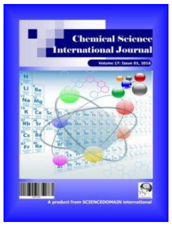

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Concentrated Np- and Npk-Fertilizers Based on Kyzylkum Evaporated Phosphoric Acid, Carbamide and Potassium Chloride

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Authors' contributions

This work was carried out in collaboration among all authors. Author TS conducted the experiments and obtained data. Author AUK analyzed data obtained and translated the paper. Author NSS is supervisor and discussed the manuscript. Author SAR wrote the manuscript. Author BBM provided with references. All authors read and approved the final manuscript.

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ABSTRACT

In the paper the processes of carboammophos and carboammophos potassium preparation based on the ammonization of the samples by evaporated wet phosphoric acid (WPA) (35.92; 40.85; 46.41; 51.07% P_2O_5) to pH = 5.3 (to obtain ammophos pulp) and pH = 7.0 (to obtain diammophos pulp) with subsequent addition of 70% solution of urea and crystalline potassium chloride (60% K_2O) were studied. Moreover, for urea-phosphate, weight ratio of the N: P_2O_5: K_2O ranged from 1: 0.5 to 1: 1: 1 for the N: P_2O_5: K_2O urea-phosphate-potassium from 1: 0.7: 0.3 to 1: 1: 1. To avoid loss of ammonia, the drying of NP- and NPK slurry based on diammonium phosphate (DAP) were produced not higher than 60 °C, and monoammonium phosphate (MAP) - first at 60°C, then at 100°C to constant weight (less than 1% H_2O). It is shown that on the basis of both MAP and DAP slurry are obtaining, samples of urea-phosphate similar in composition and properties. And all brands of urea-phosphate-potassium contain a high concentration of nutrients (up to 19.7% N.

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19.7% P_2O_5 and 19.7% K_2O). Phosphorus in them is in a form digestible for plants. The strength of both NPK and NPK fertilizer granules satisfies the requirements of agriculture. Such fertilizers in agriculture are in great demand

Experimental Design: Determination of total,l digestible, and water soluble forms of phosphorus (P_2O_5total, $P_2O_{5deg.}$ P_2O_{5water}) was performed on KFK-3 (λ= 440 nm) as phosphorus-vanadium-molybdenum complex. This method is based on measuring the light transmission of yellow phosphorus-vanadium-molybdenum complex relative to the reference solution containing a certain amount of phosphates. Slurry pH was adjusted and determined by potentiometric method on ionometer I-130M (Russia). The mass was cooled, and then scattered by the size of the particles. Granules with a size of 2-3 mm were subjected to strength testing. The static strength of the granules was determined according to State standard 21560.2-82. This method based on crushing the granules using for that specified weights on scale called MIP 10-1 (Russia), which indicate kgf/cm^2 per granule. Further dried granules of the fertilizer were performed chemical analysis. Digestible forms of P_2O_5 were determined by solubility in both 2% citric acid and 0.2 M solution of Trilon B (EDTA). The nitrogen content in the products was determined by Kjeldahl — distillation of ammonia in an alkaline medium with Devard alloy followed by titration of 0.1N NaOH.

Findings: Preparation process consists of as follow:

First slurry of ammophos and diammophos were prepared by neutralization of evaporated WPA containing 35.92; 40.85; 46.41; 51.07% P_2O_5 to pH = 5.3 (to obtain ammophos pulp) and pH = 7.0 to obtain diammophos pulp; Second to obtain NP fertilizer 70% solution of carbamide was added to MAP and DAP slurry at 60° C followed by stirring thorough. Then NP slurry was dried not higher than 100 °C for MAP and not higher than 60 °C for DAP, respectively; Third to prepare NPK fertilizer 70% solution of urea and crystalline potassium chloride (60% K_2O) were added to MAP and DAP slurries. Next NPK slurry was dried not higher than 100 °C for MAP and not higher than 60 °C for DAP, respectively; Fourth NP and NPK fertilizer were tested on static strength accordingly above mentioned study design using State standard 21560.2-82; Fifth dried granules NP and NPK fertilizers were analyzed on various form of P_2O_5 including N and K_2O. The latter was evaluated by calculation from difference N and P_2O_5 accordingly weight ratio N:K and N:P_2O_5:K_2O equal to 1:0.5; 1:0.7; 1:1 and 1:0.3:1; 1:0.5:1; 1:1:1 respectively.

Keywords: Evaporated phosphoric acid; ammonization; mono-and diammonium phosphate slurry; urea-phosphate; urea-phosphate-potassium; composition; strength of granules.

