International Fertilizer Industry Association

IFA Technical Conference

Johannesburg, South Africa
30 September-4 October 1996

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Date of receipt: 19 April 1996

PHOSPHATE FERTILIZERS OF RUSSIA

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RESUME

Des données sur la consommation d'engrais minéraux par l'agriculture en Russie et les différents engrais utilisés sont présentés dans la communication. L'analyse des raisons de la consommation d'engrais, de sa baisse, l'évaluation scientifique des besoins en engrais de l'agriculture russe sont données. Les données sur les matières premières phosphatées incluent les informations concernant la composition des apatites et des phosphorites utilisées dans l'industrie ainsi que les caractéristiques des principaux gisements.

Le procédé de production d'engrais phosphatés employé dans les usines les plus modernes qui repose sur l'emploi d'apatite de Kola et de phosphates de qualité médiocre est considéré. Des voies efficaces pour résoudre les problèmes d'environnement dans la production d'engrais phosphatés sont indiquées. L'organisation de la production industrielle, la qualité des produits finis et les problèmes de transport sont considérés en ce qui concerne le plus grand producteur mondial d'engrais phosphatés « Ammophos » JSC/Cherepovets.

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Major statements of the monograph « Phosphate Fertilizers of Russia » by V.V. Babkin and A.A. Brodsky are given in the present report. The monograph is intended for the Russian and foreign businessmen who are engaged in the problems of the production and realization of mineral fertilizers as well as for engineers and scientific staff of the chemical industry.

Russia is a major producer of mineral fertilizers. There are dozens of plants producing nitrogenous, phosphate, potash and complex fertilizers. In the period of operation at full capacity of the production units (in 1988) Russia used to produce 19 mln tons of fertilizers in terms of nutrients (the USSR produced 37.1 mln tons).

Up to the end of the 80-ies the mineral fertilizers produced in Russia went mostly to the producers of agricultural products of the former USSR. At the very end of the 80-ies and beginning of the 90-ies export of fertilizers from Russia increased significantly: in 1991 it amounted to 1791 mln dollars, which made about 5% of the total scope of the goods exported. The share of fertilizer export of Russia constitutes about 80 per cent of the total export of all the republics of the former Soviet Union.

One of the most important nutrients for the plants is phosphorus.

The history of the Russian phosphate fertilizer industry up to the end of the 80-ies includes the following major stages:

- setting up small-tonnage production units of single superphosphate on the basis of empirical regularities of chemical technology (summed capacities of the production units: 10-20 thous. tons of P_2O_5);
- formation of the phosphate raw material base of Russia on the basis of Kola apatite and fundamental research in the field of processing it into mineral fertilizers;
- setting up and operation of large-tonnage production capacities of single superphosphate on the basis of Kola apatite, using continuous technology (summed capacity: 2 mln tons of P_2O_5);
- working out the technology and setting up the production capacities of complex fertilizers of various grades of large unit capacity;
- upgrading the quality of phosphate fertilizers on the basis of studying their physical and mechanical properties.

By the beginning of the 80-ies basing on the scientific elaboration the Russian industry of phosphate fertilizers of various range (single superphosphate, TSP, ammonium phosphates, mostly ammophos, nitrophoska, nitroammophoska and small amounts of other fertilizer types) was the biggest in Europe. Below are listed some peculiarities of the Russian phosphate fertilizer industry:

- orientation of the majority of the plants to the production of a very limited fertilizer range (2 or 3 products as a rule);

- using mostly the process lines of big unit capacity;
- prevailing of sulphuric acid methods over nitric acid ones, which is economically justified;
- orientation (among the products of ammonium phosphate type) to the production of ammophos that is simpler by technology than diammonium phosphate.

General branch development strategy (introduction of technological lines of big unit capacity, orientation to the production of ammophos and other NP-fertilizers, etc.) made it possible to set up powerful modern industry in a short period and secure stable provision of agriculture with mineral fertilizers.

