importance.

Cyprus has not yet established its own fertilizer industry. All fertilizers are imported from abroad by the Co-operative Central Bank and by various private commercial firms. Fertilizers are either sold or distributed directly to farmers or through their local Co-operative Credit Societies. Fertilizers are not mixed by Cypriot farmers; most mixed or compound fertilizers used in Cyprus are imported.

Fertilizers are sold in sealed bags of 50 to 100 kilogrammes each. The Government exercices strict control to guard against adulteration by analysing samples of all imported fertilizers. The cost of fertilizer imports amounts to approximately 2 million Cyprus pounds annually.

Programmes of fertilization are based on leaf and soil analyses for various crops. This is a service provided to the farmers by the Ministry of Agriculture and Natural Resources in order that fertilizers in the right amounts and types are used.

Market

Accurate records of fertilizer consumption in Cyprus are not available, since there are no records of stocks left over at the end of each year. Table 1 shows the fertilizer imports for the period 1952—1971.

Table 2 shows fertilizer consumption, on a nutrient basis, compiled from data on the sales of the three major importer/distributors. Approximately 14,000 tons of nitrogen (N) were used in Cyprus during 1971; of which approximately 40 per cent was in the form of ammonium sulphate, 40 per cent calcium ammonium nitrate and urea, and 20 per cent mixed or compound fertilizers such as 7—11—0, 14—22—0, 14—22—9 and 6—8—8 (figures I, II and III). In spite of the increasing quantities of nitrogen used every year, and the fact that too much nitrogen is applied to some crops, it is estimated that nitrogenous fertilizers are generally under-utilised if measured by the total tonnage of nitrogen needed for agriculture.

Urea was introduced into Cypriot agriculture about five years ago and at present accounts for only a small percentage (approximately 15 per cent) of the total nitrogen consumption. The consumption of urea is expected to rise, however, owing to its low cost per unit of nutrient, high concentration of nitrogen (46 per cent), and, consequently, low handling and storage costs (figure IV).

Table 1 Fertilizer imports

(long tons)

Year	Nitrogenous fertilizers				Phosphatic fertilizers			Potassic fertilizers	Mixed fertilizers					Other fertilizers including mixed fertilizers
	21-0-0	20.5-0-0	46-0-0	Others	0-16/18-0	0-44/48-0	Others	0-0-50/52	7-11-0	14-22-0	14-22-9 a)	6-8-8	Others	
1952	3,913	...	—	—	16,334	...	—	135						[illegible]
1953	6,730	3,108	—	—	26,106	300	—	51						1,861
1954	4,879	5,536	—	—	28,300	900	—	98						[illegible]
1955	10,095	5,040	—	—	19,820	550	—	78						[illegible]
1956	13,644	6,924	—	—	33,797	1,589	—							[illegible]
1957	16,040	12,391	—	—	35,755	1,974	—	109						[illegible]
1958	17,529	8,096	—	—	25,354	1,949	—	268						[illegible]
1959	13,758	14,627	—	—	31,123	3,080	—	389			...	...		13,847
1960	15,386	6,217	—	—	35,140	2,810	—	512						12,295
1961	21,256	10,819	—	—	32,840	2,210	—	507	7,325			3,950	[illegible]	
1962	21,798	9,293	—	—	26,294	3,050	—	468	8,768			7,334	1,146	
1963	26,660	15,945	...	...	36,465	3,300	—	385	11,186			[illegible]	515	
1964	14,871	11,543	...	...	26,155	3,105	—	273						[illegible]
1965	17,419	12,506	211	706	27,371	4,481	975	494	13,200	3,470		3,050	1,200	
1966	28,528	14,604	1,405	478	22,609	3,129	10	370	7,927	1,923		8,255	5,431 a)	21
1967	17,980	8,382	509	322	15,894	4,019	—	292	10,917	3,796	6,564	3,267	195	51
1968	26,108	14,450	1,613	2,704 b)	17,716	9,435	2	583	16,647	9,988	10,383	9,015	855	821
1969	24,611	13,852	1,261	1,630 c)	14,525	3,565	—	896	11,330	5,561	3,998	1,791		2,796
1970	21,157	16,788	1,831	4,274 d)	10,496	1,872	—	840	10,721	9,109	13,709	3,390		1,350
1971	27,125	7,808	2,755	3,511 e)	11,463	2,924	—	1,572	5,090	10,138	11,315	1,638		[illegible]

Source : For the period 1952—1964, data were obtained from the Statistics Section, Department of Agriculture and the Statistics Department Cyprus. For the period 1965—1971, data are from statistics of imports and exports, Department of Statistics, Cyprus.

a) Includes tonnage for 14—22—9 ; exact figure not available

b) Includes 1,375 tons of 33/14—0—0.

c) Includes 1,330 tons of 33/34—0—0.

d) Includes 833 tons of 33/34—0—0.

e) Includes 493 tons of 33/34—0—0.

Table 2. Total annual sales of fertilizers by the three major importer/distributors
(nutrients in metric tons)

1960		1961		1962		1963		1964		1965	
(N)	(P_2O_5)	(N)	(P_2O_5)	(N)	(P_2O_5)	(N)	(P_2O_5)	(N)	(P_2O_5)	(N)	(P_2O_5)
[illegible]	7,[illegible]79	6,779	7,595	7,630	8,220	8,828	8,138	[illegible]738	8,326	[illegible]043	8,545

1966		1967		1968		1969		1970		1971	
(N)	(P_2O_5)	(N)	(P_2O_5)	(N)	(P_2O_5)	(N)	(P_2O_5)	(N)	(P_2O_5)	(N)	(P_2O_5)
9,914	9,013	10,715	9,438	11,753	10,695	10,849	8,667	14,294	14,428	14,292	10,543

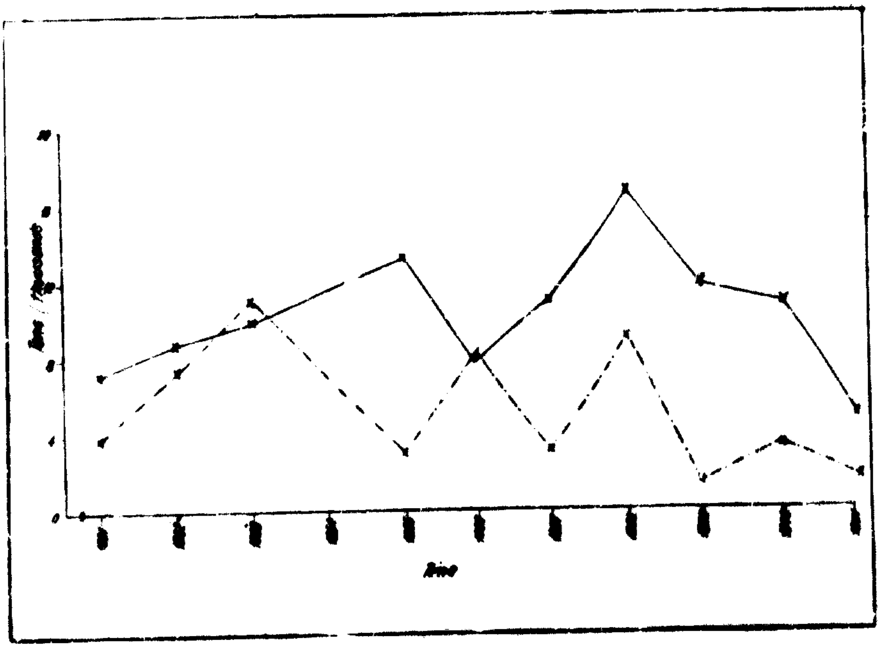


Figure I. Imports of fertilizers, 7-11-0 and 6-0-0

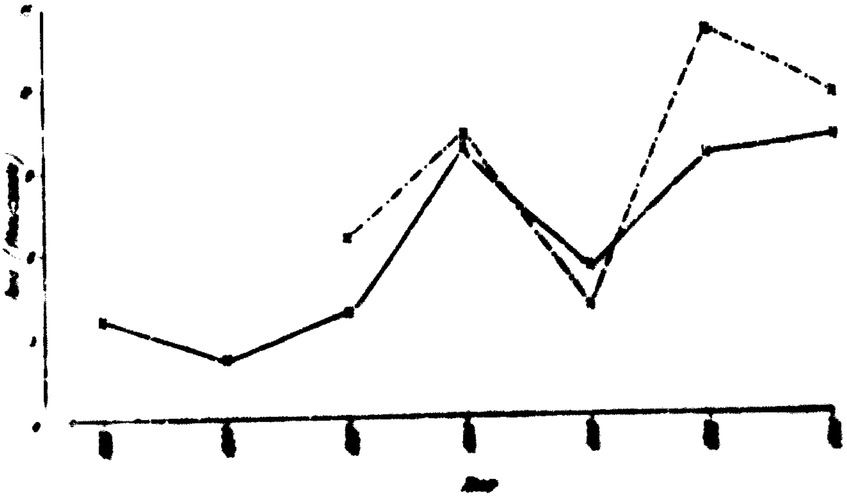


Figure II. Imports of fertilizers, 14-22-0 and 14-[illegible]-0

Source : Department of Agriculture Soils & Plant Nutrition Section

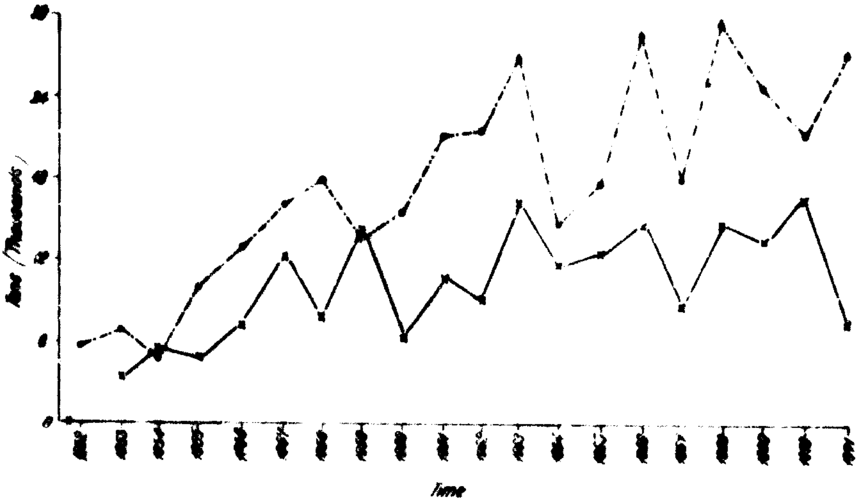


Figure III. Imports of fertilizers 21-0-0 and 20.5-0-0

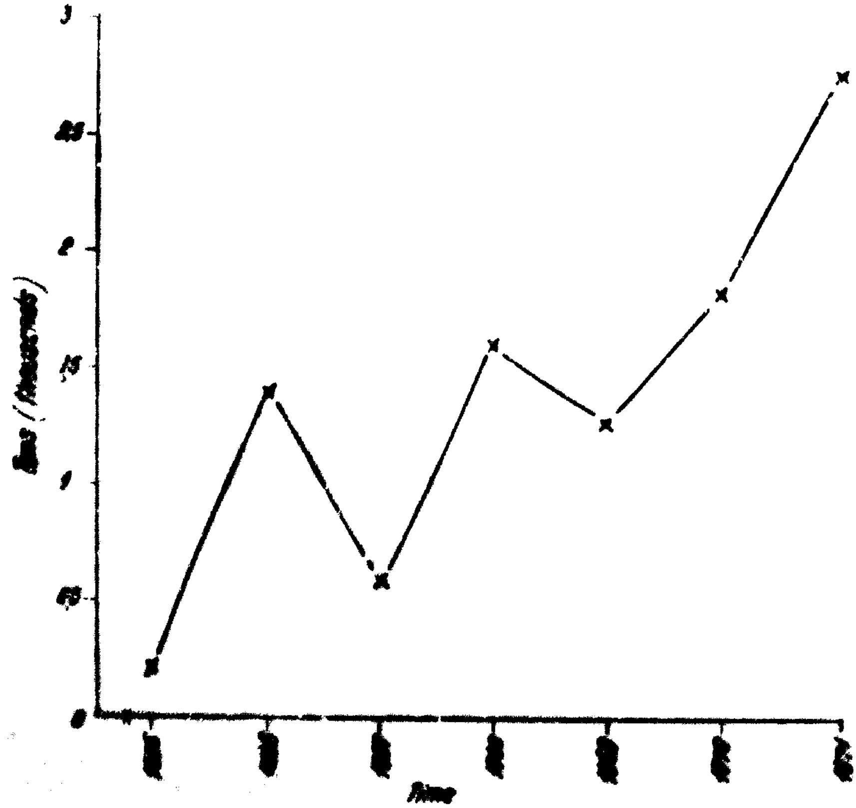


Figure IV. Imports of fertilizer, 45-0-0

Source: Department of Agriculture Soils & Plant Nutrition Section

With regard to phosphatic fertilizers, consumption amounted to about 11,000 tons P_2O_5 in 1971, with about 15 per cent in the form of single superphosphate (0—18/20—0), 17 per cent triple superphosphate (0—46/48—0), and the remaining [illegible] per cent [illegible] in compound fertilizers. The consumption of single superphosphates which about two years ago accounted for approximately 75 per cent of the consumption of total phosphorus, is being constantly replaced by the more concentrated type, 0-44/48-0 (figures V and VI). As with nitrogen, consumption of phosphorus is estimated to be below the recommended requirement of crops in Cyprus.

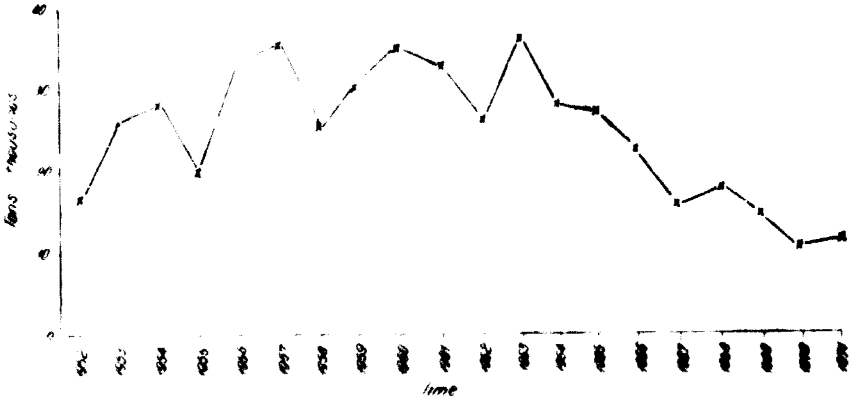


Figure V Imports of fertilizers, 0-16/18-0

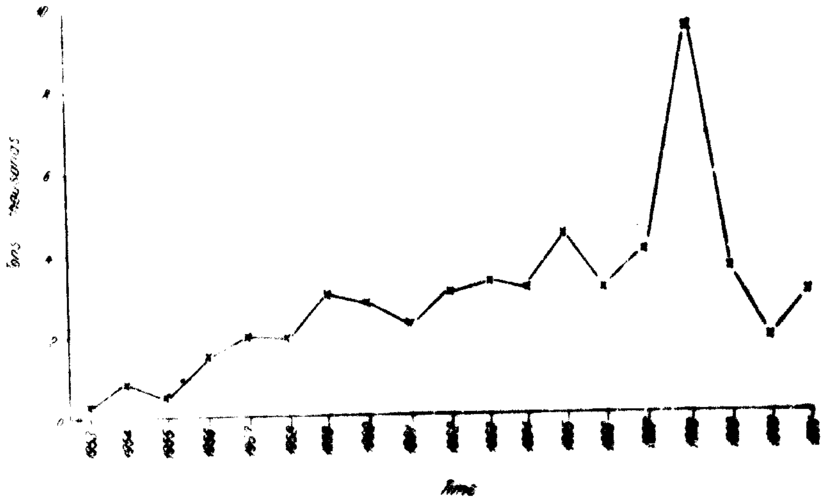


Figure VI Imports of fertilizers, 0-44/48-0

Source Department of Agriculture Soils & Plant Nutrition Section

Potassic fertilizers comprise only a small fraction of the total consumption of fertilizers in Cyprus, because the soil was (and in many areas still is) abundantly supplied with this element. However, it should be emphasized that the use of potassium frequently appears necessary for greater yields. Potassium sulphate is the main simple potassic fertilizer that is imported (figure VII), but in recent years potassium nitrate has also been imported, although on a smaller scale.

The anticipated and recommended consumption of phosphorus (P_2O_5) and nitrogen (N) is 18,000 tons and 17,500 tons respectively in 1976 and 20,500 tons and 19,000 tons respectively in 1986. The NO_3 nitrogen used as top dressing for cereals and vegetables, estimated to ammount to approximately 3,000 tons in 1976 and 4,300 tons in 1986, is not included in the above figures for nitrogen. It is also estimated that the actual consumption will be approximately 80 per cent and 90 per cent of the anticipated and recommended consumption in 1976 and 1986 respectively (table 3).

Figure VII. Imports of fertilizers, 0-0-50/52

Source : Department of Agriculture Soils & Plant Nutrition Section

Table 3 Projected land use and fertilizer needs, 1976 and 1986

1 9 7 6

Crop	Projected cultivated area (donums) a)	Recommended nutrients (tons) (N)	Recommended nutrients (tons) (P_2O_5)
Citrus fruits	134,000	4,315	910
Potatoes	65,000	1,250	1,250
Cereals	1,325,000	4,105 b)	6,095
Vines	315,000	2,585	2,585
Deciduous	55,000	1,995	580
Vegetables	75,000	560 b)	1,125
Fodders	400,000	1,200	3,845
Dry land trees	360,000	[illegible],910	1,330
	2,729,000	19,000	17,720

1 9 8 6

Crop	Projected cultivated area (donums) a)	Recommended nutrients (tons) (N)	Recommended nutrients (tons) (P_2O_5)
Citrus fruits	170,000	5,475	1,160
Potatoes	60,000	1,150	1,150
Cereals	1,150,000	3,565	5,290
Vines	330,000	2,705	2,705
Deciduous	61,000	2,215	635
Vegetables	100,000	750	1,500
Fodders	550,000	1,760	5,285
Dry land trees	360,000	2,920	1,335
	2,781,000	20,540	19,060

a) 1 acre = 3.025 donums
1 hectare = 7.49 donums

b) Excluding nitrochalk (calcium ammonium nitrate)

Feasibility studies

Two studies were carried out, one by UNIDO and the other by a foreign firm. Both concluded that a fertilizer plant would be technically and economically viable in Cyprus under certain conditions. According to an appraisal carried out by a government committee, the plant capacity should be based on the projected agronomic needs for fertilizer in about 1986. On this basis, recommendations relating to plant capacities were made (table 4).

Table 4. Recommendations for fertilizer plant capacities

Type of plant	Capacity (metric tons) (annual)	(daily, 330 days)
Ammonium sulphate	115,000 (equivalent to 24,000 of N)	348
Superphosphate	(equivalent to 20,000 of P_2O_5)	–
Mixing and granulation (assuming low-analysis mixed fertilizer)	170,000 (initial 120,000)	515 363
Mixing and granulation (assuming high-analysis mixed fertilizer)	120,000 (initial 70,000)	363 212
Sulphuric acid (unit 100 per cent acid)		
Initial	100,000	300
Final	150,000	450
Phosphoric acid (if triple superphosphate is to be manufactured)	18,000	55

A private firm ist at present seriously considering the possibility of setting up an integrated sulphuric acid-fertilizers-steel (reinforcing iron bars) complex. The basic raw material considered in this and all previous feasibility studies is the local supply of iron pyrites to be used in the manufacture of sulphuric acid.

