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Development and Implementation of Flexible Technology of Granular Slow Release NPKS/PKS-Fertilizers with Controlled Dissolution Rate

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Abstract

JSC "NIUIF", the oldest (founded in 1919) and the only one in Russia scientific research institute for phosphorus containing fertilizers, developed an innovative flexible technology of production of slow release NPKS / PKS-fertilizers with a controlled dissolution rate and controlled nutrient supply into the soil solution. These fertilizers are environmentally safe, nonradioactive; practically do not contain compounds of harmful heavy metals (arsenic, cadmium, lead, mercury, chromium, etc.). Besides the main nutrients (nitrogen, phosphorus, potassium) they also contain sulfur and calcium in a plant available form. The dissolution rate is regulated by changing the ratio between the water soluble and plant-available forms of phosphorus, as well as by addition of ammonium salts. The technology is waste free, moreover, it allows to process wastes and by-products of other production units: phosphogypsum, conversion chalk, cake from sodium tripolyphosphate production, sludge sand, etc. These fertilizers were successfully tested by the International Institute of Plant Nutrition and in the Russian Agricultural Academy named after K.A.Timiryazev to prove its high agronomic efficiency. The technology is protected by three patents of the Russian Federation. Based on the design documentation developed by JSC "NIUIF", NPKS / PKS-fertilizer plant was built and successfully set into operation at "Metakhim" plant (Volkhov city, Leningrad Region).

Keywords: Slow release fertilizers; Controlled dissolution rate; Nutrients; Granules; Phosphate rock; Wet phosphoric acid (WPA)

Introduction

JSC "NIUIF", the oldest and the only industry oriented scientific-research and design institute in Russia for phosphorus-containing fertilizers, has developed an innovative flexible technology of granular slow release PKS- and NPKS-fertilizers with controlled dissolution rate and controlled nutrient supply into the soil solution.

Method Description

The process of obtaining PKS-fertilizers implies neutralizing of wet phosphoric acid (WPA) or its mixture with sulfuric acid by calciumum carbonate, followed by introduction of potassium chloride into the resulting neutralized slurry. Sulfuric acid is used as a sulfur source and can be replaced with calcium sulfate from phosphogypsum or semi-product of WPA production-WPA slurry without separation of phosphogypsum. To produce NPKS-fertilizers, ammonium sulfate is added to the neutralized slurry in addition to potassium chloride, or additional complete neutralization with ammonia is performed. Once all raw materials are introduced, the slurry is sent for granulation and drying to a special drum combining the stages of granulation and drying-Drum Granulator Dryer (DGD) [1]. Granulation in DGD means spraying of slurry onto the curtain of particles of dry material falling from the blades installed inside the drum (Figure 1). Drying of slurry on the surface of the particles occurs due to hot flue gases. Maintaining the required amount of dry material inside DGD is ensured by its external and internal circulation (external and internal recycle).

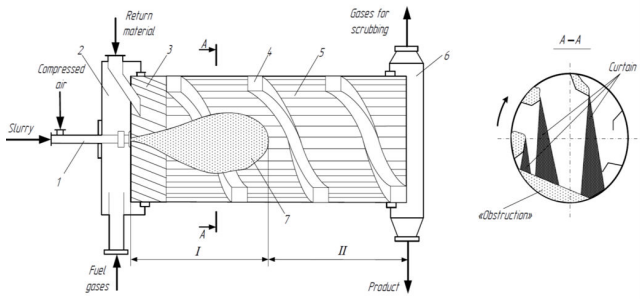

Figure 1: Drum granulator-dryer (DGD) where 1-nozzle; 2-loading chamber; 3-screw feeder; 4-reverse screw; 5-flat lifting plate; 6-discharge chamber; 7- jet; I-granulation section; II-drying section.

After drying and screening, the granules of final fraction are sent for cooling and surface conditioning, and after grinding of coarse fraction together with fine fraction it is returned to the head of DGD as a recycle.