Production of phosphate fertilizers in Russia is concentrated in the cities of Cherepovets, Voskresensk, Balakovo, Kinguisepp, Byelorechensk, Uvarovo and others. The share of the first four plants constitutes over 70% of the production facilities providing the production of phosphate fertilizers in Russia (Figure 1).

Transition to market economy resulted in some chaos in the mineral fertilizer industry. Nevertheless, thorough appreciation of the Russian fertilizer industry shows that Russian fertilizers can be quite competitive with those produced abroad when viewed by these parameters:

- Russia possesses a tremendous raw materials base (phosphate, potash base), the most technological and ecologically pure raw materials being available;
- the production facilities set up exceed by capacity those of any other country (excluding the USA);
- the technological developments carried out at the institutes and plants are on the level of the world achievements.

Attaining high economic indices by separate production facilities and enterprises of the fertilizer industry in general is aggravated by the necessity of high expenses for transportation of one or several kinds of raw materials and, in most cases, of the major products, i.e. fertilizers.

Integration of the Russian phosphate fertilizer industry into world economy will take place on condition of mobilizing all the production resources, introduction of new technology and modernization of industry.

PRODUCTION AND CONSUMPTION OF MINERAL FERTILIZERS IN RUSSIA

Russia entered the path of intensive development of production and application of mineral fertilizers rather late as compared to other developed countries of Western Europe and America.

Construction of dozens of plants for production of mineral fertilizers resulted in the fact that actual output of those products in 1988 in Russia amounted to 19.2 mln.t (nutrients).

From 1988 there is a decline of mineral fertilizer deliveries to the agriculture of Russia (thous.tons of nutrients):

Table 1: Mineral fertilizer deliveries to the agriculture of Russia

Years	Total NPK	Nitrogenous	Phosphate	Potash
1986	13667.7	5694.0	4582.7	3391.0
1987	14192.0	5923.2	4775.6	3433.2
1988	13341.0	5488.6	4639.6	3212.8
1989	12431.1	4850.3	4680.4	2900.4
1990	11050.9	4333.7	4338.9	2378.2
1991	10110.9	4017.6	3705.1	2417.9
1993	3700.0	-	-	-
1994	1500.0	-	-	-

The main reasons of the mineral fertilizer consumption decline are price rise, unsatisfactory state of chemical logistics and low level of fertilizer application efficiency. Actual payback is 3.5-4.0 kg of grain per 1 kg of nutrients, which is 2-2.5 times lower than the potential possibility.

The decline of mineral fertilizer production is accompanied by a drop in consumption.

Table 2: Production of fertilizers in Russia

Average capacity		Actual output		Rate %	Rate %	Capacity usage %	
1992	1993	1992	1993	1993 to 1992	1993 to 1988	1992	1993
Nitrogenous fertilizers, '000 t of N							
8637.2	8377.3	5821.7	4795.9	82.6	55.6	67.4	52.2
Phosphate fertilizers, '000 t of P_2O_5							
5522.2	5280.2	3041.0	2511.1	82.8	49.7	55.1	47.6
Potash fertilizers, '000 t of K_2O							
5857.3	5491.3	3469.8	2615.7	75.6	49.0	59.2	47.6

A tendency towards the decline of phosphate fertilizer deliveries manifested itself a year later than the one in regard to nitrogenous and potash fertilizers. It is due to the fact that a consumer is more interested in phosphate fertilizers; besides, advertizing by agrochemical science promotes them. A wide spread opinion is that there still exists a phosphate problem that is expressed in phosphorus shortage in agriculture, phosphate fertilizers shortage, in the fact that phosphate fertilizers are a limiting factor for crop growth. It should be mentioned, however, that the maximum level of phosphate fertilizer deliveries attained in 1988 alleviated the problem considerably. Precise calculations show that they fully provided the planned yield of agricultural crops and satisfactory balance of phosphorus in agriculture.

Notwithstanding the deep and lingering character of the crisis in the fields of production and use of mineral fertilizers, producers of agricultural products and mineral fertilizers, scientists and specialists engaged in those fields who are quite aware of the importance of preserving the national wealth, i.e. soil fertility, elaborated principle ways of forming stable reliable home market of mineral fertilizers.