Problems

The Ministry of Agriculture and Natural Resources has been recommending the use of high analysis fertilizers to farmers. The use of such fertilizers is also evident in the figures referred to earlier, indicating that concentrated types of fertilizers are being applied increasingly at the expense of low-analysis fertilizers. Whether low or high analysis fertilizers should be manufactured has been a major question raised by all feasibility studies. To evaluate the economic viability of the fertilizer project, c.i.f. prices of fertilizers and fertilizer raw materials, such as ammonia and rock phosphate, were taken as the basis for calculations. An indication as to future c.i.f. prices of fertilizers and raw materials would be very helpful in deciding whether or not a project would be economical. Finally, as sulphate of ammonia is the main, simple nitrogenous fertilizer used by the Cypriot farmers, knowledge of future price trends for this fertilizer would also be most helpful in assessing the whole project.

HUNGARY

Tibor Zsifkov

The rate of consumption of fertilizers, in Hungary is approximately equal to the medium rate for Europe. It has taken some 20 years to reach this rate which has led to the stabilization of Hungarian agricultural production.

Between 1951 and 1960, the amount of fertilizer used in Hungary was 14 kilogramme per hectare; by 1970 it had increased more than tenfold. Between 1966 and 1970 the use of fertilizers had more than doubled.

Year	Total active ingredient, kg/ha
1966	80
1967	91
1968	112
1969	173
1970	180

Over this same period the domestic production of fertilizers was

Year	1000 tons in active ingredient	
	(N)	(P_2O_5)
1966	167	131
1967	185	153
1968	245	156
1969	300	170
1970	350	167

The yields of some more important cultural plants in q/ha were

Year	Wheat	Rice	Maize	Sugarbeet	Potato
1966	21.7	16.4	31.6	330.6	62.8
1967	15.9	21.3	28.5	324.1	89.4
1968	25.2	19.3	29.9	334.2	89.2
1969	27.1	22.6	37.9	340.4	113.5
1970	21.1	19.1	33.8	287.3	104.1

Merely increasing the doses of fertilizer, however, could not satisfy increasingly varied demands. Under such circumstances, the present situation in agriculture had to be realistically assessed, and on the basis of this analysis the trend of development established. It was also considered that the quantitative development of agricultural production requires agro-technical and other measures.

Approximately 40 per cent of the fertilizers used at present are imported, including both single and compound fertilizers and raw phosphate. Simple fertilizers predominate in domestic production ; the proportion of compound fertilizers produced locally is still small and limited in assortment. Only 15 per cent of the total fertilizers used domestically, are compound fertilizers (including those imported).

The quality and the packaging of Hungarian fertilizers correspond to the standard. Recently, their physical proportion and spreadability have been improved, though in this field still further improvement is necessary.

Domestic production of nitrogenous fertilizer is sufficient to meet the present and predicted needs. On the basis of experience so far, the use of urea may prove advantageous.

The quantity of phosphoric and potash fertilizers available is not sufficient to satisfy the country's needs. Their further development is called for by the fact that the ratio of the N.P.K. will be altered in accordance with the tendency to favour phosphorus and potassium. The demand for these fertilizers is also expected to increase.

The essential problem is that the present assortment of fertilizers in Hungary is not satisfactory. In particular, it would be desirable to develop the production of compound fertilizers to the point where their proportion reaches 40 per cent of the total fertilizers used and their active ingredients vary much more widely than at present. The programme to achieve this goal includes the construction of a factory to produce compound fertilizer based on nitrophosphate and the planned construction of a mill to produce mixed fertilizer based on ammonium-phosphate. Both establishments will produce NPK products with a composition that is variable for wide usage.

Compound fertilizers combined with some microelements are now manufactured in Hungary, and, with international co-operation, spray-fertilizers combined with micro-elements and plant hormones. In the future, it is planned to increase the quantity and assortment of such fertilizers.

The problems concerning the solution-fertilizers are under study. In this field the close co-operation of industry and agriculture will be needed. At present there are no plans for the industrial production of liquid fertilizers. In professional circles a demand for producing suspension fertilizers, coated fertilizers and polyphosphates has also been raised.

MALTA

Peter J. Calamatta

Malta has no fertilizer or pesticide industry. Its requirements, which are not large, are met by imports. Both the amount of arable land (a few hundred hectares) and the number of farming families (about 7,000 at present) have been declining as a result of the lack of official encouragement of agriculture. In the past two years however, concerted efforts have been made to reverse this trend and to replace the ammonium sulphate traditionally used on the island's calcareous soils (pH 7.5 and over) by complexes.

POLAND

Jerzy Simonides

Production

The first atmospheric nitrogen fixation plant, based on a Polish process and built by Polish workers, was put into commission 55 years ago. It was a nitric acid plant using professor Moscicki's electric arc process. Another Polish contribution to the development of the nitrogen industry was made in 1905, when the Westregeln factory of the Gesellschaft fur Stickstoffdunger produced the first commercial quantity of calcium cyanamid, using an invention of the Polish born chemist F. L. Polzeniusz.

Fifty years ago, in 1922, the first state enterprise, Panstwowa Fabryka Zwiazkow Azotowych (State factory for nitrogen compounds) was established at Chorzow. This enterprise took over the nitrogen factory located at Chorzow which had been built by Bayerische Stickstoffwerke in 1915—1917.

Following Professor Moscicki's initiative, the second state nitrogen factory, located at Moscice near Tarnow, was built in 1927—1929. At that time this factory had the largest capacity for the production of ammonia in Europe.

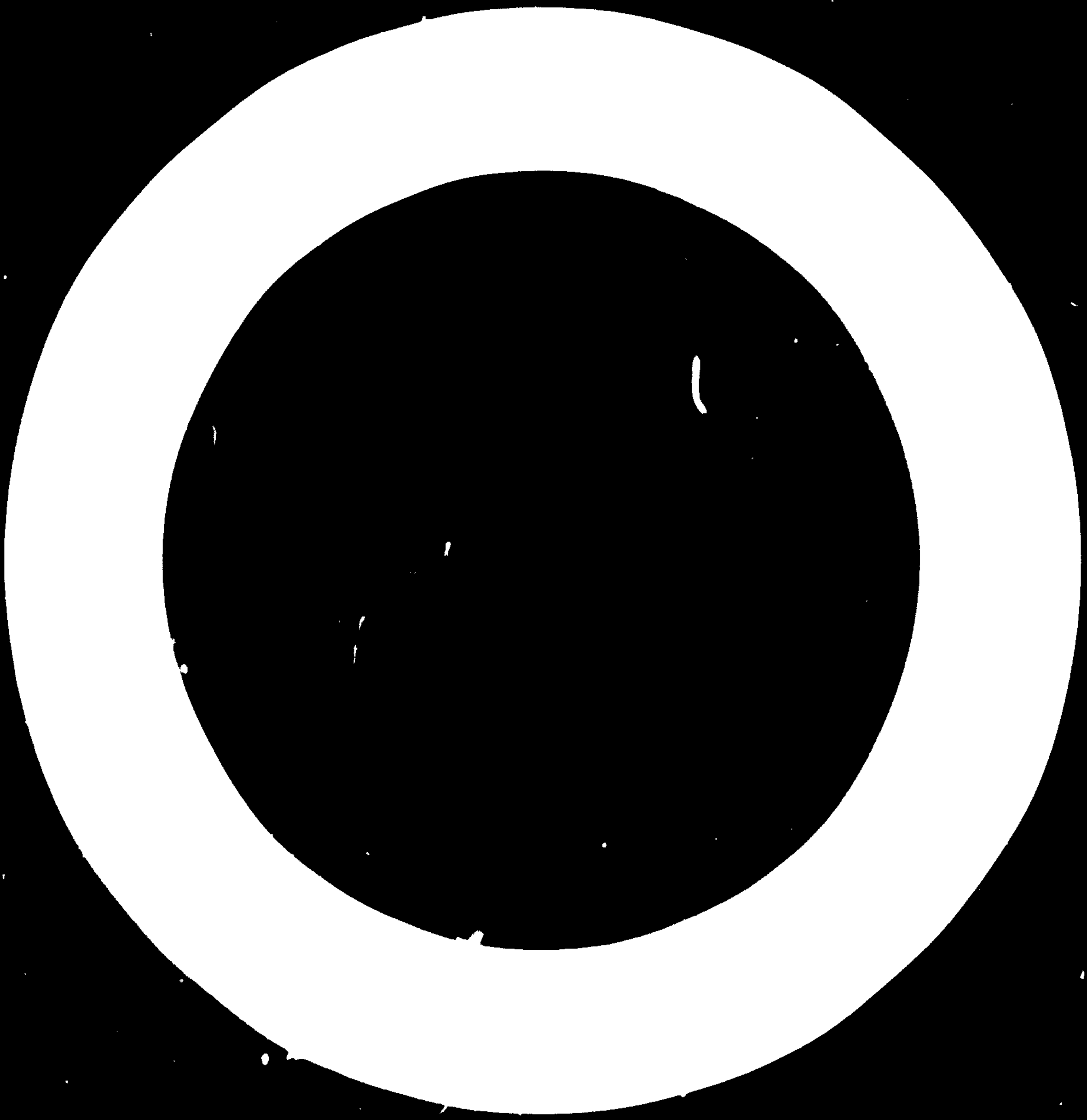
In 1939 the total production capacity of the Polish nitrogen industry, including coke-oven ammonium sulphate, was 60,000 tons per year. Owing to the poor economic situation of Polish farmers, full use of this production capacity was never made, except in the period from 1929 to 1932.

During the Second World War, the Polish nitrogen industry suffered severe losses in staff and plants. After the war, however the industry was rapidly reconstructed. By 1947, the pre-war production level was surpassed. The land reform and a new agrarian policy brought a fundamental change in the economic condition of the farmers. As a result, the demand for fertilizers began to increase rapidly. In addition to reconstructing the Tarnow Nitrogen Works it was necessary to built another large plant located at Kedzierzyn in the south west of Poland. Production started in 1954 and was expanded in the period 1958—1964.

In 1966 and 1969 the first and second branche of the Nitrogen Works Pulawy went into operation. This plant has a production capacity of 2,500 tons/day urea and 3,300 tons/day ammonium nitrate and is one of the largest in the world.

The Nitrogen Works, Wloclawek, with a production capecity of 1,500 tons/day ammonia, is the latest factory to go into operation.

Besides factories producing single component fertilizers, a large factory for NP fertilizers, the Chemical Works Police, located at Police near Szczecin, began production in 1970. Future plans are to also produce



NPK fertilizers. When this factory is completed, it will be one of the largest of its kind in Europe.

The decision on the location of the above-mentioned new works was based not only, on economic aspects, but also on the stimulating effect of industry in districts of hitherto purely agrarian character.

Table 1 shows the production of nitrogenous fertilizers (in thousand metric tons N) in comparison with the total fertilizer production (in thousand metric tons N + P_2O_5) and the per capita production of N and NP (in kg N or N + P_2O_5).

Table 1. The production of nitrogenous fertilizers

Year	NP (thousand metric tons)	Annual rate of increase (%) a)	N (thousand metric tons)	Annual rate of increase (%)	Kg per capita (NP)	Kg per capita (N)
1938	85.1	—	42.9	—	2.5	1.2
1950	160.3	—	77.8	—	6.4	3.1
1960	477	—	270	—	16.0	9.1
1965	738	—	394	—	23.4	12.5
1966	826	112	462	118	26.0	14.5
1967	974	118	594	128	30.2	18.4
1968	1,233	126	759	128	38.1	23.4
1969	1,472	120	938	124	45.2	28.8
1970	1,629	111	1,030	110	50.0	31.6
1971	1,786	110	1,081	105	54.3	32.9

Source: GUS publications.
a) Foregoing year 100%.

Table 1 gives only the figures for nitrogenous and phosphatic fertilizers; the entire requirements for potassium fertilizers are covered by imports.

Comparing table 1 with table 2, it may be noted that the figures for production are slightly higher than the figures for consumption. In the future a certain amount of the surplus of production will be kept in order to make possible some exportation of nitrogenous fertilizers.

Raw material for ammonia synthesis

In Poland natural gas steam-reforming plant for ammonia synthesis-gas production was working even before the war. The fundamental raw material for ammonia synthesis-gas production was coke and coke gas based on small native natural gas resources and a well-developed coal-mining industry. Since the early 1960 all new plants have been based on natural gas, the remainder being produced from coke gas and petrochemical tail-gases. The change in raw materials and the gradual replacement of smaller ammonia production units by up-to-date larger units should substantially reduce the average cost of production by about 40 per cent.

The assortment of produced nitrogenous fertilizers

The Polish nitrogen industry produces:

Urea
Calcium ammonium nitrate (CAN)
Ammonium nitrate (AN)
Calcium nitrate
Sodium nitrate
Calcium cyanamide
Ammonium sulphate
Aqueous ammonia

Urea Prilled fertilizer urea has been produced in Poland since 1964 by the Toyo Koatsu process in total recycle plants. The main feature of this product is its low biuret content and very good storage properties without anti-caking treatment.

Calcium ammonium nitrate Originally CAN was produced in Poland with only periodic mixing of the slurry and by pug mill granulation. The nitrogen content was 20.5 per cent. Since 1954 nearly the entire production of CAN has been done by a continuous prilling-tower process. In the late 1950's the nitrogen content was increased first to 22 per cent and later to 25 per cent. A nitrogen content of 25 per cent is a compromise between the better agrochemical properties of the 20.5 per cent product and the lower total AN fertilizing costs. It should be emphasized, however, that in spite of the higher price of nitrogen in CAN by comparision to AN, the farmers like to buy CAN because of its good agro-chemical properties.

Ammonium nitrate In order to reduce the costs of nitrogen production in 1957 some plants previously producing CAN began to produce AN.

In 1969 this production was considerably expanded by the start-up of the AN plant at Pulawy, followed in 1972, by the inaguration of the newest plant at Wloclawek. The nitrogen content of the various products is between 33 per cent and 34.8 per cent. Very good handling properties of the product are ensured by the stabilizing and anti-caking agents used.

Calcium nitrate Calcium nitrate is produced from limestone and nitric acid with an addition of ammonium nitrate, giving a nitrogen content of 15.5 per cent. In spite of very good agro-chemical properties, the output tends to decrease because of high production costs.

Sodium nitrate Sodium nitrate is produced by alkaline absorption of waste gases from low pressure nitric acid plants. Only a very small amount, is used for fertilizing.

Calcium cyanamide Calcium cyanamide was produced in Poland for fertilizing purposes in an increasing ammount from 1957 to 1965, when the supply to the fertilizer market began to decrease. In 1970 the supply to agriculture was stopped in order to be diverted to industrial needs.

Ammonium sulphate In the pre-war period, ammonium sulphate was produced in Poland from coke-oven gas and from synthetic ammonia, after the war it was produced only from coke-oven gas. An increasing amount of AS is obtained as a by-product of caprolactam production.

Aqueous ammonia The use of aqueous ammonia with 20 per cent N was introduced as a fertilizer in the early 1950 by the nitrogen industry, which invested a great deal in local storage tanks. In spite of the lowest price for nitrogen and intensive organizational efforts on the part of the industry, the demand for this form of nitrogenous fertilizer has not reached the expected level.

Other nitrogenous fertilizers The ammonium phosphate produced at Police contains 18 per cent N and 46 per cent P_2O_5. The production of an NPK fertilizer, based on this product, is planned.

The relative importance of the above mentioned fertilizers and its variation with time is shown in table 2 (percentage of total nitrogen production).

The above table demonstrates the dynamic growth of the urea quota, considering the substantial parallel growth of AN production (in absolute figures).

There are expected to be some changes in the relative importance of nitrogenous fertilizers in the next few years. In 1972, there was a noticeable increase in AN production coming from the plant at Wloclawek. The production of NP fertilizer should increase stepwise, partly in the form of NPK fertilizers. By 1975 the supply of CAN is expected to increase owing to the planned modernization and intensification of existing plants. The production of other fertilizers should remain the same as the present production. The planned stepwise change of CAN-filler from limestone to

Table 2. Various types of nitrogenous fertilizers as percentage of total production of nitrogen, 1960—1971

Year	Calcium ammonium nitrate	Ammonium nitrate	Urea	Calcium nitrate	Sodium nitrate	Calcium cyanamide	Ammonium sulphate	Aqueous ammonia	Ammonium phosphate
1960	36.43	35.37	0.15	4.67	0.19	13.04	9.78	0.37	—
1961	43.38	29.33	0.07	4.08	0.03	12.52	9.96	0.53	—
1962	43.08	30.13	0.65	4.16	0.03	10.19	11.01	0.75	—
1963	45.84	29.54	0.64	3.58	0.15	8.52	10.18	1.55	—
1964	44.85	27.77	1.89	3.37	0.17	9.16	9.36	3.43	—
1965	38.81	23.71	10.86	3.02	0.10	7.54	11.42	4.54	—
1966	37.11	24.70	15.82	1.60	0.06	5.02	11.10	4.59	—
1967	31.04	22.66	28.72	1.68	0.07	3.22	8.91	3.70	
1968	26.20	32.74	26.95	1.64	0.03	1.85	7.60	2.99	
1969	21.12	40.98	28.30	1.04	0.01	0.13	6.14	2.28	—
1970	22.10	35.93	34.05	0.69	0.01	0.12	5.76	1.34	—
1971	21.70	33.49	35.28	0.66	0.22		5.64	1.01	2.22

dolomite is also worth noting. This will yield a nitrogen fertilizer with a content of about 5 per cent MgO, which should diminish the magnesium deficit in the soil, if used continuously.

Consumption

Table 3 gives the consumption of nitrogenous fertilizers (in thousand metric tons of nitrogen) in comparison with the total consumption of fertilizers (in thousand metric tons N + P_2O_5 + K_2O), and the per hectare consumption of fertilizers in total and in nitrogen.

Table 3. The consumption of nitrogenous fertilizers

Year	NPK	Annual rate of increase (%) a)	N	Annual rate of increase (%) a)	Kg/ha sowed land b)	
					NPK	N
1949/50	362.5	—	93.7	—	24.1	6.2
1959/60	744.6	—	251.3	—	48.6	16.4
1964/65	1106.7	—	386.5	—	73.1	25.5
1965/66	1302.8	117	433.2	112	96.2	28.7
1966/67	1581.7	121	513.3	118	104.7	34.0
1967/68	1829.0	116	604.8	118	121.2	40.1
1968/69	2141.3	117	701.1	118	142.5	46.7
1969/70	2416.3	112	785.0	111	161.5	52.5
1970/71	2571.7	106	822.4	105	172.2	55.1

Source : GUS (Chief Census Bureau) publications.

a) Foregoing year = 100 per cent

b) In order to get the figure per hectare arable land as defined by the FAO Production Yearbook, multiply by :

$$0.9916 = \frac{14{,}961{,}600 \text{ ha sowed land}}{15{,}087{,}900 \text{ ha arable land}}$$

Table 3 shows that in a very short period the gap between Polish agriculture and that of the most developed countries in per hectare consumption of NPK and proportionally of nitrogen, was considerably reduced. By 1975, a consumption of 200 kg NPK per hectare — the conventional lower limit of very high consumption — is expected to be reached.

Exports of nitrogenous fertilizers

In the early 1960 Poland imported certain complementary amounts of nitrogenous fertilizers, about 15,000 tons per year N, but the growth of domestic production made it possible to start exporting by 1967. In 1971 exports had reached a figure of 320,000 tons of nitrogen. The products went to the Far East and the Middle East and also to Western Europe. It is planned to maintain nitrogen fertilizer exports at about the present level. The main products exported are urea, AN, CAN, ammonium sulphate and a certain amount of ammonium phosphate. CAN may also be supplied with a nitrogen content that differs from the domestic standard, i.e. 25 per cent, if wished, by the customer.

The exported fertilizer is in principle packed as for the domestic market, in plastic bags of 50 kg net. When needed, it may also be packed into additional jute bags.

Fertilizers we currently transported to European countries by train, but in the near future it will be possible to ship fertilizers by barges within the bounds of the European inland navigation system.