Results

Without significant changes in the main parameters of the process, only by adjusting the ratio of initial components, the technology allows to obtain a wide range of various grades of PKS- and NPKS-fertilizers: 0-20-20(5S); 0-15-15(9S); 0-24-24(2S); 0-15-30(4S); 0-20-30(2S); 1-20-20(5S); 5-20-20(5S); 5-15-30(5S); 10-15-15(10S); 4-30-10(5S); 4-30-15(3S); 5-25-15(5S); 12-17-17(9S); 10-10-20(10S); 8-16-16(9S);

6-20-30(3S), etc. Figure 2 shows the process flow diagram (PFD) for obtaining PKS- and NPKS-fertilizers [2-4].

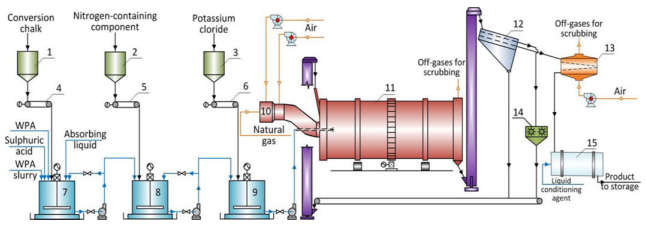

Figure 2: PFD of production of PKS/NPKS-fertilizers based on calcium phosphates, 1-3-feed tanks, 4-6- weight feeders, 7-9-reactors, 10-furnace, 11-DGD, 12-screen, 13- "fluidized bed" cooler, 14-crusher, 15-conditioning drum.

Technology is zero-effluent and waste-free, moreover, it allows to process non-concentrated WPA, slurry from WPA production without separation of phosphogypsum, as well as a number of various wastes from mineral fertilizers and salts production, for example, conversion chalk (which is a waste of complex fertilizers production by decomposition of phosphate raw materials with nitric acid), phosphogypsum, various phosphorus-containing sludges, for example, from production of sodium tripolyphosphate, etc. into the popular grades of fertilizers. In addition, it is possible to use various natural phosphate raw materials as one of the sources of phosphorus. In this case, the process includes the stage of decomposition of the phosphate raw material by a mixture of WPA and sulfuric acid.

Complex PKS- and NPKS-fertilizers are of good physical and mechanical properties, the granules are spherical, firm and homogeneous as per particle size and chemical composition with low tendency to dustiness and caking. Due to that, complex PKS- and NPKS-fertilizers are of more superior quality compared to similar products obtained by dry blend method. The costs for introduction of fertilizers into the soil are substantially reduced; the uniformity of distribution is increased, as well as release rate of nutrients available for plants.

Besides the main nutrients (nitrogen, phosphorus, potassium), granular PKS- and NPKS-fertilizers also contain sulfur and calcium in plant available form. It is also possible to pro-duce fertilizers that additionally contain magnesium and trace elements (zinc, boron, copper, manganese, molybdenum, etc.).

These fertilizers are environmentally safe, as they are produced from the purest phosphate raw materials - the apatite concentrate from Khibiny, Kola Peninsula. It is not radioactive and almost does not contain impurities harmful elements - arsenic, mercury, cadmium, lead, etc.

According to the results of vegetation and field agrochemical tests, carried out by Russian Agricultural Academy in honor of K.A.Timiryazev and the International Plant Nutrition Institute, it was found that blended fertilizers based on complex PKS- and NPKS-fertilizers are of competitive quality compared to similar products based on triple superphosphate and monoammoniumphosphate (MAP), and even superior (Table 1, Figure 3).

Source of N	Sources of P_2O_5, K_2O and S	Average weight of soyabeans, g/pot	Average harvest of soyabeans, g/pot	Average harvest of soyabeans, green mass, g/pot
NH_4NO_3	PKS-fertilizer 0-20-20(5S)	42.9	24.0	38.8
NH_4NO_3	Triple superphophate, KCL, gypsum	40.4	21.9	38.6
NH_4NO_3	KCL, gypsum	32.3	18.0	21.7

Table 1: The results of vegetation test for the purpose to study the effect of industrial sample of PKS-fertilizer 0-20-20(5S) on the harvest of soybeans.