From the estimates of the Russian Ministry of Agriculture and Russian Academy of Agricultural Sciences (RASHN) which conducted agriculture survey in the territories of the Former Soviet Union with regard to natural soil fertility, possible volumes of agricultural production and the requirements of major nutrients in 1995-1996, it is found to be necessary to use a minimum of 9 mln tons of phosphorus annually (Table 3).

Table 3: Demand for phosphorus by regions of the FSU ('000 t)

Russian Federation	4800
Ukraine	1600
Belarus	600
Moldova	140
States of Trans-Caucasian region	260
Baltic states	360
Kazakhstan and states of Central Asia	1280

Use of 9 mln t of phosphorus is a return to the level of 1988, which will make it possible to maintain the production of the major agricultural produce at the acceptable level, but without using fertilizers in long-term programmes of increasing the soil fertility.

The need of Russian agriculture is to be satisfied with efficient and universal fertilizer forms, suitable for most agricultural crops, soil types and fertilizer application methods. As prospective assortment of mineral fertilizers for the year of 2000 it was envisaged to use 4-5 forms of simple phosphate fertilizers and 10-12 types of complex blends (ratios: 1:1:1; 1:1.5:1; 1:1.5:1.5; 1:1:0.5; 1:1.5:2; 1:1:0; 1:2.5:0; 1:3.4:0; 1:4:0; 0:1:1, etc.).

PHOSPHATE RAW MATERIALS OF RUSSIA

By the size of phosphate ore resources of industrial grade prospected (over 1 bln.t P_2O_5), Russia occupies the third place in the world (following Morocco and the USA) and as a whole it possesses a potential possibility to provide a raw material base for mineral fertilizer production for a period of 100 years minimum. However, phosphate raw materials deposits exploited are located only in the European part of the Russian Federation.

The major part of the phosphate raw materials mined in Russia (over 80%) falls on the largest in the world apatite Hibin deposits (Hibin and Kovdor groups).

In the Russian Federation mining and beneficiation of apatite ores are carried out by two enterprises: AO « Apatit » and AO « Kovdor », former Kovdor mining and beneficiation complex (GOK).

AO « Apatit » is one of the largest enterprises in the world producing apatite concentrate, major phosphate raw material for mineral fertilizer production in Russia. The design capacity is about 30 mln.t/a. AO « Apatit » where apatite-nepheline ore of Hibin deposit group is mined and beneficiated includes 4 mines - Kirov and Ukspor (underground mining), Central (open method) and Rasvumchorsk (open and underground mining); 3 beneficiation factories, transportation and auxiliary units.

The principal raw material for phosphorus-containing mineral fertilizers production is apatite concentrate obtained on the basis of unique Kola apatite-nepheline ore.

The ore mineral composition(% P_2O_5): apatite 40-44; nepheline 35-40; egyrine-avgite 9-12; field spars 3-5; sphene 1,8-1,9; titanomagnetite 1,0-1,8; other minerals 3-5.

The total of 20 mln. t/a of apatite concentrate and 1,6 mln. t/a nepheline concentrate can be produced at the beneficiation factories. AO « Apatit » exports apatite concentrate to 12 foreign countries.

The comparative characteristics of technological indices of phosphate concentrate treatment used in the world practice (Figure 2) show that Hibin apatites are among the best types of phosphate raw materials.

Apatite concentrate in Russia is also produced by treatment of pond tailings of iron ore concentrate beneficiation at Kovdor mining-beneficiation complex (AO « Kovdor »).

Kovdor deposit is located in the south-western part of the Kola peninsula in the limits of ultra-basic alkaline rock massif.

The wastes of iron-containing ores beneficiation whereof mining and beneficiation are carried out at AO « Kovdor » (Murmansk area) serve as raw materials for apatite concentrate production. The deposit is developed by an open method.

Due to a relatively low fluorine content (less 1%), the Kovdor concentrate is used mostly in defluorinated phosphates production by calcining. The technical specifications for Kovdor apatite concentrate regulate content (mass fraction) of P_2O_5: no less than 36%; MgO: no more than 5%; moisture: 10,5%; the sieve residue on the wire mesh No. 0,071K no more than 60%.