The domestic retail trade prices shown in table 4 are in zloty/1000 kg.

Table 4. Domestic prices of nitrogenous fertilizers

Type of fertilizers	Percentage N packaging	Zloty/1000 kg
Calcium ammonium nitrate	25 PE bags	2,350
Ammonium nitrate	33 PE bags	2,820
Ammonium nitrate	34.5 PE bags	2,900
Urea	46.3 PE bags	3,650
Calcium nitrate	15.5 paper bags	2,050
Sodium nitrate	15.5 paper bags	1,900
Ammonium sulphate	20.5 bulk	1,300
Aqueous ammonia	20 barrel	900

When fertilizers are bought outside the season for their use, the purchaser gets a discount of from 5 to 13 per cent, depending on the time and the kind of fertilizer.

Future development of nitrogenous fertilizer production and consumption

The planned production and consumption figures for nitrogenous fertilizers to 1980, and the forecast for 1990, are :

Year	Production	Consumption
1975	1,567,000 t N	1,250,000 t N
1980	1,700,000 t N	1,500,000 t N
1990	2,200,000 t N	2,000,000 t N

These figures will mean a nitrogen consumption, kg/ha, of :

Year	Kg/ha arable land
1975	83.3
1980	100.0
1990	133.3

For the purpose of comparison, the figures for P_2O_5 and K_2O consumption are shown below in thousand metric tons :

Year	P_2O_5	K_2O
1975	1,000	1,580
1980	1,250	1,750
1990	1,512	2,200

The forecast for the total and per hectare consumption of NPK is then :

Year	Total	kg/ha arable land
1975	3,800,000	253.3
1980	4,500,000	300.0
1990	5,712,000	380.8

TURKEY

Gungor Cankara

Production

The main corporations producing fertilizer in Turkey are :

a) Turkish Nitrogen Industries Inc., which produces nitrogen- and phosphorus-based fertilizers ;

b) Fertilizer Plants Inc., which produces phosphorus-based fertilizers ;

c) Mediterranean Fertilizer Industries Inc., which produces nitrogen- and phosphorus- based fertilizers ;

d) Karabük Steel- Iron Industries Inc., which produces nitrogen and phosphorus- based fertilizers.

The amount of various fertilizers produced by the plants of these companies are :

a) Turkish Nitrogen Industries Inc.

I. *Kütahya*

Ammonium sulphate — 21 per cent N 80,000 tons per year
Ammonium nitrate — 20.5 per cent N 60,000 tons per year
Ammonium nitrate — 26 per cent N 338,000 tons per year

II. *Samsun*

Triple superphosphate (TSP) 18—46—0, 45 per cent P_2O_5 220,000 tons per year
or Diammonium phosphate 139,500 tons per year

III. *Elazig*

Normal superphosphate — 18 per cent P_2O_5 220,000 tons per year

b) Fertilizer Plants Inc.

I. *Iskenderun*

Triple superphosphate (TSP) — 43—45 per cent P_2O_5 100,000 tons per year

II. *Yarimca*

Normal superphosphate — 16—18 per cent P_2O_5 100,000 tons per year

III. *Mediterranean Fertilizer Industries Inc.*

Ammonium nitrate — 26 per cent N 600,000 tons per year
Diammonium phosphate 18—46—0 150,000 tons per year

IV. *Karabük Iron-Steel Industries Inc.*

Ammonium sulphate — 21 per cent N 8,500 tons per year
Single superphosphate — 16—18 per cent P_2O_5 22,000 tons per year

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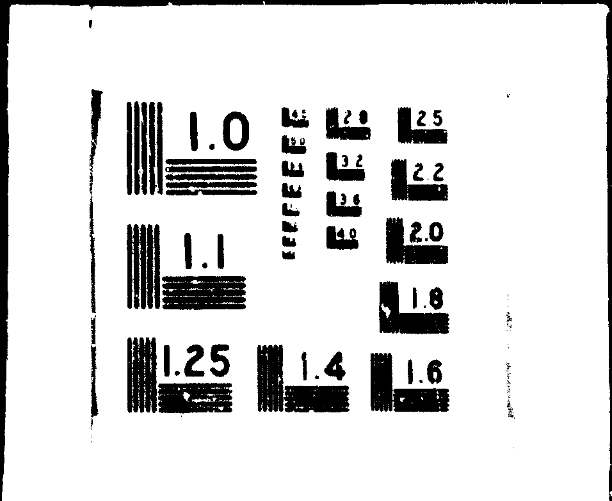


Consumption

The production and consumption of fertilizer in Turkey since 196[illegible]

Year	Production 1000 tons per year		Consumption 1000 tons per year	
	N	P_2O_5	N	P_2O_5
1960	[illegible]	[illegible]	148	[illegible]
1965	54.5	49.4	193	[illegible]
1969	[illegible]	43.4	245	107
1970	80	65.7	255	186
1972	200	196.5	378	360

Fertilizer plants

Kutahya. This complex is located in central Anatolia. It is accessible by rail and road. Production consists mainly of ammonia, nitric acid and salt.

The following fertilizers are produced in the Kutahya plants : ammonium nitrate, 20.5 per cent N, by the BASF process ; ammonia by the Haber-Bosch method , and ammonium sulphate, 21 per cent N produced by the prilling method of Kaltenbach. The necessary ammonia is manufactured by the Casale method.

Samsun. This complex is located on the central Black Sea coast. It is accessible by sea and road. The phosphoric acid and triple superphosphate or DAP plants are its major sections. The SIAPE-Chemiebau process is used to produce the TSP, and DAP can be manufactured by the Chemiebau Olin process.

Elazig. This plant is located in the south-east part of Anatolia. It is accessible by rail and road. The acidification and granulation units are the major parts of the plant. The process used is Industrial Export, and the Moritz reactor is employed.

Iskenderun. This plant is located on the eastern coast of the Mediterranean Sea. It is accessible by rail, sea and road. TSP is produced by the Broadfield-Den method.

Yarimca. This plant is located on the south-eastern coast of the Marmara Sea. It is accessible by rail, sea and road. SSP is produced by the Broadfield-Den method.

Mersin. This complex is located on the eastern coast of the Mediterranean Sea. It is accessible by rail, sea and road. The phosphoric, nitric and sulphuric acid plants and DAP and ammonium nitrate plants form its major sections.

Karabuk. This complex is located in the north-western part of central Anatolia. It is accessible by rail and road. The ammonia in the coke-oven gas obtained from the coke plant of this complex is treated with sulphuric acid in a semi-direct method to produce ammonium sulphate, with 21 per cent N, as a by-product. SSP with 16—18 per cent P_2O_5, is also produced, using the Maxwell method.

Raw materials

The main raw materials of the fertilizer industry are coal, naphtha, fuel oil, smelter gases, phosphate and sulphur-containing ores. Ammonia, and nitric, sulphuric and phosphoric acids are obtained from these raw materials and then converted to various fertilizer products.

Sulphuric acid. It is estimated that 45,000 tons of sulphuric acid were consumed (other than by fertilizer industries) in 1972. The following plants, currently manufacture sulphuric acid :

Karabuk has an annual production of 20,000 tons. The acid is produced in pyrites roasters and is sold to the market.

Murgul Copper Complex has an annual production of 20,000 tons. The acid is produced from smelter gases and is sold to the market.

The Samsun sulphuric acid unit, which is a part of the TSP plants, uses pyrites roasters and has a capacity of 215,000 tons per year.

The Bandirma sulphuric acid plant uses pyrites roasters and has a capacity of 120,000 tons per year.

The Mersin sulphuric acid plant, which will have a capacity of 214,500 tons per year, is about the commence production.

Small amounts of sulphuric acid are also produced in the Elmadag and Yarimca plants.

Pyrites, sulphurous and smelter gases are used to manufacture sulphuric acid.

Year	Pyrites production (tons)	Sulphur production (tons)
1970	88,592	26,760
1969	124,367	25,700
1968	130,057	24,180
1967	125,010	25,030
1966	120,622	22,650

The future of the fertilizer industry

Estimated production

The new plants in the 1971—1972 investment programme are the ammonia-urea plant of the Turkish Petroleum Company, the ammonium nitrate (Gemlik) and the DAP (Samsun) plants of Turkish Nitrogen Industries, and new sections of the Yarimca and Iskenderun plants of Fertilizer Plants Inc. By-product ammonium sulphate will be manufactured by the Turkish Petrochemical Industries caprolactam project. Bandirma Fertilizer Industries is in the process of erecting a single superphosphate plant in Bandirma.

The capacities of the plants being planned and built are :

Company	Fertilizer	Designed capacity (1000 tons per year)	Year of erection
Turkish Petroleum	Urea, 46% N	360	1972—1974
Turkish Nitrogen Industries (Gemlik)	Ammonium nitrate, 26% N	600	1972—1974
Turkish Nitrogen	DAP 18-46-0	220	1971—1973
Fertilizer Plants (Yarimca)	TSP, 45% P_2O_5	200	1971—1973
Fertilizer Plants (Iskenderun)	TSP, 45% P_2O_5	200	1971—1973
Turkish Petrochemical (Caprolactam)	Ammonium sulphate, 21% N	100	1972—1974
Bandirma Fertilizer	NSP, 18% P_2O_5	200	1970—1972

Estimated consumption

In 1968, the crop patterns were prescribed regionally by the Ministry of Agriculture and an attempt was made to estimate the variations from these patterns up to 1982. The possible applications of the new projects to high-priority crops and the developments in crop patterns were considered.

Estimated fertilizers consumption in selected years to 1982 are in 1000 tons

Kind of fertilizer	1972	1977	1982
N	486	707	987
P_2O_5	300	580	781
K_2O	11	16	26

MAIN PROBLEMS IN THE FERTILIZER INDUSTRY

RAW MATERIALS

Some problems have arisen in obtaining pyrites, phosphate rock and ammonia

PRICE COST PROBLEM

The price of fertilizer is especially affected by two factors : the cost of the fertilizers and the distribution charges.

The cost of raw materials is the largest item in the overall cost of the fertilizer. The distribution charge is about 20 per cent of the plant delivery price.

PRODUCTION OF THE BEST FERTILIZERS FOR TURKISH SOIL

The combination of nitrogen — and phosphorus-based fertilizers has given good results for most of the crops harvested in Turkey. With respect to compound fertilizers some detailed work is being done under the third Five year Development Plan.

SPARE PARTS

Since the existing plants and the plants under construction use mainly imported machinery and apparatus a major problem is the availability of sufficient spare parts as needed.

QUALIFIED WORKERS

To find and keep experienced and qualified employees has been a serious problem, especially for corporations with low capital return such as Government-owned fertilizer companies.

The courses given to train workers have not been sufficient to meet the demand, and exodus of qualified workers to West-European countries has aggravated the problem.

YUGOSLAVIA

Anton Vizovisek

The possibility of exploiting a domestic deposit of phosphate ore is being investigated in Yugoslavia but the results so far obtained are not very promising.

All of the potassium fertilizer used — about 200,000 tons per year is imported.

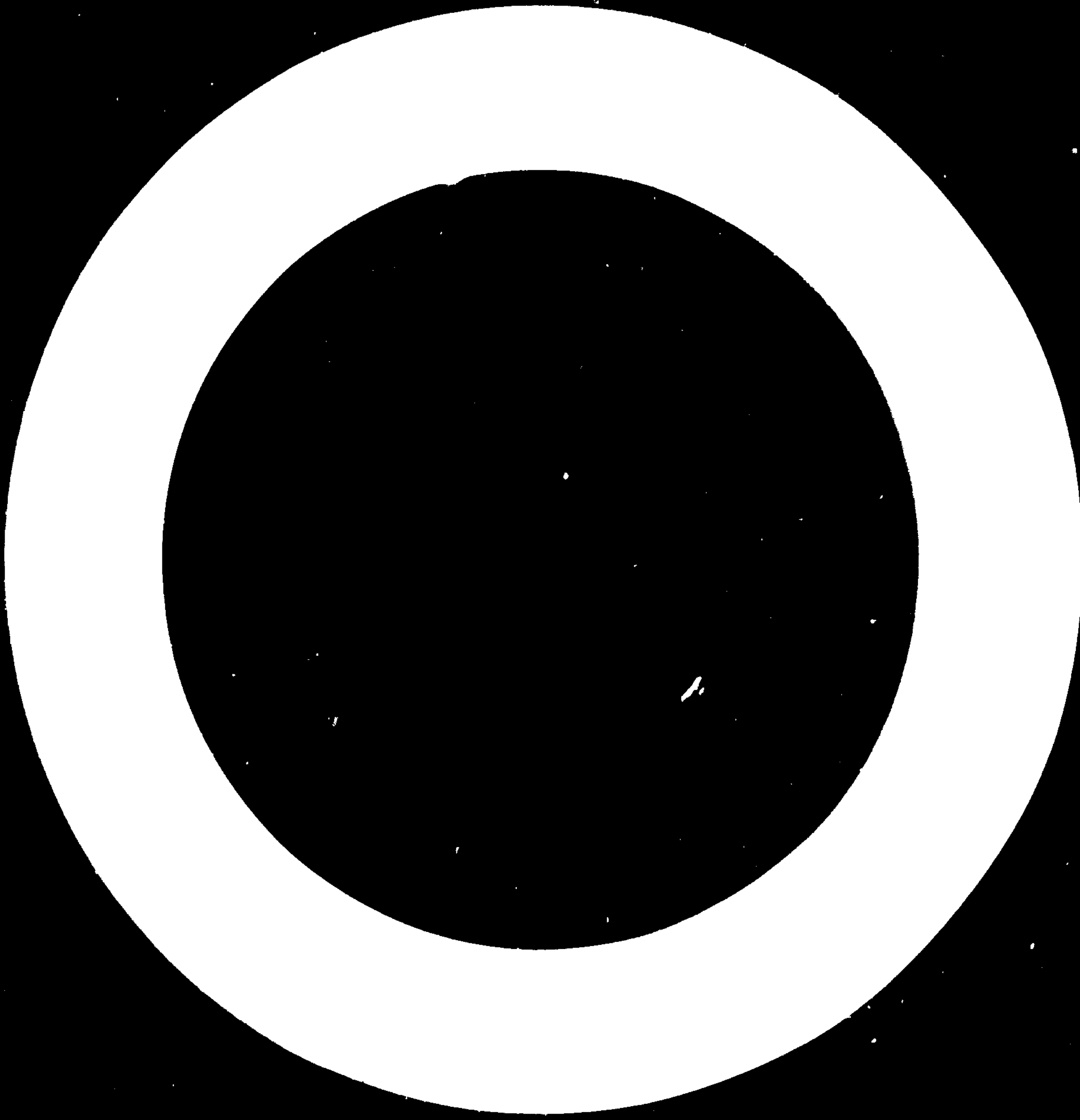
Urea is produced at Pancevo and Kutina in plants with a capacity of 100,000 tons per year each.

The national capacity for manufacture of phosphoric acid is about 160,000 tons per year acid, and for complex fertilizers, about 1.4 million tons per year product.

Consumption in 1971 was estimated at 300,000 tons N and 220,000 tons P_2O_5. The average consumption is still low about 81 kg/ha, and producers must begin to consider the specific needs of farms in their own localities.

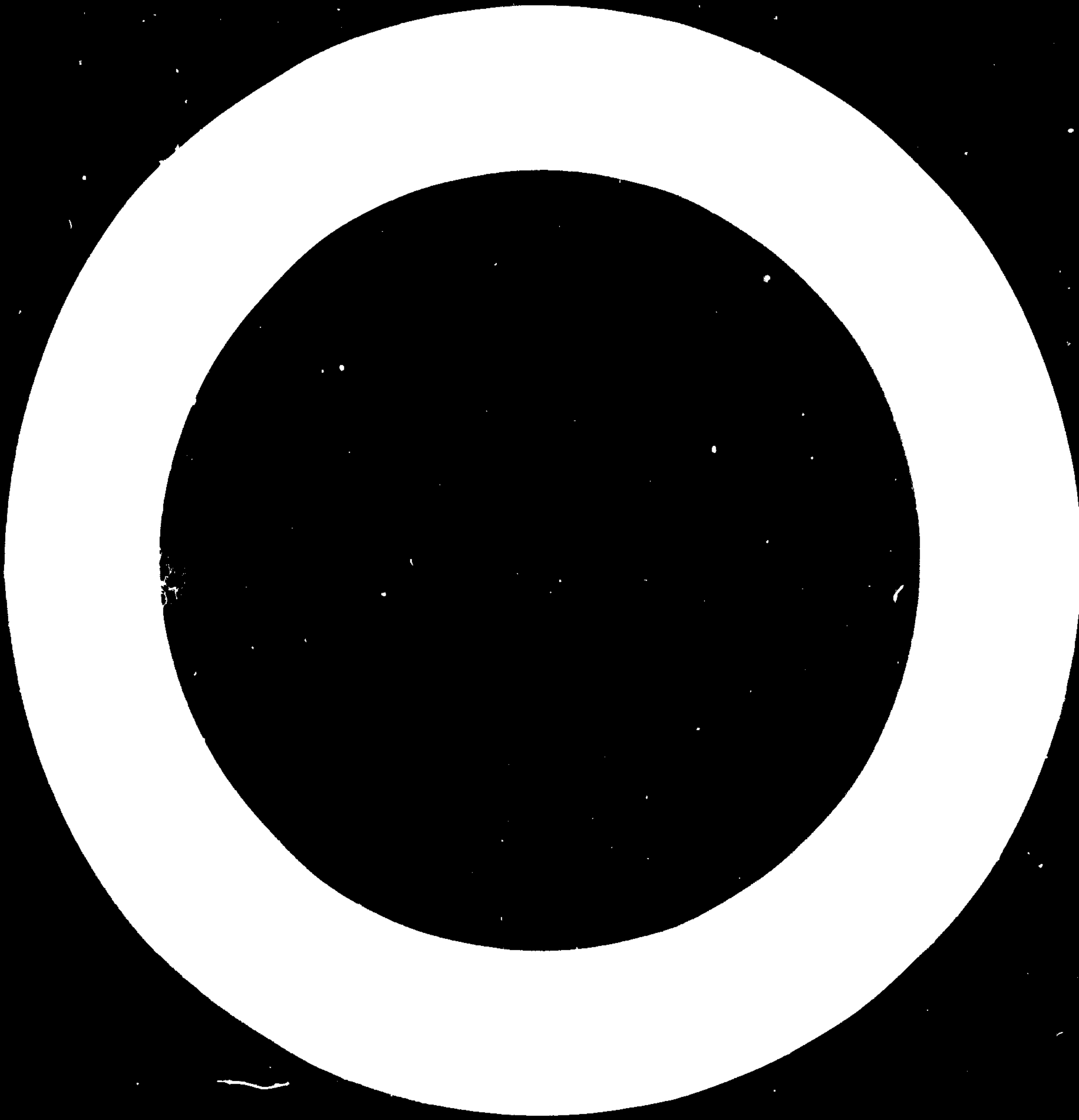
Soils in Yugoslavia tend to need more phosphorus and somewhat more potassium than they are receiving, and the intention is to increase the rates of application of these two nutrients while maintaining the nitrogen rate at about its present level.

The production and use of liquid fertilizers are being studied. The research is partly sponsored by the pesticide industry, which is interested, for example, in tank mixtures for the simultaneous application of fertilizer and pesticide. At present there is no industrial production of liquid fertilizers in Yugoslavia.



Part three

PAPERS RELATING TO THE PESTICIDE INDUSTRY



VI. PAPERS SUBMITTED BY CONSULTANTS

GRANULAR PESTICIDES

Otto Zeiser *)

Granules are becoming of great importance in industry, agriculture and other areas of our life. Granules may be used to improve storage and transport stability, to provide simpler use and better results. This holds true for instant milk powder, fertilizers and encapsulated seeds.

Granulated pesticides have gained importance only in recent years but are now being used more and more extensively.

