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Research on Improvement of Characteristics of Ammonia Nitrate using Phosphate Rock and Potassium Chloride

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Abstract: In this article, the results of research on improvement the composition and properties of ammonium nitrate using rock and potassium chloride - the most affordable potash product on the market as composite additives phosphate are given.

Keywords: ammonium nitrate, mineral additive, compositional component, fertilizer, spectrogram, nitrogen, phosphorus pentoxide, potassium oxide.

Introduction

Samples of ammonium nitrate of $N/P_2O_5/K_2O$ composition were synthesized under laboratory conditions, and their composition and properties were studied. Under experimental conditions of research, the initial compositions, i.e. water-ammonium nitrate solutions were prepared based on production ammonium nitrate, the concentration and temperature parameters of which corresponded to the indicators of technological solutions of the existing production of ammonium nitrate obtained after the first stage of evaporation. Ammonium and iron sulfates were used as additional mineral additives. When implementing the target tasks of experimental studies, each time, from the calculated mass of ammonium nitrate and water, an initial solution with concentrations of 64% - 71% and a temperature of 110-130 °C was prepared.

Main part

Calculated masses of phosphate rock, potassium chloride and mineral modifying additives were injected in the prepared initial solution of ammonium nitrate in order to obtain a suspension mixture with a temperature of 120-130 °C with the concentration of 83% - 88%. The resulting suspension mixture, with vigorous stirring for a time of 20 - 40 minutes, sufficient to obtain the target product of the required quality, was subjected to evaporation.

The resulting product, after cooling and drying to a final constant moisture content, was subjected to chemical and physical-chemical study.

In the obtained samples of ammonium nitrate with improved composition and properties, the mass ratios of $N/P_2O_5/K_2O$ were: 19.0/6.0/6.0; 16.0/7.0/7.0; 15.0/7.5/7.5; 10.0/9.0/9.0%.

Analysis of the composition and properties of the composite components and the obtained fertilizer samples was carried out according to the methods given in the normative documentation [1, 2, 3, 4], as well as using modern technical means of physical-chemical analysis, i.e. scanning electron microscope JEOL brand JSM6490LV [5], SPECORD-75 spectrophotometer, IR-Fourier spectrometer ShimadzuIR Prestige - 21 [6], X-ray phase analysis DRON-3 [7], Mettler Toledo moisture meter, and IPG - 1M granule strength meter.

For clarity, data on the composition and properties of the obtained samples of ammonium nitrate with improved composition and properties are summarized in tables 1-4.

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The results of studying the contents of nutrients in the composition of the obtained samples of target products, as well as their expected calculated values are shown in Table 1. From the data in Table 1, it follows that there is satisfactory convergence.

Estimated expected and experimental values of content of nutrient elements in target products

Table 1

No.	The content of nutrients in the target products by calculation, % mass			The content of nutrients in the target products by experiment, % mass			Discrepancies between calculated and experimental results, %		
	N,	P_2O_5 general	K_2O	N,	P_2O_5 general	K_2O	N,	P_2O_5 gener	K_2O
1	18.0	6.0	6.0	17.82	5.98	5.75	-0,18	-0,02	-0,25
2	16.0	7.0	7.0	15.96	6.75	6.65	-0,04	-0,25	-0,35
3	15.0	7.5	7.5	14.68	8.00	7.20	-0,32	+0,50	-0,30
4	10,0	9.0	9.0	9.57	9.74	8.65	-0,43	+0,74	-0,35

The results of chemical studies of the composition and properties of the obtained samples of target products are shown in Table 2. From the data in Table 2 it can be seen that obtained fertilizers, in contrast to ammonium nitrate, do not exhibit pronounced acidic properties and the total content of nutrients in them is 28-30 %. It was established that in the composition of the obtained fertilizer samples, the share of P_2O_5 of the digestible form is more than 85.71%.

Characteristics of production samples of ammonium nitrate of $N/P_2O_5/K_2O$ composition

Table 2

No.	Content of $N/P_2O_5/K_2O$ in target products, %/%/%	Content of nutrients in the products, %				Moisture of the products, %	Strength of granules of products, H/g	pH of 10% solution	Granulometric composition of target products, mass. %	
		N	P_2O_5общ	P_2O_5усв	K_2O				1-4мм	2-4 мм
1	10:10:10	10	9.0	7.25	9.0	0,17	66.15	6.65	89-91	78-80
2	15:7.5:7.5	15	7.5	6.43	7.5	0,16	62.47	6.55	92-98	81-88
3	16:7:7	16	7.0	6.00	7.0	0,15	60,65	6.50	93-98	83-89
4	18:6:6	18	6.0	5.14	6.0	0,17	58.68	6.47	93-98	84-89

Presented data show that from a mixture of ammonium nitrate solution and mineral-salt additives in the form of phosphate rock and potassium chloride it is possible to obtain a whole set of new fertilizer compositions with a nitrogen content of 10-18%, phosphorus in the form of P_2O_5 6% to 10% and potassium in the form of K_2O from 6% to 10% and with a pH of about 6.5. The latter shows that they, in comparison with ammonium nitrate with a pH of not more than 5.0, have improved consumer properties. Moreover, these results also clearly indicate their high agrochemical value, the opening of a real opportunity to expand the range of products. The obtained samples of fertilizer compositions are finely dispersed, friable powders of light gray color, readily soluble in water, with a moisture content in the range of 0.15% - 0.17% and the strength of the product granules 58.68-66.15 N/g.