AO « Kovdor » is the first domestic enterprise carrying out the complex usage of ores of complex substance composition with the formation of apatite concentrate on an industrial scale. The production volumes of apatite concentrate at the complex are dependent upon magnetite concentrate production capacities. In 1993 the apatite concentrate production capacities made up about 1,2 mln.t at AO « Kovdor ».

The other resources are presented by low quality, poorly beneficiated ores including shell phosphorites of Kingisepp deposit, nodular phosphorites of the Central and Volgo-Vyatsk region (Egoryevsk, Polpin, Vyatsko-Kamsk), Sundukovsk phosphorites of Tatarstan under development and by the prospected reserve phosphate deposits.

The data on the dynamics of phosphate raw materials production in Russia is presented in Figure 3.

Significant reduction of the volumes of ore mining and phosphate concentrate output is caused by a number of reasons which are general for the whole economy of the former Soviet Union resulting in disbalancing of the production links as well as the reasons that are specific for the industry branch.

In the period of 1990-1993 a decrease in volumes of phosphate raw materials supply to the traditional consumers including domestic mineral fertilizers production plants took place. By the estimates of the experts, this was caused partially by an abrupt increase in prices of phosphate concentrates (Figure 4), distant location of mining-processing enterprises from the plants-consumers and high transportation prices.

Due to the higher prices for transportation the deliveries of raw material components and highly concentrated mineral blends to the far off regions of the Russian Federation become economically inexpedient.

A way out of the situation can be the use of developed reserve phosphate ore deposits (as a raw material base for complex and concentrated phosphate fertilizer production) whereof geographical location is more favourable as compared to high quality types of phosphate raw materials which are quite at a distance from the production facilities.

Moreover, as the preliminary agrochemical tests have shown, a number of phosphorites from the prospective deposits are applicable as fertilizers, when in the finely ground form.

The ores of Seligdar apatite deposit and some other deposits of Siberia are considered to be the most studied prospective phosphate ores of Russia.

CONSUMPTIVE PROPERTIES AND CLASSIFICATION OF MINERAL FERTILIZERS

For proper classification and estimation of mineral fertilizers specifications, it is indispensable to establish terms and give definitions of the notions used in science, technique, production and use of mineral fertilizers. Presently the terms and notions are standardized in the Russian Federation. In general they correspond to those accepted by the countries-members of International Standardization Organization (ISO).

Terms definitions are given: general notions (nutrient, guaranteed content, etc.), properties of fertilizers (solubility, acidity, etc.), supplementary notions (soil fertility, soil fertilizer application, etc.). The total of 41 terms are defined.

The fertilizer classification system used in the monograph is based on the preparation method, namely: simple fertilizers, compound fertilizers, mixed fertilizers (blends or liquid mixtures).

There is data on all the fertilizer forms produced in Russia: simple (nitrogenous, phosphate and potash fertilizers) and compound fertilizers. The nomenclature includes 57 designations.

The most widespread grades of blends and liquid fertilizers are also given.

The monograph also contains the range and requirements to the quality of mineral fertilizers produced by the Russian industry.

Concentration of nutrients in fertilizers is defined by the assortment; specifications characterizing the fertilizers in the processes of transportation, storage, preparation for application and application are regulated by the following indices: granulometric composition, granule strength, friability, water content.

Major requirements to the consumptive properties are as follows:

1. All the solid fertilizers are to be supplied only in granulated or big-size crystalline form. It is necessary to establish uniform granulometric composition: content of granules sized 1-4 mm is 95%, thereof granules sized 2-4 mm - not less than 90% (especially for finely granulated fertilizers), granules smaller than 1 mm - 1-4%. All the product is to pass through the sieve mesh of 6 mm.