Many problems can be more efficiently resolved with the aid of granulated pesticides. In this paper, the following aspects of granular pesticides are discussed :

- general characteristics
- formulation processes
- application
- residues and toxicity hazards

Granules are mixtures of an active compound and inert matter. Their particle size ranges between hundreds and several thousand microns. In many cases, surfactants are absent. Stabilizers and binders are common adjuvants. There is no standard operation for producing granules. Some active material may need a particular carrier composition to combine mechanical and chemical stability with good field performance.

Often granular pesticides are difficult to formulate. Much effort and time are needed before being marketable. Sometimes there is no problem at all.

The best known formulation method is impregnation, which is a simple operation with a large output and low investments.

Other methods are agglomeration to form bentonite granules, compaction which may become of greater importance in the future, but needs large investments and extrusion which is feasible for a few compounds only.

Some recent developments include microencapsulation. In the United States, microencapsulated methylparathion was field tested in a large scale during the summer of 1972.

Microgranules will find a limited application.

General characteristics

The following characteristics of granular pesticides should be determined : specific gravity or bulk density, the number of particles per gram, water content, moisture uptake, swelling capacity with water, abrasion and dust formation.

The most obvious characteristic is particle size, which is defined by dry-sieve analysis with standard sieves (table 1). Granular formulations have a characteristic particle-size distribution. The narrower the particle-size range, the more uniform the coverage.

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*) *AMONN Fitochimica S.p.A. Bolzano, Italy.*

Table 1. Particle size characteristics

	Average particle size in microns	Allowed maximum deviation
Dust	< 40	max 5% > 40 micron
Microgranules	100—200	no dust
Granules	250—2000	max 5% < 250 micron
Macrogranules	> 2000	no dust

Dust content must be minimized in granules because of drift, toxicity hazards and danger of overdosage. Dust is defined by a particle size smaller than 40 microns. United States Department of Agriculture allows no more than 5 per cent fines smaller than 250 microns.

Recently microgranules with particles between 100 and 200 microns were proposed for special applications. Microgranules should not contain particles below 40 microns. Microencapsulated liquids may be as fine as 10 microns.

There is a significant difference between pesticidal dust, microgranules, granules and macrogranules when the same active material is applied at the same dose per surface area. In most cases the various formulations have the common characteristic that they act by vaporization, aqueous solution or both.

Usually no surface-active compound are incorporated in pesticide granules. In effect, this distinguishes them from wettable, water-dispersible powders.

Granules can be spherical, but they are mostly non-spherical and asymmetrically shaped. The distribution of active material within or on the granules may be homogeneous or heterogeneous depending on the formulation process. The compaction of mixed powders gives evenly distributed active compounds.

The impregnation of sorptive carriers with liquid or liquidized pesticides occurs less evenly. In this case, the sorptive carrier can have a high inner surface. This inner surface is given by the porosity and diameter of microscope. The inner surface is dependent of particle size. The sorptive capacity of common pesticide carriers and diluents are given in table 2.

On non-sorptive granules such as fertilizers, reasonable amounts of pesticide can be deposited with binders. This deposit is sometimes easily sheared off by abrasion and gives a dust of high active-material content.

Table 2. Sorptive capacity

	Bulk density (g/cm³)	Amount of water taken up to the wet flow point (cm³/g)	Specific surface (water sorption technique) (m²/g)
Talc	0.4—0.6	1.00—1.28	1.8—15.8
Mica	0.5	1.10	2.6
Botanicals	0.2—0.4	1.70—4.52 1.40—1.85 a)	—
Montmorillonite group	0.4—0.6	8.00—8.53 b)	294—397
Attapulgite	0.3—0.5	—	120—140
Synthetic SiO_2	0.20—0.25	2.55	210

a) No swelling
b) Swelling

Source: Handbook of insecticide carriers

Coating with oily layers, films of plastics or pigments is therefore fairly often exercised, if necessary, in combination with natural or synthetic gums. Such layers encapsulate or rather cover granules, giving them more mechanical stability for transport and graded release after application.

In some cases, it may be desirable to initiate the disintegration of the granules soon after application. This can be achieved with swelling carriers, such as bentonite. When moistened by rain or in contact with wet soil, especially if some wetting agent is present, swelling bentonite disintegrates pesticide granules.

New techniques are still being invented, as the possibilities for controlling the characteristics of granules have not been exhausted.

To obtain a good product, the formulator has to consider the chemical and physical properties of the active material, especially solubility in water, stability to hydrolysis, volatility, compatibility with carrier, and the adsorption and decomposition in soil.

Close co-operation with the agronomist is advisable. Environment and climate can significantly affect the performance in regard to crop and pests.

Intensive field trials give indications about the active material to be used. Quality and quantities should be based on practical results.

Formulation processes

Once the formula is elaborated, greater quantities have to be produced. It is not always easy to obtain stable granules economically.

Economic factors to be considered are costs and availability of inert material, quantities to be produced within a given period and quantities to be produced in the future. These factors determine the capacity and degree of automation of the installation and the capital investment. Personnel has to be trained, and the maintenance group must be equipped. Production costs have to be calculated.

A short description of the formulation processes follows :

A. IMPREGNATION

Impregnation is absorption of liquid or liquidized pesticides in preformed, sorptive granules. The sorptivity of the carrier gives the percentage of liquid matter that can be absorbed.

If the pesticide is a solid, it can be dissolved in non-volatile solvents. A dispersion of finely ground pesticides can also be sprayed on inert granules. In most cases, impregnation leads to good results. This method should therefore always be considered first.

The properties and performance of impregnated granules depend on the inert carrier.

Organic carriers include wood flour, ground tobacco stems, maize cobs, coffee grounds, walnut shell flour and other sorptives. The wastes from polymer manufacture can also be used.

Inorganic carriers include granular clay, especially of the montmorillonite group. Bentonite, attapulgite and sepiolite are well known inorganic carriers.

Other inert carriers are pumice which is highly sorptive, but also abrasive, calcined diatomite and granulated fertilizer. The choice of a good carrier is often difficult.

Pesticides can be decomposed by the carrier, particularly by clays. On the large inner surface are active sites, where pesticides may be adsorbed and decomposed catalytically. Spontaneous decomposition is possible and can lead to ignition.

It is possible to inactivate these sites with urea, hexamethylene tetramine or glycols. Granules are impregnated with a few percent of deactivator prior to impregnation. Tall oil may be applied as a stabilizer with the active compound. Deactivation may not always be necessary, but it deserves attention.

Studies on the compatibility of carrier and pesticide are essential. These can be done by formulating the product with well defined concentrations. The granules are stored at elevated temperatures during a given time. At intervals, the product is analysed chemically to determine changes in the active material content. If no significant decomposition after a few month at 50 C is noticeable, the formulation can be considered stable.

A better indication, however, should be given by storage under practical conditions. It is always the performance in the field that gives the final answer.

The impregnation process itself is no great problem. In the laboratory any type of rotary blender equipped with an injector can be used.

Reliable results concerning dust formation can be obtained only by using mixers of at least 200 l capacity. Dust formation is often a problem.

Untreated bentonite granules may have a favourable particle size distribution as shown in figure I. However, their stability is frequently not adequate and the treatment required is too tough, so that the impregnated granules may contain too much fines.

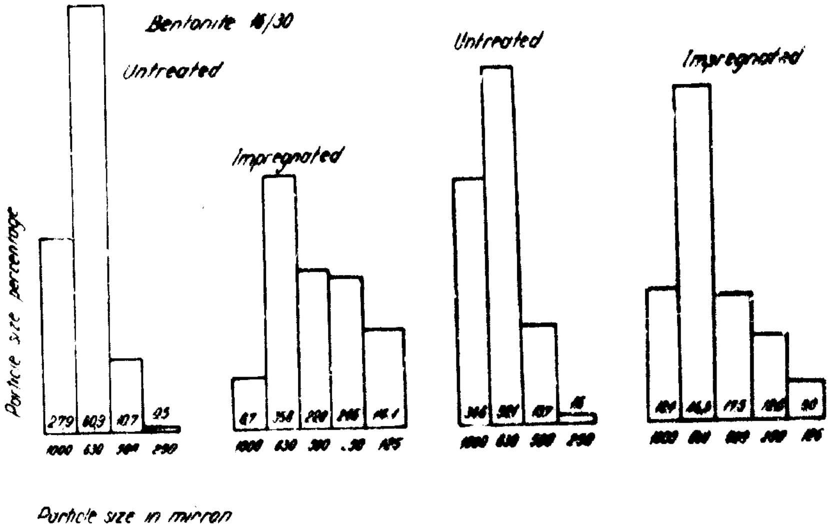


Figure I. Particle size distribution of bentonite granules

Active material is sprayed at a pressure of 3—5 atm with full cone nozzles. This may be done by pumping with a gear pump or with air pressure from a pressure vessel.

With a concrete mixer of 3—5 m³, one can obtain good results up to 2 ton/batch operation. But any other rotating drum, tumbler or not, is good for impregnation, if injection of the liquid compound is possible. A flow sheet is given in figure II.

If inert granules are transported with a screw conveyor at a constant rate, continuous impregnation is possible. The liquid is injected into the by passing granules. This installation can be fully automated. A plant cost estimate based on the autohr's experiences is given in table 3 where a batch operation with 500 ton per year output is compared with a semi-automatic and a fully automated installation. Labour is calculated at $ 3/hour. Amortization is made in ten years. Capital costs are calculated with 5 per cent over this period. Direct and indirect costs may be different.

Simple and appropriate installations give the best results and not highly sophisticated equipment.

Most important is capacity. Each installation has an optimum capacity. It is always a problem to determine and to reach this optimum. No installation can be used with full load all year round.

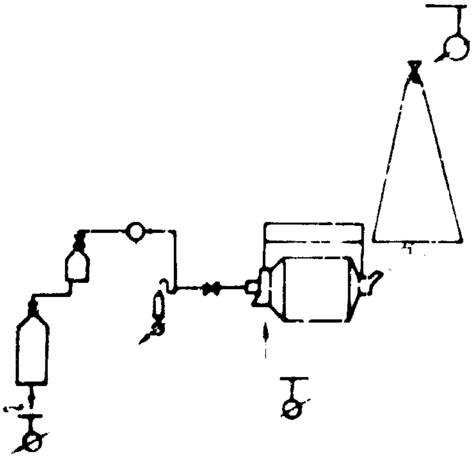


Figure II. Impregnation of granules. Flow sheet

Operation costs for granules in a well-balanced installation are not greater than costs for a wettable powder formulation, but whereas inert carriers for wettable powders cost $ 10—40/ton, the inert carriers for granules cost $ 40—80/ton. The use of organic carriers may possibly reduce material costs. Higher material costs are balanced by lower application costs.

Table 3. Cost calculation for impregnation

	Batch	Semi-automated	Automated	
Capital invested	30,000 $	50 000 $	200,000 $	
Daily output	5 tons	8 tons	40 tons	
Number of workers	8	4	7	
VG finished product per working hour	80	300	750	
Yearly output, max.	500	1,000	10,000	
Yearly output, eff.	500	500	500	3,000
Operation cost per ton	3,000/500	5,000/500	20,000/500	20,000/3,000
Amortisation 10 years within	6.0	10.0	40.0	6.7
Interest 5 per cent of invested capital	3.0	5.0	20.0	3.3
Direct wages	37.0	10.0	4.0	4.0
Direct costs	3.0	10.0	20.0	20.0
Indirect costs	5.0	5.0	5.0	5.0
Total per ton	54.0	40.0	89.0	39.0

B. AGGLOMERATION

Agglomeration of finely divided and well-mixed powders is effected by rotation and simultaneously moistening the powder with 5—25 per cent water. The percentage of water depends on the material and blender characteristics. The amount of water, time temperature, the speed of revolutions and the shape of paddles are critical factors. A well known agglomeration process is pelletizing, that is used for fertilizers, baits and inert bentonite granules (figure III).

Granules must be dried, sifted, crushed and again sifted. Fines must be recycled.

Pesticide granules need binders A few percent of ligninsulphonate may suffice to minimize dusting

In this process water has to be evaporated at elevated temperatures This may cause decomposition of active material Operation costs are affected considerably

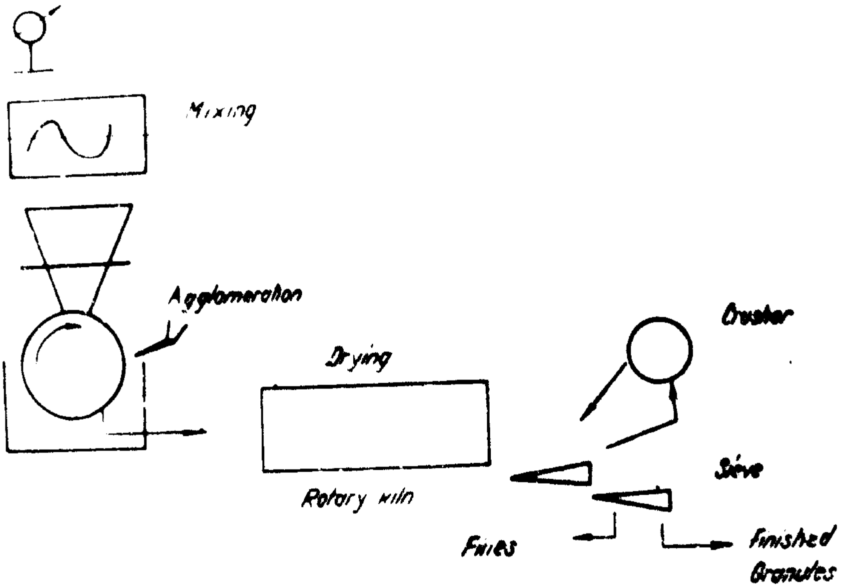


Figure III. Agglomeration flow sheet

In this connexion I have to mention a new formulation method designed by Diamond-Alkali researchers to provide controlled release of the active materials Granules are formed by using mixtures of gypsum and ammonium or aluminium sulphate as a carrier composition. In the presence of 5—30 per cent pesticide the mixture is rotated and wetted to agglomerate granules

Gypsum and ammonium sulphate in the presence of water give stable adducts, containing chemically bound water, so the granules can be dried at low temperatures

C COMPACTION

Compaction is accomplished by passing a moist mixture of powders through steel rolls The powder is compacted under enormous pressures, whereby temperatures of 80°C and more are reached, thus evaporating most of the water

With fertilizers and with matter of some plasticity, rather dense granules can be obtained after disintegrating the compacted sheets.

For pesticides binders are needed

Care must be taken that the powder to be compacted does not contain excessive amounts of air. The powder must be deaerated before compaction. This can be a problem. Controlled disintegration of the compacted sheets followed by sifting out the needed fractions gives 80 per cent fairly firm, irregularly shaped granules. They may be coated afterwards for better resistance to abrasion during transport and handling (figure IV).

This procedure lends itself to controlled release, because different effects can be built in. The process as such is complex and needs high investment of capital. The process is feasible with an output of 10,000 tons per year.

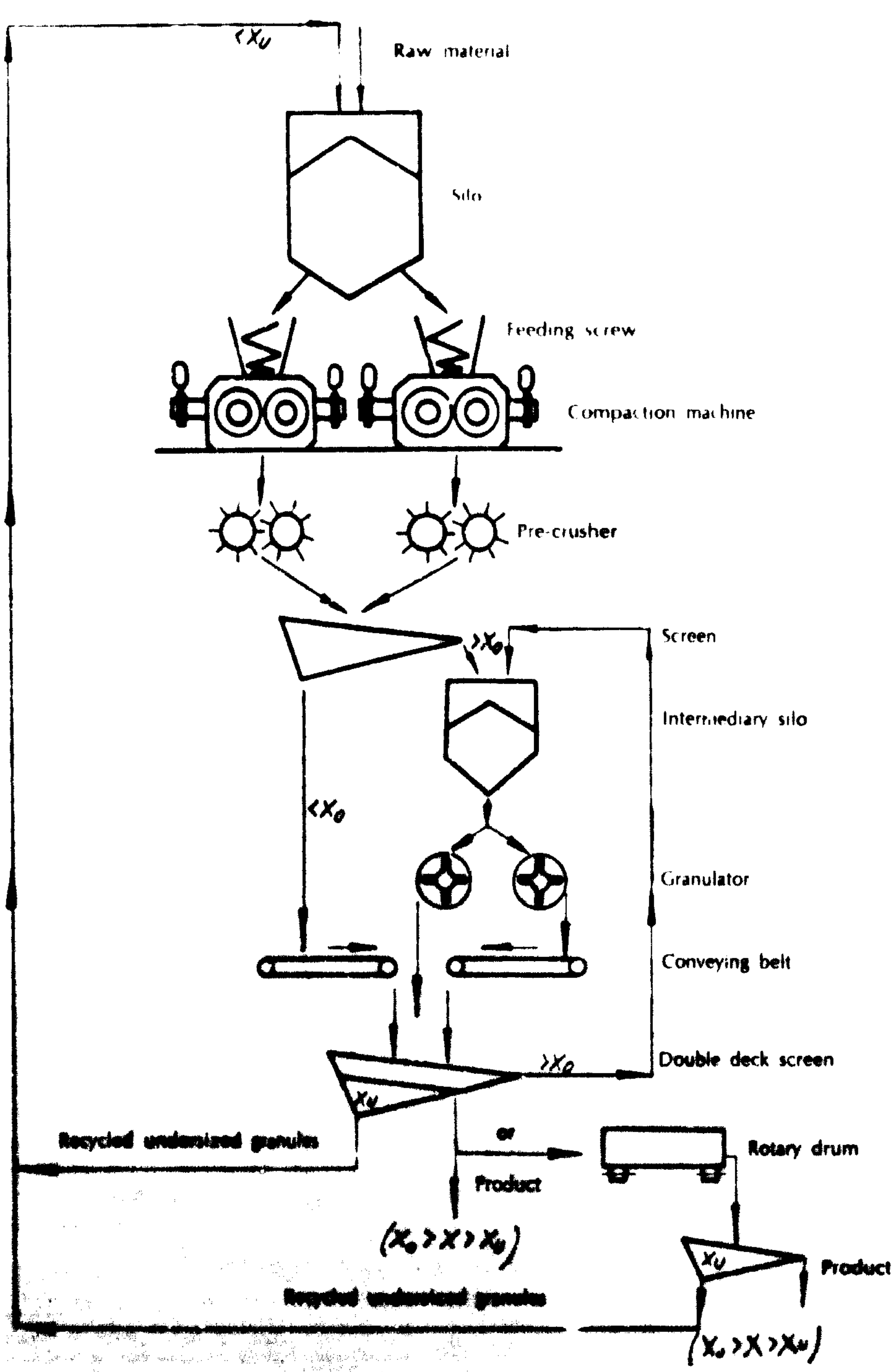


Figure [illegible]. Compaction

Source: [illegible]

D EXTRUSION

Extrusion is performed by pressing a pasty mass through small openings. Also oscillating rolls can pass over a sieve, thus extruding the material. A rotating knife cuts the threads in small pieces. 5 per cent metaldehyde with organic fillers gives macrogranules for baits without drying. Unfortunately all other formulations need an expensive drying process. Carriers such as bentonite form thixotropic masses, but they need great quantities of water — 20 per cent or more water has to be used and evaporated. Dolomite as carrier would need only 5 per cent water. This fact illustrates the importance of properly selected carriers.

In Japan extrusion is a common process, may be because paddies need very stable granules, may be because bentonite is available and energy is cheap. This process is only possible with stable, non-volatile pesticides.

E MICROENCAPSULATION

Microencapsulation of liquids to form granules with all the characteristics of dry matter is a most important process. Pesticides are not yet encapsulated on a large scale (figures V, VI).

Encapsulation may be achieved by

phase separation by coacervation

interfacial reactions by polymerization of monomers

physical methods such as spray coating in a fluidized bed.

Pennwalt encapsulates methylparathion. Particle size will be 10—40 microns but it is possible to make finer or coarser capsules to assure the desired rate of toxicant release.