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The obtained fertilizer of $N/P_2O_5/K_2O$ compositions were subjected to complex physical-chemical studies. The results of SEM, IR and X-ray fluorescence analysis of one of the obtained fertilizer samples with a composition of 16:7:7 are shown in Fig. 1-4. It was established that identical results are also characteristic of other varieties of the obtained fertilizers.

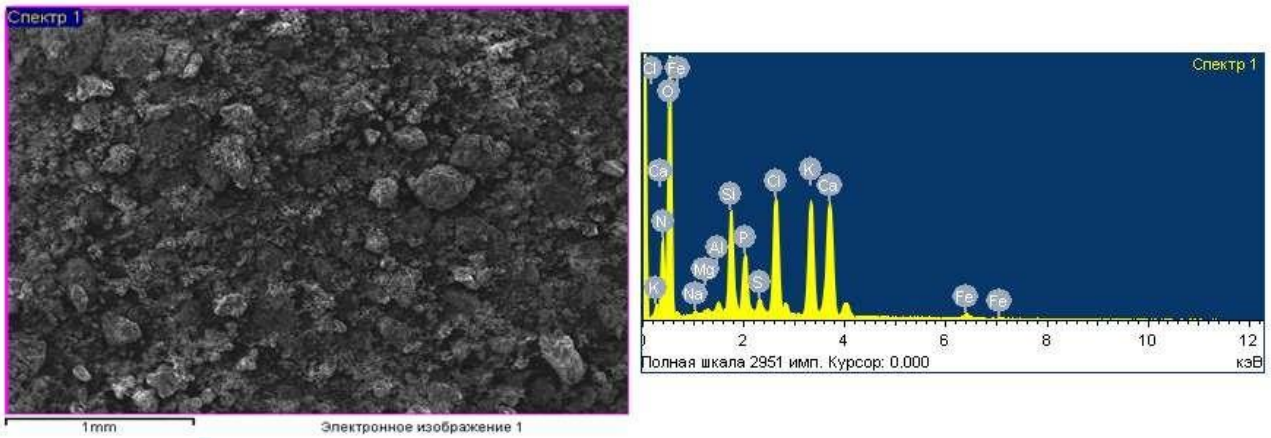

Fig. 1. Microstructure of ammonium nitrate of $N/P_2O_5/K_2O$ composition, equal to 16/7/7, obtained at a magnification of 40 times

According to the results of microscopic and spectral studies, it was established that the fertilizer sample contains 12 chemical elements in various quantitative ratios - N, O, Na, Mg, Al, Si, P, S, Cl, K, Ca, Fe. Their content in terms of oxides is: CaO - 9.18%, K_2O - 7.05%, P_2O_5 - 6.80%, SiO_2 - 5.22%, SO_3 - 1.20%, Fe_2O_3 - 0,92%, Na_2O - 0,35%, Al_2O_3 - 0,64%, MgO - 0,32%. Comparative analysis shows that chemical and physical-chemical studies of the contents of the main nutrient components, i.e nitrogen, and phosphorus pentoxide and potassium oxide give results that are close in value.

Elemental-weight composition of the new fertilizer of $N/P_2O_5/K_2O$ composition, equal to 16/7/7

Table 3

Element	Weight, %	Weight composition in terms of oxides, %
N	25.94	-
O	49.46	-
Na	0.26	0.35
Mg	0.19	0.32
Al	0.34	0.64
Si	2.28	5.22
P	3.18	6.80
S	0.48	1.20
Cl	4.82	-
K	5.85	7.05
Ca	6.56	9.18
Fe	0.64	0.92

X-ray phase analysis of the studied fertilizer sample (Fig. 1) was carried out on a DRON-3 diffractometer (general-purpose X-ray diffractometer) with a 1.5BSV29Cu X-ray tube with copper radiation and nickel filter [7]. In the X-ray diffraction pattern, the diffraction maxima with interplanar distances d/n=3.83-2.76-2.66-

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2.57Â refer to ammonium nitrate - NH_4NO_3, i.e. main phase. In addition, the diffraction maxima with d/n =2.71-2.23-1.92-1.75 Â refer to phthorrapatite - $Ca_5(PO_4)_3F$, interplanar distances d/n= 3.15-2.22-1.82 Â indicate the presence of KCl in the sample, quartzite SiO_2 is also observed with values d/n=4.24-3.34-2.29-1.81-1.53Â.