2. Quality indices of the fertilizers will indicate its suitability for bulk transportation, storing and dry blending. The fertilizers are to retain complete friability (100%) after transportation and storing in piles up to 10-12 metres during the guarantee period provided there is isolation from direct water penetration, and the blends prepared on their basis - during 30 days when storing in bulk in the warehouse. It is rational to prepare blends (70%) on the basis of ammophos or diammophos; double superphosphate must have free acidity not exceeding 1-1.5% P_2O_5 for blending. Moisture content in mineral fertilizers is not to exceed: in nitrogenous fertilizers - 0.15-0.30%, in simple phosphate fertilizers - 3.0-4.0%, in others - 1.0-2.0%.

3. Granule strength must not be less than 2.0 Mpa for nitrogenous and simple phosphate fertilizers, 3.0 Mpa for compound fertilizers, not less than 70% (dynamic strength) for potash fertilizers.

4. The fertilizers must not contain chemically aggressive admixtures, such as active chlorine, biuret. Free acidity in superphosphates is not to exceed 5% P_2O_5.

5. Liquid fertilizers are to be stable, they must not evolve deposits and gases on changing the temperature while storing and transporting, they must not have aggressive properties towards the equipment and piping.

TECHNOLOGY OF PHOSPHATE FERTILIZERS

The technology of phosphate fertilizers includes the main process of obtaining the final product and auxiliary processes: drying, granulation, etc.

The main processes can be classified into two groups (they belong to two systems) by the aggregate state of components entering the interaction:

- system solid-liquid (production of superphosphates, nitrophoska, ammophosphates, precipitate);
- system gas-liquid (production of phosphates and polyphosphates of ammonium, nitro- and carboammophos, etc).

Most of the production facilities of phosphate fertilizers operate on the basis of the above-mentioned processes.

Generality of the processes inside each group determines generality of technological schemes and apparatus implementation of the production facilities. In accordance with its physical and chemical foundations of the production, technology and equipment are considered sequentially (by groups).

Physical and chemical foundations include:

- decomposition of phosphates with mineral acids (sulphuric, phosphoric, nitric and their mixtures);
- neutralization of simple and triple superphosphate;
- ammoniation of the solutions of phosphoric and nitric acids;
- processes taking place on mixing and granulating the components.

Description of the processes including a detailed technological scheme, production parameters and consumption coefficients is given in regard to the production of the following products:

- superphosphates (single, triple, superphos);
- diammophoska;
- ammophosphate;
- nitroammophosphates, carboammophosphates;
- nitrophosphates (nitrophoska and azophoska);
- blends.

Different methods and comparison of them are given for each production. Foremost technologies worked out in Russia are described.

The main stages in the production of phosphate, nitrogenous-phosphate and nitrogenous-phosphate-potash fertilizers are decomposition of phosphate raw materials, neutralization of phosphoric, nitric, sulphuric acids with ammonia, granulation of the mixture and drying of the product.

Apparatus and equipment are to be simple in maintenance, suitable for use with various methods of fertilizer production and have high productivity. Fabrication and repair of them must not present specific difficulties. Those factors determine to a large extent economical operation of the technological process.

CHARACTERISTICS OF THE RUSSIAN PHOSPHATE FERTILIZER PLANTS

The most prevalent typical Russian plant for the production of a wide variety of phosphate fertilizers is a complicated complex of plants for the production of phosphate fertilizers and some intermediate products and auxiliary units providing the plants with energy, transport facilities, maintenance, storage services and means of management. A plant of this type was taken as an example and the basic engineering solutions were considered on its basis.

The characteristics of the plant, main stages of its development, range of the mineral fertilizers and fluorine salts produced are exemplified by AO « Ammophos » (Cherepovets, Russia).

The phosphate fertilizer plant has been producing fertilizers since 1974. Within a short period the units for the production of sulphuric and phosphoric acids, mineral fertilizers and fluorine salts were commissioned and put into exploitation. In 1992 as a result of privatization the plant was reorganized into a joint-stock company of an open type AO « Ammophos ». 51% of shares belongs to the work collective.

« Ammophos » is an important fertilizer supplier to the Russian market and the foremost exporter of the products to the CIS countries, Western Europe, Asia, America and Africa.

In compliance with the domestic market demand a special fertilizer grade containing all the nutrient elements has been developed by « Ammophos » company. The prices for the fertilizers in the domestic market have been kept at a low level as compared to the similar plants.