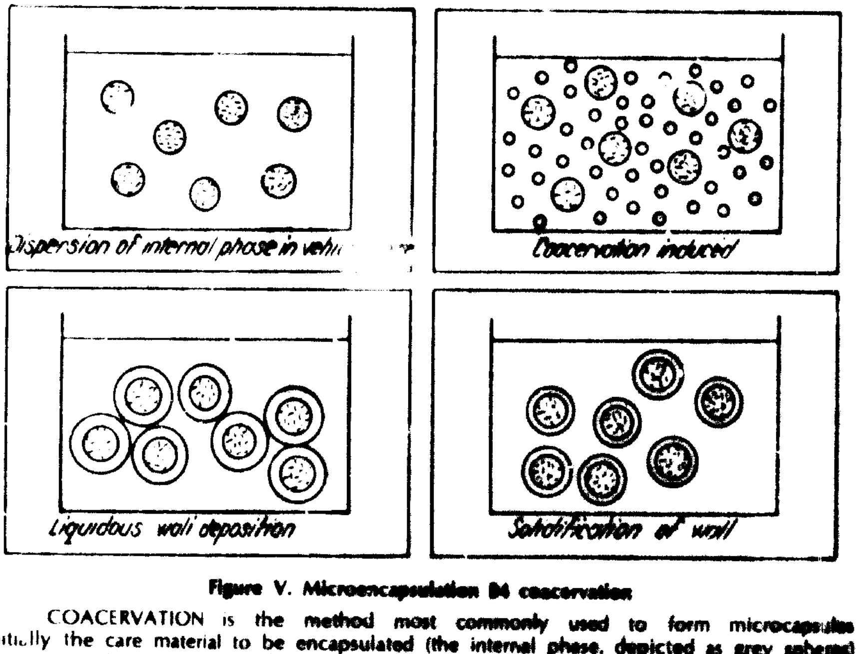


Figure V. Microencapsulation by coacervation

COACERVATION is the method most commonly used to form microcapsules. Initially the care material to be encapsulated (the internal phase, depicted as grey spheres) exists as a dispersion suspended in a liquid (the vehicle phase, in pale colour) in which it must be immiscible. A wall material, such as gelatin, is also suspended as a sol in the dispersion medium or actually dissolved in it (this, the external phase, is therefore not visually evident in the first illustration). To induce coacervation the temperature, pH or composition of the system is changed in some significant and carefully controlled way. The wall material comes out of solution (as the coacervate, shown in deep colour) and eventually aggregates around the core particles to form continuous encapsulating walls. These are then hardened.

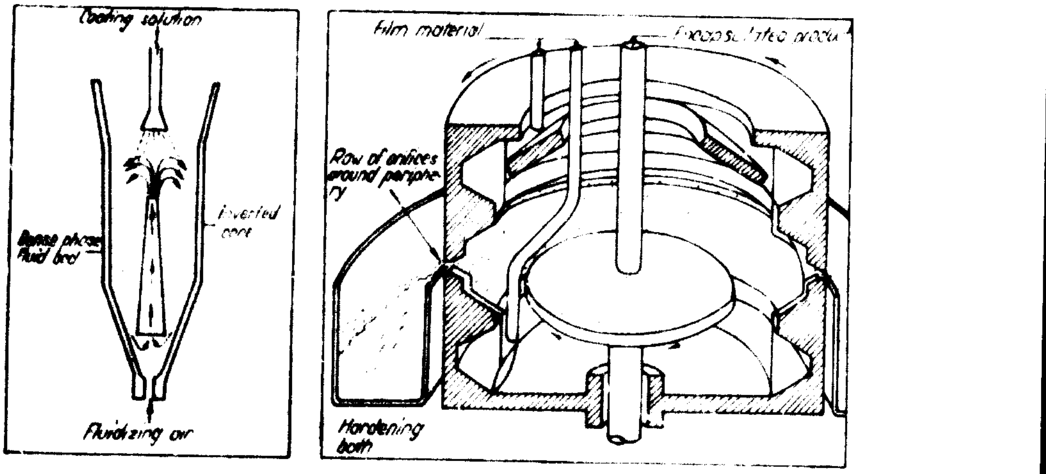


Figure VI. Microencapsulation with mechanical methods

MECHANICAL METHODS of encapsulation are preferred for some systems and research into these techniques is very active. In the modified fluidized bed method (left) air is pumped vertically up through a dense fluid bed of core particles. The latter, which may be either solid or liquid, constantly circulate and are blown upwards at high speed through a tapering cone. Wall material is deposited on the relatively widely separated particles above this cone. Centrifugal encapsulation follows a principle patented by the US Southwest Research Institute (right). Wall material is fed to the inside of a spinning drum and escapes through fine peripheral holes. Core particles are flung from a rotating disc and build up on the wall membrane over each escape hole. When enough core has gathered at one hole centrifugal force causes it to distend the wall membrane through the hole and tear it away to form a microcapsule, which then drops into the hardening bath. The hole is immediately re-covered by fresh wall membrane and the process continues.

Mire is experimentally encapsulated by NCR as baits for fire ants while Pennwalt is encapsulating disparlure, the isolated sex attractant of the gypsy moth.

Formulation costs for this process are very high and at the moment there are only a few companies specialized in this technique.

F. MICROGRANULES

Microgranules were developed to apply herbicides of the hormone group with lesser costs and reduced drift. Microgranules are highly concentrated granules with application rates of 5—10 kg/ha.

Application

The application of granules is cheaper and simpler than conventional spraying. Taking into account manpower, machinery and maintenance, $ 10/ha are needed for conventional spray treatment. The same treatment with granules costs only half this amount, i.e. $ 5/ha. The higher price of granular formulation can be compensated by lower treatment costs.

But even if it is not possible to compensate the higher price (comparisons of this kind are always difficult) we have strong arguments for using granules, as follows : simple application, in some cases without any machinery at all ; no problem with the preparation of dispersions or emulsions ; no use of water, no pumping and nozzle problems ; no drift of highly toxic material, less danger for farmers. Application of granules provides new possibilities for improved results. With one treatment of aldicarb granules, aphids on roses are controlled at least for 6 weeks. Submerged weeds are controlled with dichlobenil or diuron granules, no other formulation is as effective.

To achieve pest and weed control, 1—10 kg/ha of well chosen material has to be deposited in predetermined locations. This may be a spot, row or even spread treatment. Spot treatments are made with a tube equipped with a simple dosage device or by hand. Band treatments may be made with drill machines or with one of several devices in use; the best application machinery works by pneumatic distribution. An air stream carries a continuous jet of particles to bands of 20—200 cm width. These pneumatic distributors are also good for overall treatments.

Overall treatment can also be made with fertilizer distributors if they are calibrated exactly. The problem in this case is exactness: fertilizers are used with 1000 kg/ha and more; it is not critical if some rows are treated twice. Herbicides are applied at rates of 30—100 kg/ha. An overdose may mean a heavy loss or complete kill of the crop.

Drift is no problem with conventional granules. Table 4 demonstrates drift measured for dichlobenil granules at various wind velocities. With microgranules drift could be a problem and there should be no wind during application. Granules can be easily mixed with other granules if they have the same size range and the same specific gravity. Otherwise there may be separation problems.

Table 4. Drift of dichlobenil granules at various wind velocities

	— Drift in cm —											
Wind in meters/sec	0.5			1.2			2			5		
Fall height in cm	20	40	60	20	40	60	20	40	60	20	40	60
Granules 0.25-0.5 mm	1.5	1.5	4	2	2	8.5	4	8	16	8.5	29	50
Size 0.5-1 mm	1	1.5	3	1.5	1.5	4	3	4.5	9	6	16	30

The distribution pattern is characteristic for only one specific granule. Calibration should be made for every new formulation.

Granules are used for soil, plant or water treatment. Application in soil involves a combination of different factors: type of soil, structure, nutrient status, micro-organisms, water content, temperature and many others.

Fumigants when granulated (e.g. Nemagon) are easier to use. Granulated Dazomet releases the toxic gaseous methylisothiocyanate slowly. Application is easier because there is no drift of dust. Nematocides are often highly toxic compounds. Application of granules lowers toxicity hazards. Aldicarb absorbed on an organic carrier, coated and containing a warning odor gives excellent results and is easy to apply.

Soil insects such as wire worms, rootworms and cutworms are well controlled with aldrin granules. The carrier may be a fertilizer. Residues with aldrin are becoming a problem, so less persistent insecticides should be used. The problem is that most of the substitute compounds are decomposed by hydrolysis or by biodegradation before they can act.

Granulation controls release, rate of hydrolysis and biodegradation, which also depend on temperature, acidity, movement, aeration, rate of application and amount of water.

Decomposition in soil was studied by many authors. P. T. Walker gives a good survey in volume 40 of *Residue Reviews*. Parathion, applied at 5 kg/ha may be 70 per cent decomposed after 12 days (E.P. Lichtenstein *J. Econ. Entom.* 57, 618—627, 1964). In Mediterranean climates this may be as long as six weeks. Depending on insect species considered and time of application, this period may be enough to give sufficient control from ten weeks to a full season. There is a number of phosphorus compounds which persists up to 6 months in soil : fensulfothion, trichloronate, chlorfenvinfor, but these compounds are rather expensive. So it is of great interest to find improved formulation and applications for parathion granules which are relatively cheap. Fungicides such as quintozene can be phytotoxic to some crops. Granulation with controlled release solves this problem.

Applications on plants give possibilities for selective effects. In cereals broadleafed weeds are treated with 2,4-D, MCPA and similar compounds. With conventional spray techniques drift is a problem, especially if vineyards are nearby. Microgranules applied at 5-10 kg/ha adhere on broadleafed weeds better than on cereals and grasses. Drift is also less a problem than with conventional sprays.

Conventional granules would not adhere, but fall on to the soil. The pesticide penetrates through the upper soil layer and finally reaches the root systems. Results may be quite different as compared with microgranules of the same pesticide.

Corn borer control is possible with carbaryl granules, because granules mainly fall and collect in the leaf sheath of corn, where the borers attack. With rain or dew small amounts of carbaryl are dissolved, sufficient to control the corn borer.

Controlling pests in water is often a problem if they live on the bottom of canals, lakes, paddies. With granules it is possible to reach them. Development of submerged weed may be controlled with herbicides such as dichlobenil. For example, a canal of 10 m width is treated with two applicators on the embankements. It is possible to treat 3—5 km/hour. The same results may be obtained with treatments from a boat.

The highest concentration of pesticide in water is given by its solubility. Pesticides with high water solubility must be carefully applied. Since pesticides are absorbed by plants and plankton, accumulation in fish is possible, even if the solubility in water is not high.

Residues and toxicity hazards

Residue problems and toxicological hazards are connected with various characteristics of the particular pesticide and not only its intrinsic toxicity.

By formulating hazardous pesticides in a granular form it is to a limited extent possible to keep unwanted side effects somewhat under control. But one cannot possibly expect to eliminate hazards completely.

Theoretically, a compound that would decompose easily can be encapsulated so that it will permanently remain within the wall and thus never become active.

In practice there are factors that bring about changes at the surface of the capsules. Humidity, temperature and micro-organisms are such factors, thus the encapsulated toxicant will not always be released at the same rate.

In discussion, Dr. Zeiser said that prospects for expansion of granulated fungicide consumption seem to be best for soil insecticides and systemic fungicides.

Best carriers for organophosphorus insecticides are probably corn cobs, where they are cheap, although they are not really dense enough for easy distribution, and bentonite.

One of the participants suggested that the reasons for the slow growth of granule use lie in difficulties of production, particularly the safety aspect, and application. The rate of application of a pesticide is much more critical than that of a fertilizer for example. Yugoslav experiments on pesticide application are currently concerned with micro-granules, and here again application equipment is the main problem.

VII. COUNTRY PAPERS

BULGARIA

Stojan Gaitandjiev

Bulgaria is a country of intensive agriculture, distinguished by the variety of plants grown. Thus plant protection requires the application of a comparatively large number of pesticides.

In comparison with other branches of industry, pesticide production is not well developed. The chemical industry produces fungicides and some herbicides. At present, insecticide production is chiefly based on the importation of active substances, which are formulated into agricultural chemicals suitable for application. Part of the demand is met through imports from countries that are members of the Council for Mutual Economic Assistance and from some Western European countries. At the same time Bulgaria supplies many countries with the fungicide „Perozin", based on zineb.

Some of the problems of the industry arise because a great variety of pesticides must be applied but only in small quantities. International specialization and regional cooperation help to overcome such difficulties.

Another problem is to secure an adequate supply of raw materials, which cannot all be easily supplied from the domestic resources of a small country. Difficulties also arise because pests may develop resistance to certain pesticides and therefore new product varieties must be applied.

The industry faces problems of industrial hygiene since most pesticides are to some extent toxic to man.

Standards of medical supervision of workers in the pesticide industry are high in Bulgaria. Some plants whose waste products have been polluting rivers or lakes face the great expense of constructing purification facilities.

To overcome some of these difficulties, Bulgaria has chosen to import the active ingredients of many pesticides and to produce domestically only their final formulations. The purchase price of the active substances is crucial, since it determines whether domestic formulation will be profitable or not.

Other problems concern (a) the production of highly concentrated wettable powders from active substances having a comparatively low melting point; (b) the formulation of compounds for low-volume and ultra low-volume spraying; and (c) the production of agricultural chemicals in the form of small granules. The problems of packaging as a whole, including the use and reuse of rather cheap and of high quality packaging material, must also be considered.

A point of interest for Bulgarian industry is the potential of universal (multi-purpose) installations or plants. These facilities allow, by means of small adaptations, the production of several alternative agricultural chemicals of similar technology.

Regulations concerning industrial safety in Bulgaria are stringent. However the level of automation that secures a high degree of safety in the work is not economically feasible for small enterprises. This is another problem to be solved.

CYPRUS

John P. Zyngas

Introduction

Cyprus is the longest island in the Eastern Mediterranean but only the third largest in the Mediterranean Sea. Its area is 3,572 square miles, the extreme length is 140 miles and its greatest width is 60 miles. The highest mountain is Troodos at 6,400 ft above sea level. The climate is of mild Mediterranean type. Summers are hot, especially on the plain with maximum at about 36—38 C, while the winters are relative mild.

Twenty-three per cent of the cultivated area is irrigated.

The main crops are citrus (oranges, grapefruit, lemons, etc.), potatoes, grapes (wines), carobs, vegetables (carrots, tomatoes, cucumbers, etc.), olives, etc.

Table 1. Area, production and exports of the main crops (1970)

	Area, donums	Production, tons	Exports	
			tons	£
Cereals	12,000	922 (dry year)	—	—
Legumes	125,500	10,291	--	—
Potatoes	80,000	208,280	161,919	6,517,241
Tobacco	11,000	700	1,474 (included stock)	515,705
Vegetables	32,000	72,000	—	—
Grapes	—	182,880	10,360	1,217,384
Raisins	—	5,000	6,484	423,223
Wines } Spirits	—	—	—	1,400,000
Olives	—	7,620	—	—
Carobs	48,768	—	34,560	864,000
Citrus — Oranges	—	—	—	3,683,496
Lemons	—	--	—	1,630,392
Grapefruit	—	—	—	1,792,573

Plant protection in Cyprus

One of the main factors for the increase of production and the improvement of the quality of the agricultural products is the protection of crops from pest and disease.

A major plant protection program was initiated in 1965 by the government in order to encourage farmers to use the proper measures for control of pests and disease. This program included the issue of subsidized sprayers and dusters (1965—1968), the issue of pesticides for collective sprayers demonstrations, educational campaigns, publicity through press, radio and TV, issue of leaflets and bulletins, implementation of biological control, the use of aeroplanes, etc. The Plant Protection Service was strengthened by appointment of university graduates at the Headquarters and the Districts.

The results were very satisfactory.

Chemical methods for the control of pests and diseases have been expanded very considerably.

It may be stated that one of the main factors for the increase of the production is due to the use of pesticides. The Plant Protection Section of the Department of Agriculture of the Ministry of Agriculture and Natural Resources is responsible for the implementation of the plant prosector projects and specifically with the plant quarantine (implementation of the importation of Produce (Control) Orders 1957—1965 under the Plant Prevention Law), General Pests and Diseases Campaigns (locust, rats, stink bug, hornets etc.), demonstrations, collective sprayings, plant protection publicity (leaflets, bulletins, press, radio, TV), biological control, potato seed certification, control of insects in stored products, agricultural chemicals, agricultural aviation, beekeeping, etc.

The role of pesticides

Pesticides have been used extensively in Cyprus for the last 8—9 years. The whole quantity of pesticides used is imported and most of them are used in the same formulation in which they are imported. Certain pesticides, especially dusts, wettable powders and cereal weed-killers are imported in concentrated form, and are formulated and packed at lower concentration in Cyprus.

Tables 2 and 3 show the quantities of pesticides imported for the past four years.

Table 2. The annual import of pesticides into Cyprus (1968—1971)

	1968		1969		1970		1971	
Commodities	Quantity, CWT	Value, £	Quantity, CWT	Value, £	Quantity, CWT	Value, £	Quantity, CWT	Value, £
Insecticides	26,316	225,264	29,905	227,427	19,976	234,322	18,003	261,848
Fungicides	3,891	37,681	2,931	37,756	6,498	79,583	5,224	65,643
Weedicides	1,599	26,967	7,023	398,668	3,632	50,993	6,783	500,950
Disinfectants	1,361	10,730	2,024	14,520	2,831	15,950	2,338	21,307
Others	1,180	15,989	1,844	33,104	1,661	52,510	4,057	266,328
Total	34,347	316,631	43,727	711,475	34,598	433,358	36,405	1,116,076

CWT = 40 okes (112 lbs)
800 okes = 1 long ton (2,240 lbs)

Table 3. Imports of pesticides
(Total quantities and value)

Year	Quantity, CWT	Value, £
1962	2,638	184,336
1963	3,194	259,558
1964	2,635	190,190
1965	2,899	188,819
1966	3,605	319,267
1967	2,969	312,182
1968	1,717	316,631
1969	2,186	711,475
1970	1,731	433,358
1971	1,820	1,116,076

The main pesticide producing companies of Europe and the United States are represented in Cyprus, and quite newly-developed pesticides are imported here. The pesticide importers have contacts with the Plant Protection Service, and all available technical data, such as toxicity, residue, efficacy, tests, etc., are submitted to the Plant Protection Section. The countries from which the pesticides are imported, are indicated in table 4.

There are about seven major importers. As from 1964, the Co-operative Central Bank plays an important role in importing, repacking and sale of all main pesticides (Insecticides, fungicides, weedicides, etc.) through well-organized teams all over the island.

Table 5 shows this trend.