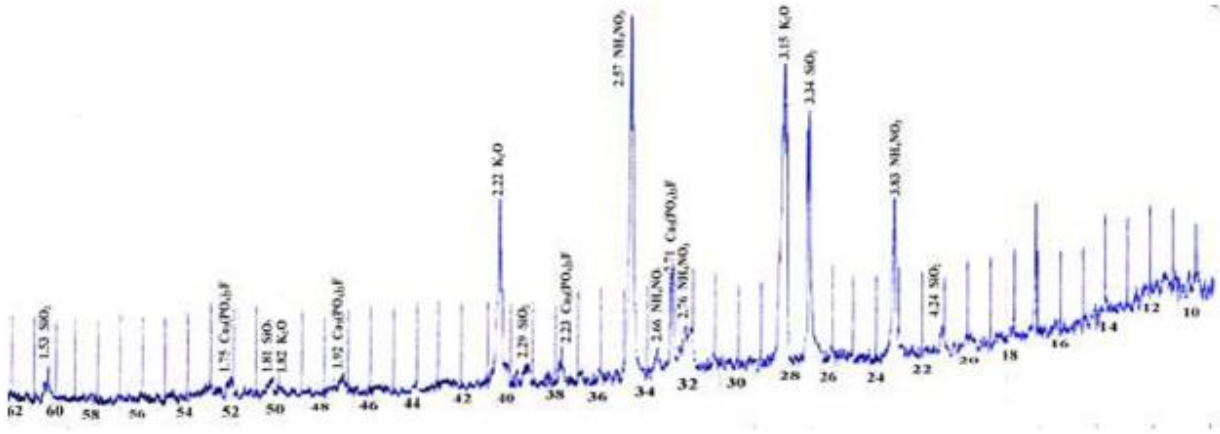

Fig. 2. X-ray diffraction pattern of ammonium nitrate of $N/P_2O_5/K_2O$ composition, equal to 16/7/7

In parallel with the X-ray phase analysis on the same sample, IR-spectral studies were carried out to clarify the structural features and establish the composition of impurities of the new fertilizer of 16/7/7 composition. IR spectra were recorded on a spectrometer

Interpretation of peaks in the result of IR analysis of ammonium nitrate of $N/P_2O_5/K_2O$ composition, equal to 16/7/7

Table 4

No.	Peak	Intensity	Corr. Intensity	Base (H)	Base (L)	Ares	Core. Area
1	547.78	94.763	3.587	567.07	536.21	0,505	0,238
2	590,22	95.322	1.804	601.79	576.64	0,390	0,097
3	713.66	82.805	9.049	725.23	659.66	2.537	0,523
4	825.53	71.792	17.153	837.11	740,67	5.919	1.530
5	933.55	79.418	2.985	960,55	840,96	10,135	1.378
6	1041.56	70,597	11.178	1049.28	987.55	6.494	1.097
7	1099.43	76.240	1.133	1107.14	1053.13	5.732	0,472
8	1138.00	75.209	0,252	1141.86	1111.00	3.703	0,020
9	1280,73	61.573	15.546	1381.03	1145.72	37.428	10,548
10	1408.04	75.828	6.755	1496.76	1384.89	7.617	1.439
11	1712.79	98.086	1.094	1724.36	1674.21	0,246	0,118
12	1755.22	96.905	2.614	1782.23	1735.93	0,246	0,171
13	2330,01	101.205	0,597	2341.58	2276.00	-0,648	0,055
14	2364.73	101.274	0,173	2391.73	2360,87	-0,266	-0,008
15	2862.36	96.368	0,499	2870,08	2758.21	0,676	0,114
16	3059.10	89.679	3.087	3109.25	2939.52	6.181	1.290
17	3194.12	89.616	0,134	3197.98	3136.25	2.567	0,002
18	3240,41	88.228	4.897	3425.58	3201.83	0,657	-0,128

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IR spectrograms (Fig. 2) show the spectra of the sample under study. In Fig. 5 and 6 it can be seen that IR spectra of the studied sample of the target product are characterized by intense absorption bands at 1288 cm^{-1}, 825 cm^{-1}, 1755 cm^{-1}, and 2334 cm^{-1}, which indicates the presence of functional group of NO_3 type. There are also intense absorption bands at 3000 cm^{-1}, 3450 cm^{-1}, 1650 cm^{-1}, which is typical for OH group. Less intense absorption spectra 1423 cm^{-1}, 1458 cm^{-1}, are characteristic for phosphorus compounds with the P=O group.