Foreign economic activities of the plant include mineral fertilizer sales, acquiring industrial equipment and instituting joint ventures.

« Ammophos » is considered to be a reliable and advantageous partner and the proof of it was admission to International Fertilizer Association in 1993.

AO « Ammophos » is a large-scale chemical complex comprising a number of production plants most of which have no analogues in the world practice.

The main assortment of the fertilizers produced is: monoammonium phosphate (ammophos); diammonium phosphate; diammophoska (NPK); liquid complex fertilizers. All of them meet international standards.

The main factors responsible for the quality priority of the AO « Ammophos » fertilizers are as follows:

- the use of the technology eliminating dust formation during transportation;
- homogeneity of granulometric composition;
- stable content of nutrient elements.

The list of fluorine salts produced by AO « Ammophos » is diversified: calcium fluoride, silicofluorides of sodium, ammonium and potassium.

RECOVERY AND PROCESSING OF FLUORINE COMPOUNDS

Two major tasks are solved on recovering and utilizing of fluorine evolving when processing phosphate raw materials: expansion of fluorine compounds production and prevention of damage to the biosphere caused by the emission of fluorine substances into the environment (first of all, into atmosphere and natural reservoirs).

The biggest specific weight in processing of phosphate rocks from the point of view of fluorine compounds recovery belongs to the production of wet-process phosphoric acid, then comes the production of single and double superphosphates.

In phosphate fertilizer production fluorine gases are mostly absorbed by water, fluosilicic acid being formed; for sanitary gas cleaning lime milk (1-2% CaO) is used. In some cases, on forming closed systems of fluorine salt production mother solutions formed on processing of solutions of fluosilicic acid and ammonium silicofluoride into aluminium fluoride and ammonium bifluoride are used to recover fluorine compounds.

The implementation includes hollow scrubbers, foam apparatus, Venturi absorbers, etc.

Processing of the by-product, fluorosilicic acid formed by the recovery of the fluorine gases is one of the major concluding stages in the production of mineral phosphate fertilizers.

Solutions of fluorosilicic acid are processed to obtain fluorine products. To meet the demand for fluorine compounds the following fluorine products are produced in the mineral fertilizer plants: aluminium and sodium fluorides, cryolite; sodium, potassium and ammonium silicofluorides, ammonium bifluoride, hydrogen fluoride, hydrofluoric acid. The technology of the products is considered in the monograph.

Fig.1. Production capacity distribution (%) by the phosphate fertilizer production plants of Russia.

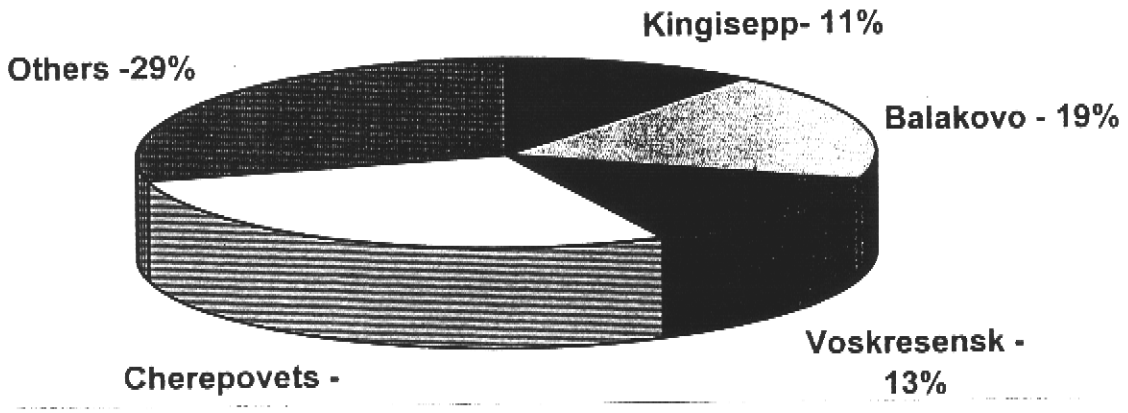
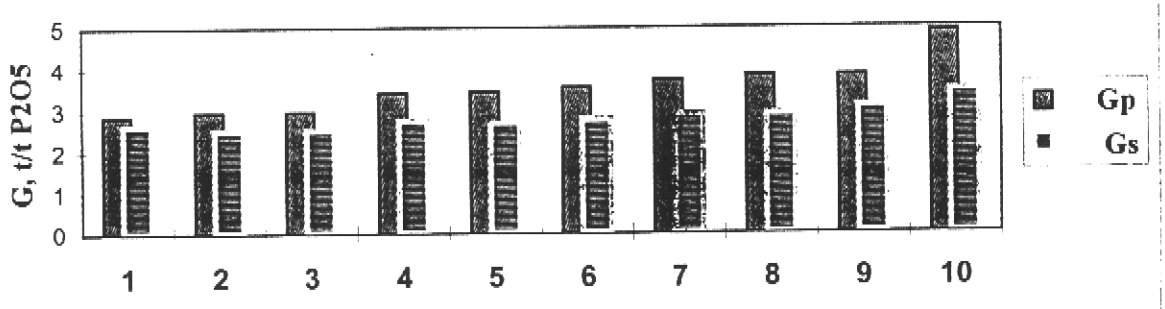