Table 4. Quantity and value of pesticides by countries of origin (1969—1970)

Commodities and countries of origin	Total imports 1969		Total imports 1970	
	Quantity CWT	Value £	Quantity CWT	Value £
Disinfectants				
Israel	150	1,366	40	332
Italy	27	293		5
United Kingdom of Great Britain and Northern Ireland	1,748	11,325	2,123	12,152
United States of America	60	904	50	707
Other countries	39	632	618	2,754
Total	2,024	14,520	2,831	15,950
Insecticides				
Belgium	79	418	101	801
Bulgaria	138	1,288		—
Czechoslovakia	846	3,201	80	257
Denmark	977	14,499	1,022	15,935
France	194	8,833	1,469	17,827
German Democratic Republic	1,831	10,504	1,546	11,106
Germany, Federal Republic of	4,982	40,373	2,213	29,616
Greece	1,078	6,384	681	3,129
Israel	9,074	42,804	7,035	32,677
Italy	1,637	15,379	673	21,605
Netherlands	1,930	21,678	1,317	28,474
Switzerland	382	16,956	419	16,569
United Kingdom of Great Britain and Northern Ireland	4,514	18,601	2,743	35,629
United States of America	2,219	25,946	490	18,042
Other countries	24	562	137	2,655
Total	29,905	227,429	19,976	234,322
Fungicides				
Belgium	394	4,182	—	—
Bulgaria	196	1,788	492	4,476
France	417	2,479	2,260	21,472
Germany, Federal Republic of	415	9,154	239	3,252
Israel	93	1,126	883	9,595
Italy	961	11,553	1,511	15,859
Netherlands	20	1,024	51	2,693
Switzerland	—	—	189	8,852
United States of America	239	4,158	766	9,606
Other countries	196	2,292	107	3,778
Total	2,931	37,756	6,498	75,583
Weed-killers				
German Democratic Republic	591	7,575	1,772	18,109
Germany, Federal Republic of	49	3,861	60	4,270
Greece	1,042	3,070	1,213	3,702
Israel	173	2,332	78	945
United Kingdom of Great Britain and Northern Ireland	253	6,130	136	10,104
United States of America	4,638	370,118	71	7,260
Other countries	277	5,582	302	6,603
Total	7,023	398,668	3,632	50,993
Other				
France	—	—	30	89
Germany, Federal Republic of	484	6,416	380	5,143
Israel	505	2,505	106	2,193
Italy	3	133	14	283
Switzerland	288	9,387	220	20,200
United Kingdom of Great Britain and Northern Ireland	[illegible]	2,137	[illegible]	10,085
United States of America	[illegible]	[illegible]	284	12,173
Other countries	[illegible]	[illegible]	79	2,344
Total	[illegible]	[illegible]	[illegible]	52,510

Table 5. Sales of pesticides and fertilizers through the Co-operative Central Bank

	1964		1965		1966		1967	
	Tons	Value	Tons	Value	Tons	Value	Tons	Value
Fertilizers	[illegible]	[illegible]	67 720	1 224 571	71,877	1 462 348	73 999	1 569 183
Sulphur	[illegible]	26 505	[illegible]	31 739	1 135	40 180	1 121	39 718
Pesticide		34 795		63 000		111 194		109,204
Total	[illegible]	[illegible]	[illegible]	1 319 310	73 012	1 613 722	75 120	1 718 105

	1968		1969		1970		1971	
	Tons	Value	Tons	Value	Tons	Value	Tons	Value
Fertilizers	78 133	1 789,653	67 792	1 582 094	77 363	1 851 256	71 381	1,610,977
Sulphur	1 267	52,865	1,297	54 109	1 347	44 489	1,402	44,201
Pesticides		147,945		153 325		176,729		208,277
Total	79,400	1 990,463	69,089	1 789 528	78 710	2 072,474	72,783	1,863,455

There are also six small industrial units for re-packing pesticides in small-size bags or lower concentration. For example, concentrated technical Parathion is imported and then it is mixed with fillers and the new formulation of lower concentration (2 per cent) is packed and sold. This work is done with certain pesticides of dust or wettable powder formulation. There are, also, two units for liquid formulations, i.e. a concentrated liquid formulation is imported and then it is diluted with suitable solvents such as xylene. Tables 6 and 7 show the main pesticides imported as technical or concentrate and formulated to dusts or emulsion concentrates.

Table 6. The main products which are imported as technicals or concentrates and formulated to field dusts

1. Dicofol (acaricide)
2. Aldrin (soil insecticide)
3. Famid (Ciba-Geigy) (control of cockroaches)
4. All-Green (foliar fertilizer)
5. BHC (insecticide)
6. Captan (for seed dressing, etc.)
7. Chlorobenzilate (dust formulations)
8. Copper oxychloride (dust formulations)
9. Crotothane (dinocap) (dust formulations)
10. Azinphos ethyl (dust formulations)
11. 2,4-D herbicide (dust formulations)
12. DDT insecticide (dust formulations)
13. Dimethoate insecticide (dust formulations)
14. Ethion acaricide (dust formulations)
15. Fenitrothion (dust formulations)
16. Fruit setting hormones (dust formulations)
17. Lindane technical (dust formulations)
18. Lannate insecticide (dust formulations)
19. Carbaryl insecticide (dust formulations)
20. Maneb fungicide (dust formulations)
21. Malathion insecticide (dust formulations)
22. Parathion insecticide (dust formulations)
23. Profytol
24. Tritox
25. Triosail
26. Thiohalkini
27. Thiutox
28. Thiozinohalkini
    etc.

Different dust formulations
containing the following :
a) Fungicide for powdery mildew
b) Insecticide or/plus acaricide
c) Fungicide for downy mildew

29. Sanigran (seed dressing)
    Organomercury with or without insecticide
30. Zineb fungicide (dust formulations)

Table 7. **The main products which are imported as technicals or concentrates and formulated after dilution with suitable solvents to lower emulsion concentrate**

1. Chlorobenzilate
2. Fenitrothion
3. Malathion
4. Diazinon
5. 2,4 D Butyl Ester 60 E C
6. Parathion (methyl or ethyl)
7. Summerwhite oils (special emulsifiers added)
8. Winter oils with DNOC (formulated in Cyprus)

About 40 per cent of the pesticides sold have been locally formulated and re-packed in lower concentrations. This concerns mainly weed-killers for cereals and pesticides for dusting.

One of the major importers and distributors of pesticides and fertilizers in the Co-operative Central Bank. The main points of its activities are indicated below :

a. Budget of the Unit

The expenses of the industrial unit of the Co-operative Central Bank, which is the main importer and dealer in pesticides, were about £ 15,000 in 1971. The value of pesticides which were formulated in the unit of the Co-operative Central Bank was £ 126,500.

b. Value of pesticides imported

The value of pesticides imported by the Co-operative Central Bank in 1971 was £ 157,000.

I. Pesticides sold as imported	£ 106,930
II. Pesticides sold after formulation and packing	£ 100,350
Total Sales	£ 207,280

c. Personnel

Twenty-three persons in seven shops and stores work in the pesticides division. Eight mobile sale units are also available.

d. Investment

Investments for the industrial unit and for sales :

Equipment	£ 13,250
Cars	£ 8,950
Factory	£ 31,270

e. Sales

The sales of pesticides through the Co-operative Central Bank are indicated in table 4.

Problems of Industry

The main problems of the industry are the finding of suitable cheap fillers and solvents, and the finding of trained workers.

Legislation

The Pest Control Law was enacted in 1967. The Regulations under this law have just recently been approved by the Council of Ministers and in a very short time this law will be implemented. The main points of this law are the registration and labelling of pesticides. A Board, which will represent the interests of all concerned, will be responsible for the implementation of this law.

Prospects for expansion of the pesticides industry

It is expected that in the near future the main importers, such as the Co-operative Central Bank and others will expand their activities by getting new machines for packing dusts and liquid pesticides, and will cover a large number of pesticides.

HUNGARY

Ferenc Hargitai

Development of plant protection through use of chemicals

During the last decade, the use of plant-protection chemicals has increased rapidly. In Hungary the value of such chemicals consumed in 1972 was 400 per cent greater than it was in 1960; for herbicides the increase reached 1,500 per cent. The rate of increase has accelerated particularly during the past five years as shown below :

Year	Million dollars
1968	24.5
1969	24.6
1970	32.0
1971	41.0
1972 (estimated)	53.0

Plant protection is one of the factors of a complex production technology ; its significance, role and economic efficiency are inseparable from the level of development of the technological system as a whole.

With conventional methods of cultivation, plant protection has the role of increasing yields and of improving quality, but with the complex, mechanized methods suitable for large farms it becomes a precondition of production. It can be anticipated that the role of plant protection -- in particular protection, through the use of chemicals — will become even more important in the future.

The forms that pesticides may take are very simple : dusts, liquids, or granules. Working with them, however, requires at least as much special knowledge as handling a complicated machine. That is to say, the action of pesticides can go beyond the immediate objective and contaminate the environment. Since 1968, persons engaged in pesticide production, have been required by law to have special qualifications.

A strict system of registration has been set up to control plant-protection chemicals. This system is similar in many respects to the well-known system of the Federal Republic of Germany, but in some respects it is stricter. It is directly administered by the Ministry of Agriculture and Food.

A continuing programme of chemical analysis in factories, in commercial store houses, and even on farms provides for quality control at the plant protection chemicals and for detection of pesticide residues.

The well-equipped laboratories in which pesticide residues are analysed, carry out the control and inspection of all plant products imported or exported, and of all those grown on large farms for domestic consumption.

A further increase in the demand for pesticides is expected. It is estimated that their consumption in Hungary will by 1980 be twice the present level. With such an increase in demand, the question arises as to whether production can continue to meet it.

The situation of pesticide industry

As it is well known, at the beginning of the 1960's the Hungarian industry produced a considerable quantity of DDT and HCH. In 1967 the use of both chemicals was prohibited, thus the proportion of the home industry in the trade of pesticides fell from 70 per cent to less than 50 per cent. In parallel with this, import from Western Europe was significantly increased: in 1967 its rate of participation was 22 per cent and at present it approaches 40 per cent. Of course, from economic angles it is not acceptable for the Hungarian plant protection to depend on imports, and therefore increased efforts have been made for developing home products.

As a first step we addressed ourselves to several leading manufacturing companies of Europe with the request to purchase licences, but the answers concerning the up-to-date products and technologies were uniformly negative.

In this situation there were two possibilities left: domestic formulation of active ingredients from abroad, and the development of independent production of active ingredients. Undoubtedly the easier and more rapid solution is to formulate the active ingredient from abroad; in this way, however, the foreign-exchange savings are not significant, and the strong dependence on foreign industry invariably remains. Thus from the point of view of national economy, carrying through the production of the active ingredients seems to be more advantageous. Besides the chlorophenoxy-derivatives, chloramino-triazines, mercaptotriazines, DCPA, trichlorphon, DDVP and DNOC traditionally manufactured for years, and the formulation of about fifteen active ingredients from abroad, the Hungarian industry, on the basis of independently developed procedures, effected the production of paraquat-di/methylsulphate, trifluralin, linuron, monolinuron, propachlor, pyrazon, prolate, chlorphenvinphos, O-ethyl-S, S-dipropylphosphodithioat (Mocap), dioxacarb, benomyl, a mercury-free seed-dresser and a number of other compounds.

An industry of intermediates for pesticides serving the above productions and a biological-toxicological experimental station meeting the needs of industry are in the process of development. As a result of these developments, we expect that through the demand for pesticides will be doubled by 1980, the import from Western Europe will be decreased to the half or one-third its present level. Naturally, those foreign companies which support themselves the development of the Hungarian industry within the framework of co-operations of different types will be best able to hold their ground on the narrowing Hungarian market. Such co-operations have already come into being, or rather the talks are at an advanced stage.

Considering the present status of the Hungarian agriculture and industry, as well as the long range goods thereof I see possibilities for UNIDO to assist countries desiring to develop their pesticide industry in the following fields.

Fields of support by UNIDO

Efforts must be made that the industrial companies of the developed countries should sell the developing countries not the products considered to be out-of-date in their own countries, but supply the most contemporary and newest ones, or should transfer the licence of those.

The partners must establish an efficient co-operation in the field of formulation and production of active ingredients, and also in production of intermediates. The co-operation must be realized not only in technical field, but in the exchange of specialists and in their training.

Since safe agricultural application is also in the interest of the industry, the industry and industrial organizations should support the establishment of networks of specialists for the farms, the supply of the inspecting and controlling networks with specialists, instruments, and the realization of controlling systems.

At this moment Hungary expects support in the up-to-date technologies of formulation and, in exchange, it undertakes the extension training of specialists working in the controlling network.

MALTA

Peter V. Calamatta

As I stated earlier in the meeting with reference to fertilizers, records and statistical data in Malta are very limited and rather erratic. We have no pesticide manufacture, and although we consume quite a number of products, their use up to the present has been rather haphazard.

Years ago the Government introduced a spraying service for farmers and gardeners, but this can no longer cope with the demands made on it.

Very recent legislation controls the selling and labelling of pesticides which previously were often adulterated.

Our main present interest is in the control of the Mediterranean fruit fly, and in this respect I officially request UNIDO's help in obtaining advice based on good experience, and to a smaller extent the olive fruit fly.

During the past year, the Government of Malta has been negotiating with the Food and Agriculture Organization of the United Nations (FAO) to set up a pesticide research centre for developing countries in Malta. The participating and executing agency would be FAO, in co-operation with the United Nations Industrial Development Organization (UNIDO), the International Labour Organization (ILO), World Health Organization (WHO), the International Atomic Energy Agency (IAEA), and also representatives of the pesticide industry under the GIFAP group.

The purpose of the centre would be to investigate problems related to the use of pesticides with particular reference to the associated user hazards, residues in foods and the environment, and the interests of the developing countries. The types of activity envisaged for this centre are:

– the investigation of chemical-technical problems which must be studied before FAO can endorse the use of certain agricultural pesticides for use for particular purposes in the developing countries. It would be confined to pesticides which are not being investigated by industry because the compounds are not of real commercial interest to any particular company at present because they are not now protected by patent, such as BHC. Many such compounds are widely used in the developing countries because they are relatively inexpensive and have a low acute-toxicity hazard, but the available scientific data regarding the associated environmental and food residue hazards are not sufficient to allow FAO and WHO to endorse their use and establish acceptable daily intakes and tolerance levels in food.

Another activity would be the investigation of chemical-technical problems relating to promising compounds which for technical or other reasons have not been developed to the marketing stage by industry, possibly because of the limited market potential. This work would be particularly related to the often-voiced desire for narrow-spectrum pesticides which because of their limited market potential are of small commercial interest. Such compounds are now market largely as a result of „fall-out'' from research and development programmes.

There would also be investigation of problems related to contamination of the environment by agricultural chemicals and the occurence of these chemicals as residues in food.

Under the supervision of the Director of Research (the project manager, who will be chosen later), and based on recommendations of the annual meeting of the FAO working party of experts and the WHO expert committee on pesticide research, investigations of technical-chemical questions as outlined above would be conducted by project support and contracts with appropriate universities and research institutes. The extra-mural research contacts would be on a no-costs, partially sponsored or fully sponsored basis from the standpoint of the project.

In this plan, which still needs ratification, the intention is to use Malta, not as a location for testing pesticides, but as a centre where all the data can be collected and co-ordinated as they arrive from other countries in the interest of all developing countries. Any help that can be forthcoming from members who are present here, and from UNIDO in particular, will be greatly appreciated.

In discussion the representative of Cyprus stated that they had found control of the Mediterranean fruit fly quite easy by regular weekly spraying with a malathion-based pesticide.

POLAND

Stanislaw Byrdy

I have to speak mainly about the achievements in the production of pesticides for control of Colorado beetle (Leptinotar decemlineata) in Poland, but at the beginning I would like to say some words about the pesticide industry in Poland as a whole.

Pesticide production in Poland amounts to about 10 per cent of fertilizer production in value, and is still developing.

This year we stop the production of DDT, but the chlorinated hydrocarbons, lindan and methoxychlor (DMDT) which you know, have a very low toxicity for animals will be still produced. DDT in mixture with lindan and methoxychlor as the preparation named tritox is being used only in the control of Colorado beetle; it is forbidden to use DDT on other crops. About the details of the Colorado beetle control I will speak later.

As alternative substance for DDT our chemical industry produces the insecticides of the phospho-organic compounds, and carbamates such as: trichlorfon, malathion, fenitrothion, dichlorfos, chlorfenvinfos, and tetradiphon as an acaricide.

In the group of fungicides we produce copper oxychloride, colloidal sulphur, thiuram and captan, and we are preparing the production of karboxine as a systematic fungicide.

As seed dressing substances we produce mercury organic compounds, thiuram, quintocen, HCB. In the near future the production of organomercury compounds is being limited in favour of the nonmercury compounds such as thiuram, HCB, quitocen, karboxine and its mixtures.

In the herbicide group the Polish chemical industry produces 2.4-D, MCPA and some mixtures with dicamba and propionic acids for the control of resistant weeds. Our chemical industry prepares the production of urea derivatives such as diuron, linuron, monolinuron. From the growth regulators we produce CCC.

All the mentioned compounds are produced in the form of dusts, wettable powders, emulsifiable concentrates and aerosols.

For particular application such as protection of fruit trees we import pesticides from western countries in the amount of 10 per cent value of our pesticide production. I would mention that we are an exporter of pesticides in the amount of about 25 per cent value of our production.

Achievements in the production of pesticides for control of Colorado beetle (Leptinotarsa decemlineata Say.) in Poland

Poland is one of the greatest potato producers in the world. The potatoes are grown there on more than 2,800,000 ha.

Colorado beetle is certainly one of the most serious pests of potatoes not only in Poland but in all Europe, and a constant increase of its population density is observed in spite of continuous chemical control.

Colorado beetle feeding on potatoes, especially in June and July, can cause the loss of 30 per cent or in the case of complete defoliation, even of the whole yield, because of the beetle's high reproduction ratio and high food uptake. Theoretically the progeny of the female laying 500 eggs would destroy in the third generation 100,000 potato plants growing on the average on 2.5 ha.

In our climatic conditions the appearance of the larvae of the first generation gets its peak in June and July. The larvae complete tehir development during 2–4 weeks and the maximum of beetles of the first generation appear at the end of July and the beginning of August. Only very seldom do the larvae of the second generation complete their development in Poland. It happens only in extremely favourable weather conditions and then the beetles of the second generation appear in September or October.

Until 1971 the Colorado beetle was controlled in Poland by the use of chlorinated hydrocarbons, mainly DDT in dust, emulsion, wettable powders and aerosols.

For several years a decrease of the effectiveness of DDT used against Colorado beetle was observed due probably to the development of resistant populations. For better control a mixture of DDT and BHC named Ditox and a mixture of DDT, BHC and DMDT named Tritox were introduced.

In the Institute of Organic Industry studies were carried out on the alternative pesticides.

In the years 1966 to 1971 the efectiveness of several carbamates and organophosphorous compounds was evaluated in field experiments. The results are presented in tables 1 to 4. Carbaryl was very effective when

Table 1. The activity of Birlane and Bidrin in the control of Colorado beetle (Leptinotarsa decemlineata Say.) compared to Azotox and Sevin

Preparation	Dose, kg a.s./ha	% of mortality	
		Larvaes L_4	Beetles
Bidrin EM 24	0.5	94.0	20.9
	0.25	96.8	14.0
Birlane EM 24	0.25	100.0	97.4
	0.125	94.0	81.4
Azotox Z-50	1.20	100.0	39.6
	0.60	39.4	26.7
Sevin Z-85 U.S.A.	1.20	100.0	8.3
	0.60	100.0	19.1
Z-75 IPO (carbaryl)	1.20	100.0	17.0
	0.60	94.0	20.9

Table 2. The activity of carbamate insecticides in the control of Colorado beetle (Leptinotarsa decemlineata Say.)

Preparation	Dose, kg a.s./ha	% of mortality	
		Larvaes L_4	Beetles
Minacide (Karbamult) promecarb	3.0	100	86.7
	1.50	100	93.7
	0.75	100	76.7
Metiokarb (Mezurol)	3.0	100	83.3
	1.50	100	76.6
	0.75	83.3	73.3
Propoxur (Unden)	3.0	90.0	86.7
	1.50	93.3	83.3
	0.75	86.7	90.0
Carbaryl (Sevin)	3.0	100.0	63.3
	1.50	100.0	33.3
	0.75	83.3	—
Z-60 (carbaryl)	3.0	100.0	43.3
	1.50	100.0	50.0
	0.75	96.7	33.3

Table 3. The activity of phospho-organic insecticides in the control of Colorado beetle (Leptinotarsa decemlineata Say.)