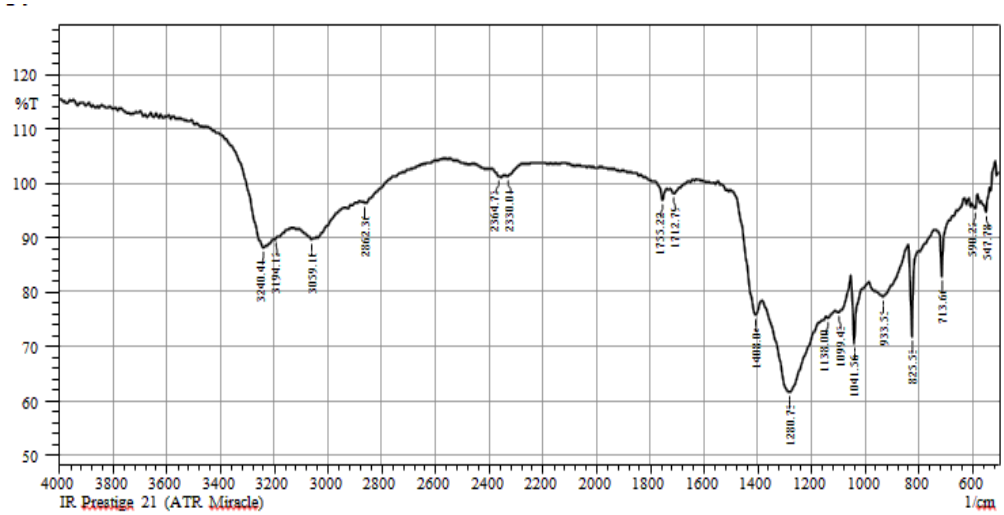

Fig. 3. Result of IR analysis of ammonium nitrate of $N/P_2O_5/K_2O$ composition, equal to 16/7/7

Based on the data in Fig. 1-3 and tables 2 and 3, it can be concluded that the compositions obtained based on solution of a primary evaporated ammoniated solution of nitric acid, phosphate rock, potassium chloride and modifying mineral additives are essentially new complex fertilizer mixtures, where the content of fertilizing components N, P_2O_5 and K_2O can be changed in a wide range – from 10% to 18% for nitrogen and from 6% to 9%, respectively, for P_2O_5 and K_2O. At the same time, the total content of the main nutrients in them will be 28% - 30%, which indicates their high agrochemical value. Unlike nitrogen-contained ones, the new fertilizer compositions contain a wide variety of other fertilizing elements, i.e. potassium, sulfur, calcium, magnesium, iron in macro and micro amounts. Of these, as is known, potassium plays the most important physiological role in carbohydrate and protein metabolism of plants, improves the conditions for the use of nitrogen in the ammonia form. Potassium is a powerful factor in the development of plants, promotes the accumulation of sugars in cell sap, increases their frost resistance, and improves the quality of agricultural products. With a lack of potassium, fungal diseases affect plants. Phosphorus accelerates the development of plants, stimulates the processes of fertilization, formation and ripening of fruits, increases productivity and quality of products. Sulfur is of great importance in protein metabolism and in redox processes, affects the formation of chlorophyll. Lack of sulfur in plants disrupts metabolic processes and protein synthesis, which reduces plant productivity and fruit quality. Calcium participates in the protein and carbohydrate metabolism of plants, has a positive effect on the growth of their roots. Without calcium, the destruction of plant root cells takes place. Magnesium participates in photosynthesis, is a part of chlorophyll. Lack of magnesium leads to a decrease in crop yields. Iron participates in redox processes, is a part of chlorophyll, and plays an important role in the formation of respiratory enzymes.

Conclusions

Thereby, based on the results obtained in the practical implementation of targeted research in laboratory conditions, we can conclude that:

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- based on aqueous solution of production ammonium nitrate with a concentration of 64-71%, the concentration and temperature parameters of which correspond to the indicators of the technological solution of the existing production of ammonium nitrate, obtained after the first stage of evaporation of phosphate rock and production potassium chloride, it is possible to obtain a fairly wide range of fertilizers;
- the obtained target products of $N/P_2O_5/K_2O$ compositions are stabilized complex fertilizer compositions with a total content of nitrogen, phosphorus pentoxide and potassium oxide from 28% at a minimum, and up to 30% at a maximum;
- it was established that the obtained samples of fertilizer compositions are finely dispersed, crumbly powders from light gray to white, readily soluble in water, with a moisture content in the range of 0.15-0.17 % and pH 6.47-6.65. During storage in the open air for several months, they do not show a tendency to caking and clumping, retaining unchanged both the color and all the originally established physical-chemical properties.
- it was established that all samples of newly synthesized nitrogen-phosphorus-potassium fertilizers are easily granulated, forming granules with an average static strength of the order of 58.65–66.15 N/g. All this indicates to their rather satisfactory commercial quality.

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