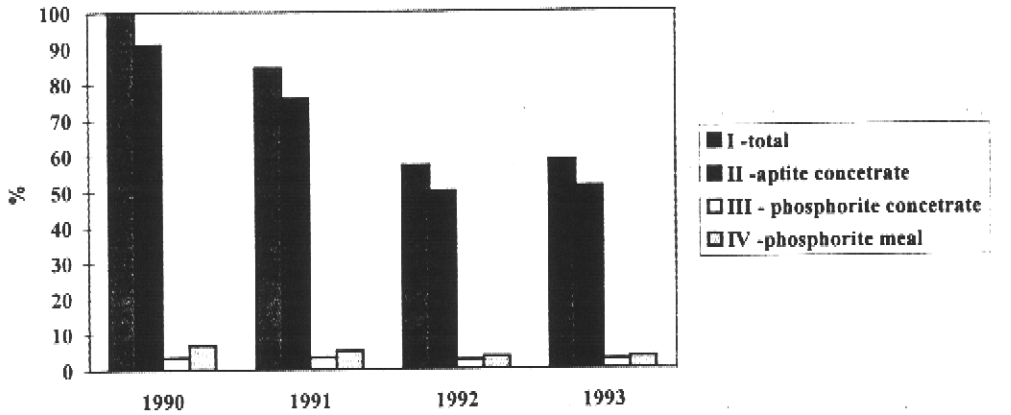
Fig.2.Phosphate raw materials and sulphuric acid consumption rate G.



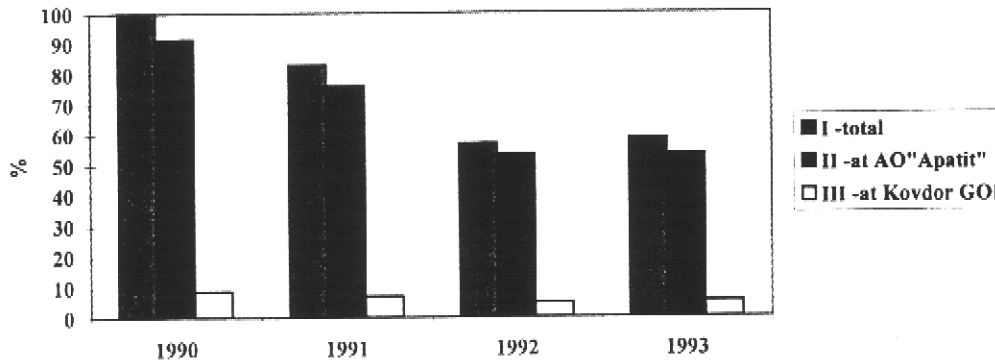
1 - Russia, Hibin
2 - Togo, Benin (BLS-80)
3 - Senegal, Tie (80)
4 - Florida (72-73)
5 - Morocco, Huribga (75-77)
6 - Morocco, Usufi (70-72)
7 - Florida (66-68)
8 - Tunisia (66-68)
9 - Egypt, Safaga (65-68)
10 - Kazakhstan, Karatau