Preparation	Dose, kg a.s./ha	% of mortality	
		Larvaes L4	Beetles
Birlane (Shell)	0.5	100.0	100.0
	0.25	100.0	93.3
Chlorfenvinfos IPO	0.5	100.0	82.2
	0.25	100.0	75.6
Naled (Dibrom)	2.0		26.7
	1.0		6.7
Methyl Dimetoat	2.0	—	20.0
	1.0	—	13.3
Fenitrothion (Owadofos)	2.0	—	36.7
	1.0	—	16.7
Vamidothion (Kilval)	2.0	—	10.0
	1.0	—	10.0
Menazon (Sayfos)	2.0	—	0.0
	1.0	—	0.0
Phosalon (Zolone)	1.0	100.0	56.7
	0.5	100.0	56.7
Imidan	1.0	100.0	60.0

applied against Colorado beetle larvae, but not against beetles themselves. It killed at most 50 per cent of the beetles. Its effectiveness depended considerably on temperature. In our experiments the effectiveness was higher above 20°C and lower below 20°C. As in our climatic conditions during maximum appearance of beetles the temperatures are often quite low, we

Table 4. List of insecticides for the control of Colorado beetle (Leptinotarsa decemlineata Say.) investigated in the Institute of Organic Chemistry at Pszczyna (Poland) in the years 1966—1971

Control of larvae			Control of beetles		
Preparation	The lowest active dose, kg a.s./ha	Period of investigation (years)	Preparation	The lowest active dose, kg a.s./ha	Period of investigation (years)
IPO-62	0.1	2	IPO-62	0.2	2
Birlane	0.1	6	Chlorfenvinfos	0.2	1
Chlorfenvinfos	0.1	1	Gammarol Supra	0.2 pre.	1
Dexpirol	0.15	2	Birlane	0.25	6
Gammarol Supra	0.2 pre.	1	Gusation	0.25	1
Gamakarbatox	0.2	2	IPO-63	0.4	2
Gusation	0.25	1	Supacron	0.5	1
Supacron	0.25	1	Gamakarbatox	0.5	2
Thiodan	0.25	1	Thiodan	0.5	1
Tritox extra	0.25	2	Karbatox extra P	0.5	2
Insektizid 6607	0.25	1	Azotox WP 75%	0.5	1
Padan	0.25	1	Cz 6000	0.5	2
Propoxur	0.3	2	Insektizid 6607	0.5	1
Unden	0.3	5	Padan	0.5	1
IPO-63	0.3	2	Bidrin	0.5	2
Karbatox Extra P	0.4	2	Propoxur	0.6	2
Azotox WP 75%	0.5	1	Unden	0.6	5
Cz 6000	0.6	2	Carbamult	0.75	2
Sevin	0.6	4	Tritox extra	0.75	2
Carbamult	0.6	2	C [illegible]	1.0	2
C [illegible]	0.6	[illegible]	Sevin	1.0	4
[illegible]	1.0	1	[illegible]	[illegible]	[illegible]
[illegible]	1.0	1	[illegible]	[illegible]	1

had to search for other chemicals more effective at low temperature or to produce mixtures of carbaryl and other chemicals increasing its effectiveness in Colorado beetle control.

In table 4 are presented the results of four years' experiments. Based on these experiments we decided to produce a product named *Gamakarbatox*. It belongs to the chemicals of the III class of toxicity for animals, LD 50 oral equals 662 mg/kg of rat weight. The recommended rate of application is 1 kg of Gamakarbatox per ha, this means 0.5 kg of active substance. The cost is also very low, only 93.50 zl per ha.

We are also preparing to produce the next insecticide named *Karbatox extra P* in the form of a wettable powder 75 per cent LD 50 on rats equals 211 mg/kg weight. The recommended rate of application is 0.75—1.0 kg of Karbatox extra P per ha. The cost is about 100—120 zl per ha.

The dusts *Gamakarbatox dust* and *Methoxykarbatox* will also be produced. Both will be applied at the rate of 20 kg/h. *Chlorfenvinfos*, the active ingredient of Sapecron (50 per cent) and Birlane (24 per cent) is highly toxic for mammals, LD 50 oral for rats is 30 mg/kg of weight, but at the same time it is very effective against Colorado beetles at the dose of 200—300 g/ha. Based on several years' experiments we decided to produce Sapecron basing on the imported concentrate. Due to its high toxicity Sapecron will be applied only by the specialist brigade.

One treatment would cost about 160 zl. per ha.

Very good results were obtained in Colorado beetle control also with the use of the following chemicals:

IPO-62 experimental substance in the form of an emulsifiable liquid containing 25 per cent of a new active ingredient synthesized in Poland — an enolophosphorus compound. Its toxicity for mammals is 3—5 times lower than that of Chlorfenvinfos. The effective dose of IPO-62 is 200 g/ha (table 4) which would cost less than 150 zl.

IPO-63 experimental substance in the form of an emulsifiable liquid containing 25 per cent of a new active ingredient synthesized in Poland, also an enolophosphorus compound. It belongs to the III class of toxicity for mammals and has very low dermal toxicity. The effective dose of IPO-63 is 400—500 g/ha in the control of Colorado beetles which would cost about 300 zl/ha.

UNDEN — wettable powder containing 50 per cent of propoxur produced by Bayer, belonging to the II class of toxicity for mammals. It is a short-life insecticide which must be applied on very exactly established date on the development of Colorado beetles. The effective dose equals to 300—400 g active ingredient per ha.

The results of laboratory and field experiments showed that propoxur increases the effectiveness of DMDT and lindane against Colorado beetle, and may be a valuable component of mixtures of prolonged activity period for Colorado beetle control.

ROMANIA

A.

Iuliu Moldovan

The accomplishment of industrial plants on the basis of original research, process design and development includes the following steps: laboratory research, systematic research and design of pilot plant, building up pilot plant, pilot plant operation, design of industrial plant, building up industrial plant, starting into operation and attaining the operational parameters.

A research and development process can be stopped at the laboratory or pilot-operation stage for different reasons expense, incomplete or unsuccessful research, delays in research, or equipment worn out by time or high corrosion.

Generally speaking, before passing the pilot plant step, a laboratory process should be studied carefully by the design group from the economic standpoint so that the research can be aimed at obtaining the most economical process. Generally a laboratory research staff involved in a process includes 13—15 people, each working about 2,000 hours per year. As compared with the average cost of research abroad (6 dollars/hour/person) Romanian costs are low (about one-tenth of this). Laboratory research is cheapest, of course, when the process goes into industrial production. Without industrial development the expenses represent irrecoverable loss.

Pilot plant research and generally what is called development of a process represent major expenses in the world, the average cost being 150—500 dollars/pilot unit. In some countries the cost of engineering, and systematic operation of pilot plants, is included in the cost of design of an industrial plant which is different from country to country ; in the Federal Republic of Germany 40 marks, in the United Kingdom of Great Britain and Northern Ireland £ 3.00, in the United States of America 16 dollars per man-hour. In the United Kingdom the design cost represents 9 per cent and in the United States 13 per cent of the industrial equipment value.

Sometimes one can pass directly from the laboratory to the industrial scale, the pilot plant being actually one of a semi-industrial type. This situation is represented in our country by pilot productive plants, the plant capacity corresponding to the quantities necessary for testing the products for quality and for biological efficacy in field trials.

In order to reduce the research expenses in pilot plants and especially to reduce the research period, there is the possibility of operating in „universal" pilot plants or of reusing one pilot plant for investigating many other processes. Existent industrial plants can also be modified slightly to study similar processes on the pilot scale, especially in the case of fertilizers.

Generally the method and the operation in the pilot plants are different for pesticides and fertilizers. With pesticide processes, there are certain chemical unit operations (sulphonation, alkylation, condensation, etc.) and every stage can be treated separately for mass, thermae and energy transfer and balance. With this type of process the problems consist in choosing and calculating the basic equipment and some small difficulties arise with stirring reaction vessels.

In processes with interdependent and continuous stages, for instance plants for manufacture of ammonia and generally for fertilizers, the necessity of elaborating dynamic mathematical models is obvious. In the fertilizer field there are processes in which the reactor is essential, and nere not only the geometry of the reactor but also the systematic kinetics and thermodynamics must be taken into account.

We can distinguish two different methods of working, one used in the United States and the other generally used in Europe. In the United States co-operation with the industrial plant designers begins during the laboratory stage. In this system a team is formed which co-operates unitl the final stage, when it is joined by the technical corps belonging to industrial units which will be involved in production. The advantage of this method within systematic research is the possibility of earlier specification of the equipment, which currently can be supplied on the warranty of the specialized metallurgical companies, and of contracting certain parts of the equipment under turn-key delivery. There are also possibilities of simplifying the pilot plants, a much safer transition from the laboratory to the industrial plant and considerably reduced research period.

In Europe there has been a sharp separation between research activity in the laboratory and pilot plant, and industrial plant development. With small differences in Europe there are specialists concerned with research and chemical engineering in pilot plants, and others concerned with chemical industrial engineering work, carried out in specialized design offices.

Along the same line there are also design offices which have already a package of general data for industrial design which can be completed with additional data after checking the processes, for example ammonia, urea, ammonium nitrate, phosphoric acid plants where we can talk about industrial processes already checked and known.

In Europe checking on the equipment models in micropilot plants, equipment executed at two or three dimensional scales, is used as a modern system for determining the similitude factors necessary for industrial design and therefore for selecting and sizing the equipment.

In our country the research and development for fertilizer and pesticide processes has been approached differently. In the field of fertilizers, where the processes are continuous, we use the pilot-plant system, which represents on the small scale a process or a stage from the process in study.

A co-operation has been established with the industrial plant designer, as in the United States system, the main problems, the process and equipment design for the pilot plants being done by the designer of industrial plant.

The pilot plant is built in the factory in which it is planned to operate the new process for production, but responsability for the new technology rests with the research staff which elaborated the laboratory process until the process is put into industrial operation. This method is feasible because the technological laboratory research is performed mainly by engineers trained in chemical engineering.

In this way pilot plants for manufacture of NPK fertilizer through nitric attack, for manufacture of superphosphoric acid and the alkaline pure salts by the extraction with organic solvents, for manufacture of phosphoric acid and complex fertilizers via clasical wet route were realised. Many of the new processes have been checked directly in the existing industrial plants, for example recovery of fluorine from the processing of phosphatic rock.

In the pesticide field, at the beginning we started from the idea of similitude of processes with those for drugs and dyes, excepting the formulation stage which is proper to the pesticide industry. We have accomplished universal pilot plants for condensation, chlorination, phosgenation, etc., and also for formulation.

Our experience showed us the necessity of having pilot plants, particularly for a group of products allowing the multilateral usage of the pilot plants. Similarly the industrial plants are preferable to be flexible for adapting to new processes and products. We all know about negative economic consequences in reducing the production of organochlorine persistent pesticides like DDT. In the United States the partial reutilization of these plants has been accomplished for manufacturing an interesting polymer on the basis of polychloral ; our experience in pesticides also demonstrates the necessity of working in batch system with unit chemical operations. It is important also that technical products and active substances be obtained in a storable form, and the formulation be carried out in a separate formulation unit.

Formulation is a very important stage and sometimes if it is not well studied and established, it can reduce the value of a product. It is necessary for our pesticide industry, which is in full development, to have a formulation pilot plant of universal type, serving to develop new and various formulations required by agriculture.

The Romanian delegation comes with the suggestion to UNIDO to set up an experimental pilot plant for the formulation of pesticides, and for biological testing, within the Joint Centre UNIDO/Romania to which all interested developing countries may have access. This suggestion takes into account the experience we have, the achievements obtained up to the present and the programme for future development.

Concluding, every new process will have economical industrial significance only if it is feasible on the industrial scale, otherwise the research time and expenses will be lost. On the other hand, the existence of universal pilot plants can considerably reduce the period for the transition of a process from the laboratory to the industrial scale.

ROMANIA

B.

Silvia Nicolau
Constantin Popa

Nowadays the importance of using pesticides in agriculture is recognized by the overwhelming majority of specialists all over the world and a modern and efficient agriculture cannot be conceived without the contribution of these products in spite of some inconveniences they may generate.

On the world level efforts of specialists are being directed towards the promotion of new products having a reduced acute toxicity, a low persistence and a satisfactory degree of selectivity, and towards their use with maximum economic efficiency and minimum secondary effects. Although, as is known, this wish is not easily accomplished, the results obtained in recent years allow us to believe that progress will further continue on this line.

Production and use of pesticides on a large scale in our country started after the Second World War and were intensified in the past five-seven years. The promotion of pesticide production and use was based on the permanent and steadfast interest shown by the agricultural sector on one hand and on the other hand, or the setting up of a powerful petrochemical and basic organic chemicals industry, capable of supplying the required raw materials and intermediate products.

Further on we will set forth significant aspects regarding the production and use of pesticides in our country.

1. Main factors that require and influence the use of pesticides in Romania

Our country, crossed by parallel 45, is situated near the Black Sea and has an extreme continental climate characterized in general by dry summers and cold winters, sometimes with small quantities of snow. Another characteristic is its varied relief, which determines differentiated climatic conditions from one area to another.

At the same time, the high-organic content soil in many areas of the country and especially in the South-Eeast area (the so called Baragan) requires, in most cases, the use of higher rates of pesticides than other countries.

The structure of the cultivated surface for the main crops and groups of crops is shown in table 1.

Table 2 presents the main pests to be met in our agriculture.

Due to the diversity of crops and of pests existing in our country as well as to the various climatic conditions, a large range of pesticides is required. At the same time they must assure the rotation, called for by the appearance of resistance phenomena towards insecticides and the prevalence of certain weed species as a consequence of repeated herbicide treatment.

The same considerations also require the use of a variety of formulations, suitable to the differentiated conditions encountered in Romania.

Obviously the use of pesticides in our country as in other countries is imperatively necessary to ensure a highly economic efficiency, by reduction of the quantitative and qualitative losses brought about by pests.

Table 1. The structure of the cultivated area of Romania given on main crops and groups of crops (1970)

Name of crop	Surface, 1000 hectares
Cereals for grains — total	5,900.9
of which	
wheat	2,321.1
maize	3,084.0
barley	288.4
Technical plants — total	1,004.7
of which	
sunflower	604.1
white beet	169.9
Potatoes	286.2
Vegetables for grains — total	237.5
of which	
pea	106.5
— soya	79.1
Vegetables — total	224.6
of which	
— tomatoes	56.0
onions	40.0
Forage plants	1,423.1
Orchards	350.0
Vineyards	229.8

Note. To these a forest area is to be added having 6,315 thousands ha.

Table 2. The main pests (insects and plant diseases) encountered in Romania's crops

Crop	Insect	Plant disease
Wheat-rye	Zabrustenebrioides Euxoa segetum Eurygaster segetum	Tilletia tritici Tilletia nanifica Ustillago tritici
Barley	—	Ustillago hordei Ustillago avenae
Maize	Tanymecus dilaticolis Pyrausta nubilalis Euxoa segetum Anoxia villosa	Sorosporium holci sorghi
Sunflower	Tanymecus diliaticolis	Plasmopara helienthii Sclerotinia sclerotiorum
White beet	Bothynoderes punctiventris Tanymecus palliatus Aphididae	Cercospora beticola
Potatoes	Leptinotarsa decerulineata	Phytophtora infestans
Orchards		
Apples-pears	Quadraspidiotus perniciosus Anthonomus pomorum Hoplocampa testudinea Carpocapsa pomonella Aphididae Acarinae	Endostigma inaequalis Endostigma pyrina Podosphaera leucotricha
Plums	Quadraspidiotus perniciosus Hoplocampa minuta Aphididae Acarinae	Monilia sp. Polystigma rubrum
Apricots-peaches	Quadraspidiotus perniciosus Anarsia lineatella Aphididae Acarinae	Clasterosporium sp. Taphrina deformans Monilia sp.
Sweet and sour cherries	Quadraspidiotus perniciosus Rhagoletiscerasi Acarinae	Monilia sp. Polystigma rubrum
Vineyards	Polychrosis botrana Acarinae	Plasmopara viticola Uncinula necator Botryotinia fuckeliana

2 Actual status of pesticide production in Romania

Practically speaking we cannot say that there was a production of pesticides in Romania before 1938, small quantities of imported inorganic insecticides were formulated in rudimentary workshops. The only product applied on a large scale was copper sulphate, under the form of Bordeaux mixture for the prevention of downy mildew of vine.

After the Second World War, in 1946, the production of BHC, in relatively small quantities, started. In 1956 began the production of DDT, of 2.4-D herbicide and of ANTU rodenticide. The production of these pesticides covered only to a small extent the steadily growing domestic requirements so that new production capacities of DDT and BHC were put into operation in 1960 and in 1962 mercury-ethyl chloride, used for the wheat-seed treatments started to be manufactured.

During this period our chemical industry began to deliver the first quantities of Dibutox, an insecticide on dinoseb basis, used for winter spraying against San-Jose scale in pomiculture.

As a consequence of the important development of our chemical industry, pesticide production broadened after 1965. Capacities for manufacturing 2-4 D herbicide, the organo-phosphorus Fostotox, Carbetox and Ethion, Lindane, Pinetox insecticide and Atrazin herbicide for maize were put into production at short intervals.

Table 3 shows the pesticide production of Romania in 1965 and 1971, expressed in active ingredient.

Table 3. Pesticide production of Romania
(as active ingredient)
— tons —

Name	1965	1971	Formulation
A. INSECTICIDES			
a) **Organic chlorinated compounds**			
1. DDT (as p-p'isomer)	4,500	4,500	dusting powders 5 and 10%
2. **BCH (asgamma isomer)**			EC-25%
2. **Carbetox (nalathion)**	1,500	2,500	dusting powders 1.5 and 3% (based on gamma isomer)
3. **Lindane**	—	800	EC-20%; dusting powder 3%
4. **Pinetox (chlorinated terpenes)**	—	600	EC-65%; conc. solutions - 30% for LV application; dusting powders 10 and 20%
b) **OP — compounds**			
1. **Fosfotox (dimethoate)**	—	400	EC-50
2. **Carbetox (nalathion)**	—	300	EC-50
3. **Ethion**	—	100	EC-50
c) **Other insecticides**			
1. **Dibutox (dinoseb)**	500	500	EC-25
2. **Mineral oil — for inter sprays**	3,000	3,000	EC
B. FUNGICIDES (copper sulphate not included)			
1. **Mercury ethylchloride**	25	25	dusting powder — 2% for seed treatment
C. HERBICIDES			
1. **2,4-D (acid equiv.)**	130	525	as Na-salt; in 1972 the production of esters and dimethyl-amine salt was started
2. **Atrazin [illegible]**	—	2,000	
D. OTHER PRODUCTS			
1. [illegible]	[illegible]	30	dusting powder 40%
2. [illegible]	[illegible]	—	—

Most of the pesticide units mentioned above were erected on the basis of our own research, carried out in the frame of the Central Institute for Chemical Research of the Ministry of Chemical Industry.

As is shown in table 3, during 1965—1971 a substantial progress in the production of pesticides was recorded the active ingredient varieties increasing from 7 to 14, and the tonnage from 9,755 tons per year to 15,340 tons per year.

As is seen, the weight of organic chlorinated insecticides as a proportion of the total production decreases to a certain extent in 1971 as compared to 1965, although in absolute weight an increment takes place. As will be mentioned further on, the use of these products will diminish in the coming years, because of the necessity to limit or even to remove chlorinated insecticide residuals from crops.

Production of organo-phosphorus insecticides, having a good biological efficiency and a low persistence is at present (as shown in table 3) 800 tons per year and it will be largely increased in the coming 7—8 years.

At present domestic production ensures more than half of our country's demands and the percentage will be increased.