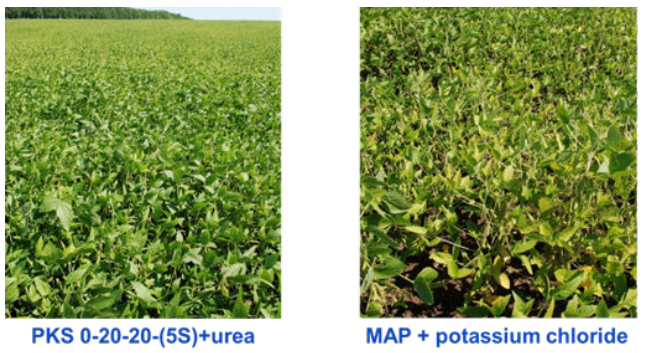

Figure 3: The results of filed test with soybeans.

Also, according to the results of two-year vegetation tests, it was found that PKS-fertilizers are of intense slow release effect and continue to provide plants with nutrients even the following year after being introduced into the soil.

The slow-release effect of PKS-fertilizer occurs due to a dense frame of poorly soluble dicalcium phosphate (DCP) and calcium sulfate in the structure of the granule, that prevents premature leaching of soluble fertilizer components. The release rate of nutrients can be adjusted by changing the amount of calcium carbonate supplied for neutralization of acid mixture, also by changing the product particle size composition and by introducing nitrogen-containing additives into it.

An increase in amount of calcium carbonate leads to an increase in the content of poorly soluble dicalcium phosphate (DCP) in the product, which is well plant available. Figure 4 shows the characteristic curves of relative content of phosphorus in water-soluble and plant available forms, depending on amount of calcium carbonate introduced. You can see that with an increase in amount of calcium

carbonate, the content of a water-soluble form of phosphorus decreases and the content of plant-available form stays almost the same. The stoichiometric amount of calcium carbonate is calculated so that to neutralize a mixture of WPA and sulfuric acid resulting in calcium sulfate and monocalcium phosphate (MCP).

Figure 4 shows the characteristic curves of dissolution rate of granules in water for PKS- and NPKS-fertilizers of various grades. For comparison, here is given the data for NPK-fertilizers of most popular grades. You can see that an increase in the average diameter of the granule of PKS- and NPKS-fertilizers leads to a decrease in its dissolution rate. According to the results of lab vegetation tests, it is also proved that bigger granules are of a more slow-release effect.

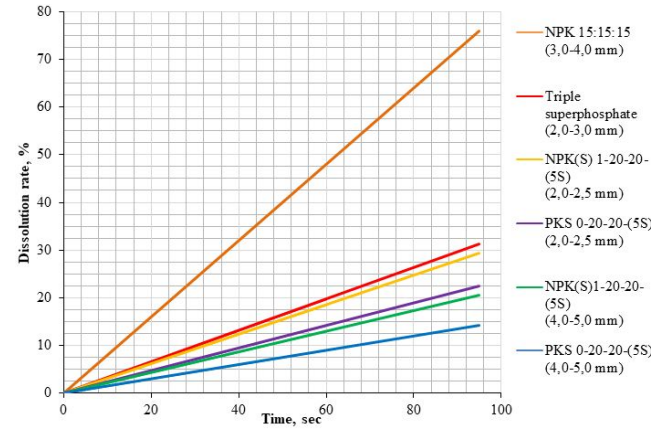

Figure 4: Characteristic curves of dissolution rate of granule in water for PKS-, NPKS- and NPK-fertilizers of different grades.

Introduction of nitrogen into the composition of PKS-fertilizer contributes to an increase in its dissolution rate due to addition of highly soluble salts into the structure of the granules. NPKS-fertilizers, with nitrogen content of more than 2-3%, almost do not have a slow-release effect and in terms of dissolution rate tend to be like the standard NPK-fertilizer grades.

Conclusion

The proposed technology is protected by three patents of the Russian Federation and was successfully implemented at one of the Russian plants in 2014 (there was installed and set into operation a fertilizer production unit with capacity of 100,000 TPA). Nowadays, upgrading and modernizing of this production unit is ongoing, with JSC "NIUIF" taking active part in it, both regarding capacity and yield increase, as well as product assortment enhancement.

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