Fig.3. Production of phosphate raw materials and phosphorite meal in Russia in the period of 1990-1993.

a) all types



b) apatite concentrate



c) phosphorite meal

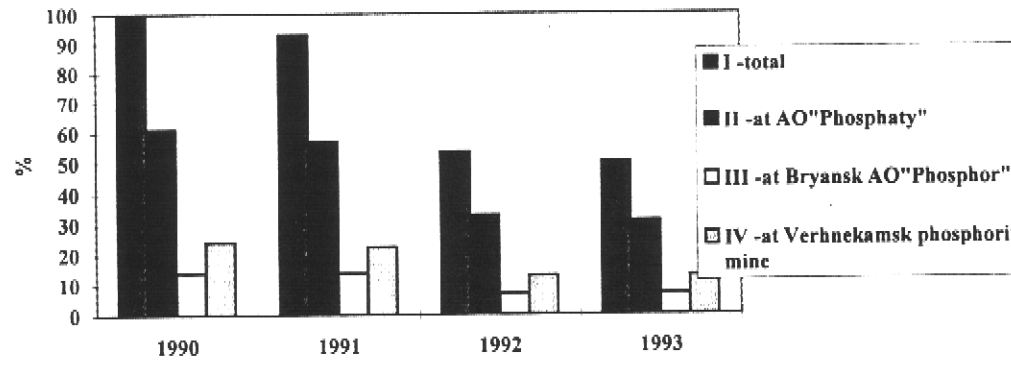
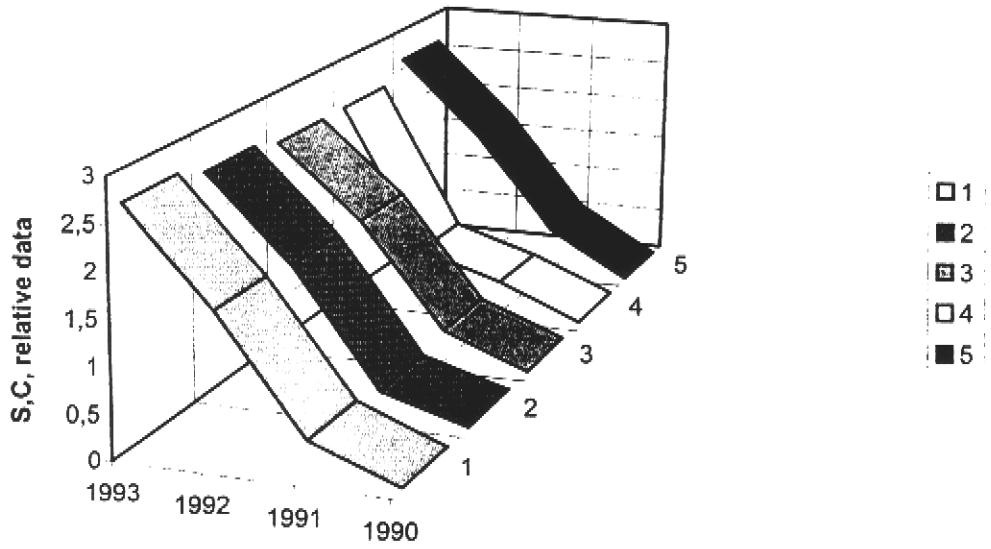


Fig.4. Dynamics of apatite concentrate cost price growth S and producer's prices C (relative data, the data for 1990 is accepted for a unit).



1- AO"Apatit", producer's prices for apatite concentrate in the RF;
2- the same, manufacturing cost of ore mining;
3- the same, manufacturing cost of apatite concentrate, mining expenditures included;
4- Kovdor GOK, manufacturing cost of apatite concentrate;
5- the same, producer's cost for apatite concentrate.