3 Development of pesticide production in the period 1976—1980

In the coming years pesticide production in Romania will continue its upward line, the following considerations have determined the direction to be observed :

a Strong reduction of organo-chlorinated insecticide application

An important reduction of organo-chlorinated insecticides in the coming period is forecast, as a result of the restrictions imposed by the Ministry of Health ; DDT and BHC are the products that will be affected while the use of Lindane and of Pinetox will remain constant

b Increment of OP insecticides production

Concurrently with the production of organic chlorinated insecticides the variety and quantity of OP insecticides, of well known advantageous properties, strong biological action, reduced acute toxicity and low persistance will be increased. In this way, by 1975, three new products trichlorphon, fenchlorphos and bromophos will be added to the existing ones.

c Beginning of carbamate insecticide production

In the coming two-three years carbaryl production based on a Romanian technology will start.

d Increase of organic and inorganic fungicide production

In the future captan, folpet, mercuryphyl acetate, copper oxychloride, wettable sulphur, dust sulphur, thiuram, ziram and other fungicides will be produced. The production of fungicides will strongly increase.

e. Increment of herbicide production

The output and variety of herbicides (especially symtriazine derivatives) will substantially increase, in order to meet the lack of man-power in agriculture expected to be encountered in the coming years, and the increase of irrigated surfaces.

f. Introduction of economic forms of formulation

Great emphasis will be laid on the production of granulated insecticides, and the weight of concentrated solutions for air treatments of low volume (LV) and ultra low volume (ULV) will also increase. The production of insecticide dusting powders will be strongly reduced, the application of pesticide mixtures (insecticide + insecticide, insecticide + fungicide, fungicide + fungicide, herbicide + herbicide) will be increased in order to enlarge their biological activity spectrum thus reducing the treatment costs.

The major goals of the development of pesticide production in our country in the next 7—8 years are as follows:

- complete covering of domestic demands for controlling pests in the basic crops
- reduction of undesirable secondary effects to the minimum
- export availabilities

Table 4 shows pesticide production plans for 1975 and preliminary figures for year 1980 that are still to be finalized with the agricultural sector.

Table 4. The development of pesticide production in Romania
(forecasts for 1975 and 1980 — given as active ingredient)

— tons —

N a m e		1975	1980
A. INSECTICIDES			
a) Organic chlorinated compounds		5,400	2,000
b) OP-compounds		5,750	6,160
c) Carbamates		2,000	2,000
d) Dibutox (dinoseb)		2,000	4,000
e) Barium polysulphide		3,000	6,000
f) Others		50	1,000
	Total	18,200	21,160
B. FUNGICIDES			
a) Inorganic compounds		8,300	12,000
b) Organic compounds		4,925	9,800
	Total	13,225	21,800
C. HERBICIDES			
a) 2-4.D (acid equivalent) (esters and dimethylamine salt)		1,000	1,000
b) sym-triazine derivatives		6,000	8,660
c) Carbamates		—	4,650
d) Quaternary dipyridyl compounds		—	1,500
e) Others		—	2,400
	Total	7,000	18,210
D. OTHER PRODUCTS		160	1,265
	Grand total	38,585	62,435

Note: forecasts for 1980 are informative only.

4. Romania's capabilities to participate in the development of pesticide production in other countries

In accordance with FAO prognosis, the annual growth rate of food demands — in the world — will be 2.3 — 2.7 per cent until 1985, while for the developing countries an annual growth rate of 2.8 — 3.6 per cent is forecast.

These figures clearly illustrate the necessity of rapidly increasing agricultural production, to which an important contribution is brought by pesticides.

In this respect, a larger demand of pesticides from a great number of developing countries can be predicted.

Romania is able and wishes to be considered among the countries which contribute to the promotion of pesticide production and application in the interested countries, being ready to offer its assistance based on the experience it has in this field as follows:

— Elaboration of projects for pesticide manufacturing and formulation plants

Building and erection work

Technical assistance during investment and starting up

Personnel training in similar plants operating in our country.

The pesticides for which our country possesses the necessary technological experience are the following :

a. Insecticides
   - Dimethoate
   - Malathion
   - Ethion
   - Dinoseb
   - Pinetox
   - DDT
   - BHC
b. Herbicides
   - 2,4-D (sodium salt, esters, dimethylamine salt)
   - Atrazine

In addition, our country is able to grant, through the experts in plant protection working in the agricultural research and production sector, technical assistance in biological screening and application of pesticides.

In connexion with this, we want to mention that pesticide registration in Romania is done by the Interdepartmental Committee for pesticides, and is based on biological screening carried on in laboratories in green-houses and in field.

For the promotion of new pesticides to be produced in Romania the research sectors and the manufacturing units permanently collaborate with the departments concerned of the Ministry of Agriculture.

The Romanian Ministry of Chemical Industry is willing to give careful consideration to any proposals that will be suggested.

TURKEY

Güngör Cankara

1. The status of the pesticide industry

1.1. Production consumption status

In the pesticide industry, the usable capacity differs from the actual production. The reason for this difference is that the selling rate of pesticides depends on the seasonal demand. If the plant's capacity is held small, then it will be necessary to produce all around the year and to stock the product for seasonal demand. However, the cost of the preserving the products in this manner is much higher than the investment cost of a high- capacity plant.

In relation to above mentioned considerations, the amount of production and the usable capacity for different pesticides, in 1970, are as follows :

Main pesticides	Usable capacity	Production
	(tons per yea.	
DRUGS		
Powdered drugs	28,000	18,404
Hygroscopic drugs	7,400	1,967
Liquid drugs	27,050	4,228
Drugs for weeds	5,310	1,303
Mineral oils	8,350	2,710
Powdered sulphur	20,000	17,288
Drugs for seeds	10,800	1,972
ACTIVE INGREDIENTS		
DDT	2,500	2,397
BHC	4,500	4,282

In recent years the demand for active ingredients, excluding copper sulphate and sulphur have been as follows

Organic synthetics	1970	1969	1968	1967
	8,051	7,883	8,840	6,124

The demand for pesticides in Turkey 1970—1969 (t)

Main pesticides	1970	1969
I. Insecticides (a, b, c)	6,746	6,718
a. Organics	4,342	5,715
b. Mineral oils	2,391	975
c. Fumigates	13	28
II. Fungicides (a, b)	532	684
a. Inroganic compounds	93	281
b. Organic compounds	439	403
III. Herbicides (a, b)	761	474
a. Chlorinated compounds	703	466
b. Others	58	8
IV. Molluscides	2	1
V. Rodenticides	4	—
VI. Various	8,051	7,883
VII. Copper sulphate	1,914	2,064
VIII. Sulphur	17,741	19,633

1.2. **Pesticide plants in Turkey (Manufacturing units)**

- — Agro- Merck Pesticides Industries Inc.
- — Bayer Pesticides Industries Ltd., Inc
- — Hetas Commers Inc.
- — The Shell Company of Turkey
- — Prentive Pesticides Inc.
- — Midiltipi Pesticides Inc.
- — Chemists' Pesticides Inc.
- — BP Petroleum Inc.
- — Sandoz Chemicals Ltd.
- — Rabak Electrolytic Copper and Products Inc.

The above mentioned factories are located in the province of Istanbul with the exception of Sandoz which is located in Izmir.

1.3. **Raw materials status**

The products, considered as semimanufactured are produced in Turkey.

The import of raw materials, 1969—1970 was :

Raw materials, for	1970 (t)	1969
ACTIVE INGREDIENTS		
I. Insecticides	4,580	4,160
II. Fungicides	720	344
III. Herbicides	587	419
IV. Molluscides	2	1
V. Rodenticides	4	—
ADDITIVES		
I. Sulphuric acid	[illegible]	1,200
II. Solvents	[illegible]	3,334
III. [illegible]	[illegible]	750
IV. [illegible]	[illegible]	415

Of the raw materials needed for the production of inorganic pesticides mercury and copper are obtained domestically and so is part of the sulphur.

2 The future of the pesticides industry

In order to produce sufficient active ingredients in every group of pesticides the following manufacturing units have been proposed to be established or improved

Mercury-based pesticides

Etibank is considering the establishment of a 70 tons per year phenyl mercury acetate plant. The product would be sold entirely to the Ministry of Agriculture and regional stations would be set up to monitor any possible toxic effects.

Mineral oil production

Copper oxide and copper oxychloride

Dithiocarbamate production

Organic phosphate-based pesticide manufacturing units

Herbicide manufacturing units

3 The main problems of the pesticides industry in Turkey

3.1 *Training*. Turkish peasants, for the time being, could not find the opportunity to be trained well enough to appreciate the pesticides.

3.2 *Distribution*. Even though there are enough establishments in every province, the organization does not function well enough in this field.

YUGOSLAVIA

Anton Vizovšek

The production of pesticides has a good tradition in Yugoslavia. Before World War II, we were making copper sulphate, calcium and lead arsenates, calcium sulphite, barium polysulphides, mercury compounds and pyrethrum dusts. After the war, new synthetic products were introduced. In co-operation with UNRRA, the production of DDT was started in the early 1950s.

The development of the pesticide industry is closely connected with the production of organic chemicals and intermediates, and even now we have no basic synthesis, but only the production of pesticides on the basis of imported intermediates or raw materials.

There was very dynamic growth, particularly in the period 1960—1966, and we established the production of copper suboxide, copper oxychloride, lead arsenate, zinc phosphide, mercury triacetate, methoxyethyl mercury chloride and acetate, zineb, DNOC, DDT, lindane, TMTD and aminotriazines.

In 1966, we produced 11,900 tons of copper sulphate and 3,430 tons of other pesticides. The amount of copper sulphate used is diminishing because of increased use of organic compounds, and in 1970 only 8,000 tons of the 14,900 tons manufactured were used in agriculture. In the same year, production of other pesticides was 6,000 tons.

The production of phenoxyacetic acid derivatives, such as 2,4D and MCP was begun, but had to be stopped because of problems of river pollution with phenolic wastes. The production of pyrethrum dusts was increased, and there was also a domestic production of pyrethrum extract, but this was neglected because of competition from the imported extract, and has now ceased. Changes in the use of chlorinated hydrocarbon derivatives have brought us considerable problems in the control of soil and forest pests.

Besides the problem of our underdeveloped organic synthesis industry, there is also the problem of economic capacities of plants. In many cases, plants of small capacity are uneconomic, and the import of active ingredients is cheaper, but as soon as there is a surplus problems of exports to Western countries arise, owing to patent and marketing differences. In recent years, an increased trend towards joint capital investment even in this branch of industry became possible under new regulations.

The second problem is the steady change in the use of pesticides. There are only a few compounds which could hold the position of copper sulphate or DDT. In Yugoslavia, triazine seems to have similar importance and considerable expansion of its production in the next few years can be foreseen. From the beginning of this year, the use of chlorinated organic compounds was severely limited and partially prohibited.

There are also problems connected with the control of pollution. Compliance with the regulations not only increases the capital cost of new plants, but also limits the choice of location.

There is also another minor reason for the slow development of pesticde production in our country. This industry has a relatively low labour requirement in comparison to its capital investment cost and the value of the final products.

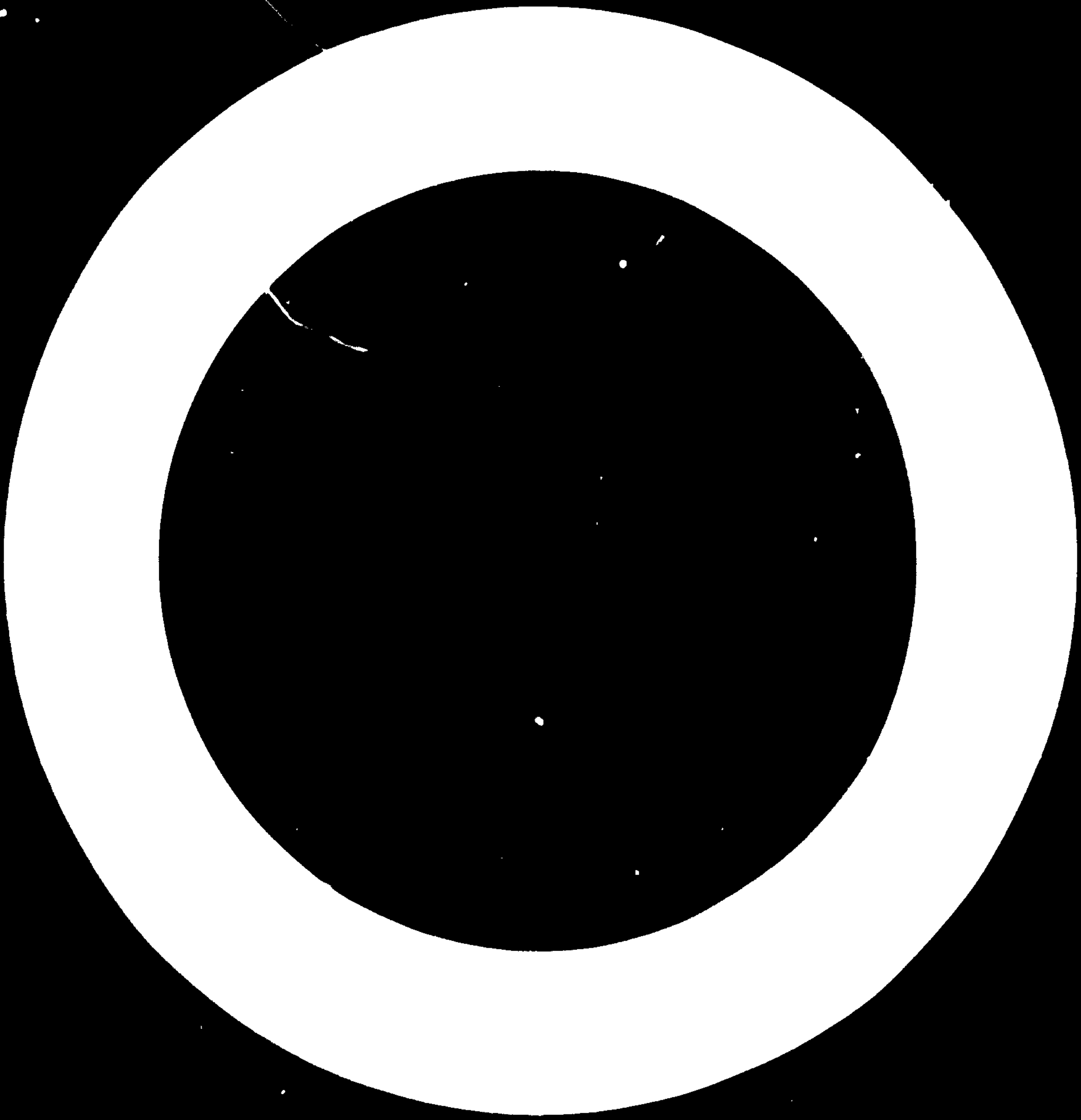
Yugoslavia has a rather well-developed capacity for the formulation of pesticides. The production of raw materials takes place in eight factories, formulation in twelve, mainly because of transport difficulties and the different needs of agriculture in different regions. These companies formulate about 450 final products, and besides active materials from domestic production use about 110 types which are imported. We have domestic production of some surface-active agents and solvents, and there is a choice of good fillers and carriers for dust and granular formulations.

Statistics produced in Yugoslavia refer to products, not active materials. In 1965, all formulators produced 118,000 tons of different final products, but in 1970 the figure was only 33,800 tons. The difference is due to exports of different dust formulations and the rapid change of use from simple dusts to wettable powders with a very high content of active ingredients. The general change to more concentrated products of better physical properties is slow due to lack of experience and the high cost of imported equipment, but nevertheless does not pose such great problems as the synthesis of active ingredients, and today total capacity of the formulating industry is about 45,000 tons per year (products).

The future trend will be towards modernization of existing plants, and no new capacities are planned. Statistical data show that we used 2.1 kg/ha in 1965, and 2.7 kg/ha in 1970, less than our neighbours in Bulgaria, Hungary and Romania. This is due to differences in the structure of agriculture and to the uneven development of regions of Yugoslavia. The largest consumption is on the plains in the northern part of the country. Future growth will depend on the intensivity of agricultural production, where it is necessary to consider not only higher yields but also proper application equipment, and just that can be the problem of the small farmer who is an important factor in the structure of Yugoslav agriculture.

I think that in some developing countries problems of the availability of proper equipment must be considered with the same attention as the production of pesticides.

At present, Yugoslavia produces pesticides almost entirely for home consumption, and future trends will depend strongly on progress in agriculture and the profitability of agricultural production; on possible arrangements for export to other countries; and on further improvement in the general standard of living.



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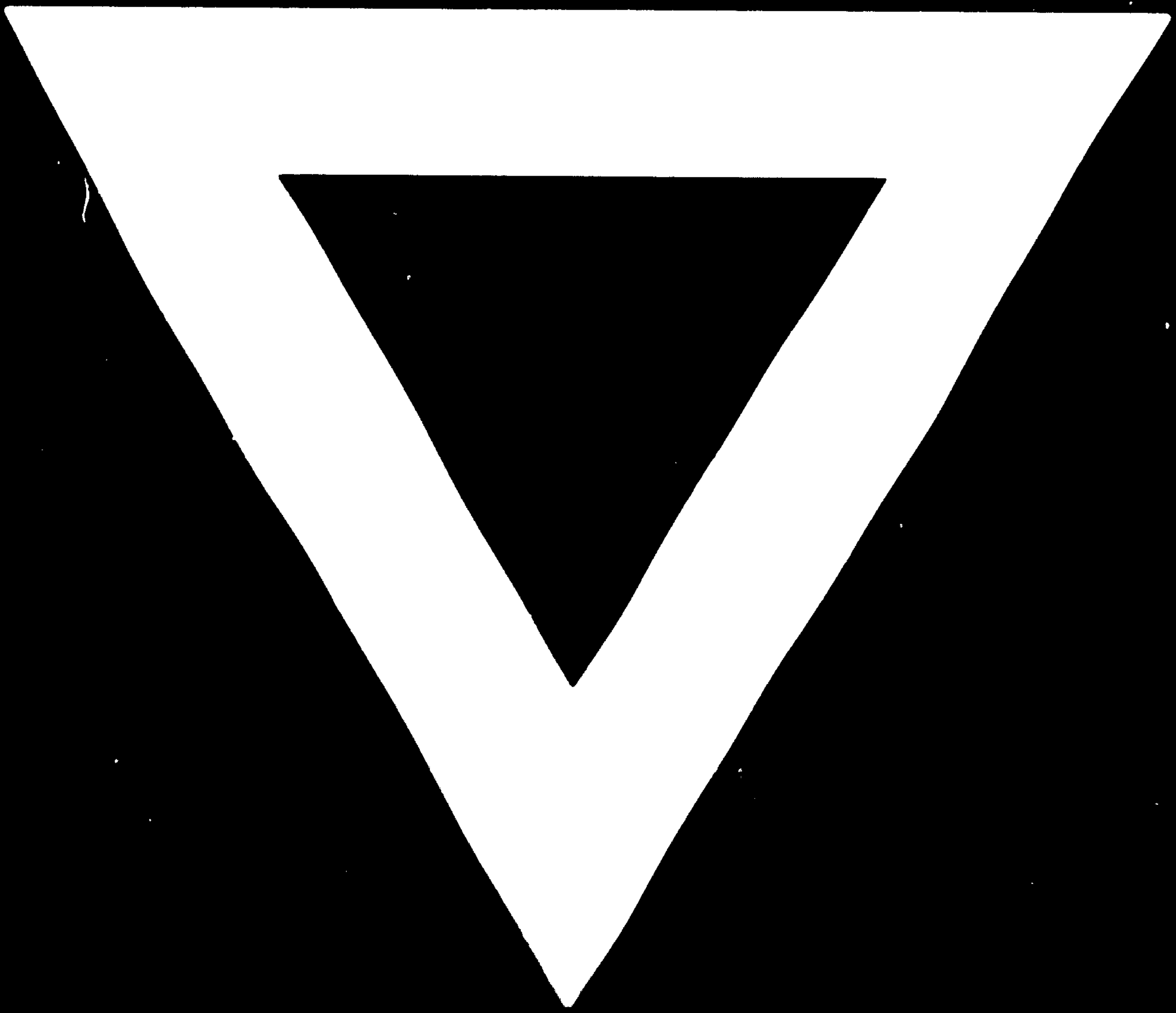

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