1. INTRODUCTION

Due to the inability of the plant to obtain nitrogen, phosphorus and potassium from the soil, it is more preferable to jointly make these macroelements by using them as complex fertilizers. A high concentration of nutrients (N, P_2O_5, K_2O) in complex fertilizers, amounting to about 50%, can significantly reduce (compared to simple fertilizers) the cost of transportation, storage and application to the soil. At the same time, the scientifically based norms of mineral fertilizers for the main crops require the introduction of 150–200 $kg{\cdot}ha^{-1}$ of N, 100–120 $kg{\cdot}ha^{-1}$ of P_2O_5 and 50 $kg{\cdot}ha^{-1}$ of K_2O for grain crops for irrigation, and 215–240 for medium-fiber cotton $kg{\cdot}ha^{-1}$ N, 145-165 $kg{\cdot}ha^{-1}$ P_2O_5 and 95-110 $kg{\cdot}ha^{-1}$ K_2O, for vegetable crops 145-200 $kg{\cdot}ha^{-1}$ N, 100-110 $kg{\cdot}ha^{-1}$ P_2O_5 and 70-75 $kg{\cdot}ha^{-1}$ K_2O, under rice 200-220 $kg{\cdot}ha^{-1}$ N, 140-145 $kg{\cdot}ha^{-1}$ P_2O_5 and 150-180 $kg{\cdot}ha^{-1}$ K_2O [1].

In the production of complex NP-and NPK-fertilizers usually used evoporated phosphoric acid with a concentration of 45-55% P_2O_5 [2-4]. Such fertilizers are obtained by ammonization of concentrated phosphoric acid with the addition of nitrogen and potassium components, followed by processing of the resulting melt into a granular product. Great interest is paid to the processes of obtaining concentrated complex fertilizers such as urea-phosphate (26.10% N and 17.10% P_2O_{5deg}. including 25.20% P_2O_{5water}) and urea-phosphate-potassium (17.10% N, 17.10% P_2O_5, 17.10% K_2O) using ammophos, carbamide and potassium chloride. In technical requirements (Specification 6-08-285–74) for urea-phosphate and urea-phosphate-potassium provide for the same crush strength of their granules - not less than 2.0 MPa (20 kgf / cm^2), grain sizes 1-4 mm not less than 90% and granules less than 1 mm no more than 3% in the absence of sizes 6 mm [5]. As shown, the introduction of urea into ammophos pulp leads to adduct formation, which leads to an increase in the content of slow-acting forms of nitrogen in the product, as well as an increase in the proportion of P_2O_5 in water-soluble form.

The processing of low-grade phosphorites, such as Karatau (24.5% P_2O_5) into concentrated compound fertilizers presents a number of difficulties compared to the processing of the Khibiny apatite concentrate (39.4% P_2O_5). This is primarily due to the presence of a large amount of impurities in the phosphorites, which form an insoluble compound during sulfuric acid extraction. Especially magnesium compounds (up to 3.0% MgO) significantly impair the ability of phosphoric acids to evaporate, which also limits their ability to be processed into fertilizers. It should be noted that in the apatite concentrate the MgO content does not exceed 0.03%. At relatively high temperatures (above 80°C) magnesium silicate fluoride decomposes to form fine magnesium fluoride crystals. In this case, the viscosity of the acid greatly increases, and when cooled, it can completely lose its mobility. Because of this, evaporation of phosphoric acids from Karatau phosphorites is carried out, as a rule, to a concentration of P_2O_5 not higher than 34-37% [6]. The addition of active silica (for example, silica gel) to the evaporated acid facilitates the chemical interaction of MgF_2 with phosphoric acid, since the reaction takes place at elevated temperatures:

$$2MgF_2 + 4H_3PO_4 + SiO_2 = 2Mg\ (H_2PO_4)_2 + SiF_4 + 2H_2O,$$

As a result of which fluorine is removed in the form of SiF_4 and soluble monomagnesium phosphate is formed. This allows to evaporate the acid to a concentration of 50-53% P_2O_5 without its subsequent thickening [7].

2. MATERIALS AND METHODS

In Uzbekistan, there is such a streamlined production of phosphoric acid from washed calcined phosconcentrate (26% P_2O_5) obtained in the dihydrate method at JSC “Ammophos-Maxam” and containing (wt.%): 18.14 P_2O_5; 0.20 CaO; 0.28 MgO; 0.73 Al_2O_3; 0.46 Fe_2O_3; 1.27 SO_3; 0.89 F. In contrast to Karatau phosphorites, MgO is less than 1.85% in burned calcined phoconcentrate. This suggests that WPA from washed calcined phosphate concentrate can be easily evaporated to a concentration of 50% P_2O_5 without any special technological difficulties in standard vacuum evaporation plants widely used in industry.

In the present work, we studied the possibility of obtaining urea-phosphate and urea-phosphate-potassium on the basis of evaporated WPA. Before evaporation, the initial WPA (18.14% P_2O_5) was desulfurized using with high-carbonate phosphorite powder. At the same time, the optimum norm of the phosphorite for the sulphur free of WPA was 100% of stoichiometry for the formation of $CaSO_4$. The degree of its sulphur free amounted to 72.56% [8]. It should be noted that during the evaporation of sulphur free WPA up to a concentration of 57% P_2O_5, its thickening was not observed, and it was in a fluid state. After completion of the evaporation, samples of concentrated WPA were settled for 24 hours. Then the contents were clarified by the method of decanting. The concentration of samples of clarified and purified acids was about 35.92; 40.85; 46.41 and 51.07% P_2O_5. And they served as the starting components for the preparation of MAP and DAP. For this, neutralization of evaporated WPA was carried out with gaseous ammonia at a temperature of 80°C to a pH from 4.5 to 5.3 (for the preparation of MAP) and from 5.5 to 8.0 (for the preparation of DAP) [9].

In order to obtain a balanced NP-fertilizer – urea-phosphate, we added 70% aqueous solution of urea to the MAP slurry (at pH = 5.3) and DAP (at pH = 7.0) before their granulation, at a weight ratio of N: P_2O_5 = 1: (0.5- 1). The duration of mixing the starting components was 15 minutes. And in the case of the production of NPK-fertilizers – urea-phosphate-potassium, after taking a 15-minute mixing, a portion of potassium chloride (60% K_2O) was added to the urea-phosphate-slurry. At the same time, the weight ratio N: P_2O_5: K_2O =1:(0.7-1): (0.3: 1) was varied. All these ratios of nutritional components are considered the most in demand agriculture. The process of mixing NPK-slurry lasted another 15 minutes. In all experiments, the temperature was maintained at 70-80°C. To obtain finished products, granulation of both NP- and NP-slurry was carried out in the process of drying by the method of vigorous stirring and pelleting. In order to avoid loss of ammonia, DAP-based pulp was dried not higher than 60°C, and MAP was first dried at 60°C, then at 100°C to a constant weight (not more than 1% H_2O). As the melt cooled, solid granules of a round shape were formed. The mass was cooled, and then scattered by the size of the particles. Granules with a size of 2-3 mm were subjected to strength testing, after which their chemical analysis was performed [10]. Digestible forms of P_2O_5 were determined by solubility in both 2% citric acid and 0.2 M solution of Trilon B (EDTA). The nitrogen content in the products was determined by Kjeldahl — distillation of ammonia in an alkaline medium with Devard alloy followed by titration [11]. The static strength of the granules was determined according to State standard 21560.2-82 [12].

Static strength was calculated by equation 1 presented below (kg/granule)

$$X = \frac{P_1 + P_2 + P_3 + \cdots + P_{20}}{20} \quad (1)$$

where, P_1, P_2, P_3, …, P_{20} is crushing force of granule (кг).

Then data obtained was transferred into Y (kgf /cm^2) using equation 2 as follow:

$$Y = \frac{\sum_{i=1}^{20} P_i}{20 \cdot S} = \frac{\sum_{i=1}^{20} P_i}{\frac{20\pi d_{av.}^2}{4}} = 0.063 \frac{\sum_{i=1}^{20} P_i}{d_{av.}^2}$$

Here,

P_i – force, which is necessary to destroy each granule (kgf);

S – granule sectional, cm^2;

$d_{av.}$ – average diameter of granule, cm.

3. RESULTS AND DISCUSSION

From Tables 1 and 2 it can be seen that the increase in the weight ratio N: P_2O_5 from 1: 0.5 to 1: 1, that is, a decrease in the mass fraction of urea in the slurry, although it leads to a decrease in the nitrogen content in the products, but to an increase in the total content of P_2O_5, without affecting at the same time on the relative content of digestible and aqueous forms of phosphorus. And the pH of the slurry does not have a strong influence on the change in these indicators. So, for a phosphoric acid concentration of 40.85% P_2O_5 with a ratio of N: P_2O_5 = 1: 0.5, the resulting product contains 34.89% N, 17.42% P_2O_{5total}, relation of digestible P_2O_5 to total P_2O_5 is presented as P_2O_{5deg}.by citric acid : $P_2O_{5\ total}$ = 96.04%, P_2O_{5deg}.by EDTA : P_2O_{5total} = 94.02%, P_2O_{5water}. : P_2O_{5total} = 90.87%, and with N: P_2O_5 = 1:1 - 28.01% N, 28.02% P_2O_{5total}, P_2O_{5deg}.by citric acid : P_2O_{5total} = 96.57%, P_2O_{5deg}.by EDTA : P_2O_{5total} = 94.72%, P_2O_{5water} : P_2O_{5total} = 91.43% (Table 1).

Table 1. Composition and strength of urea-phosphate's granul models based on ammophos and carbamide slurry (pH = 5.3)

Weight correlation N : P_2O_5	N, %	P_2O_{5total}, %	P_2O_{5deg} / P_2O_{5total} by 2 %-citric acid %	$P_2O_{5deg.}$ / P_2O_{5total} by 0.2 M EDTA, %	P_2O_{5water} / P_2O_{5total} %	Strength of granules MPa
Based on the WPA with concentration 35.92% P_2O_5						
1 : 0.5	34.65	17.31	95.96	93.99	90.53	3.21
1 : 0.7	31.11	22.05	96.01	94.24	90.74	3.29
1 : 1	27.72	27.73	96.21	94.33	90.77	3.48
Based on the WPA with concentration 40.85% P_2O_5						
1 : 0.5	34.89	17.42	96.04	94.02	90.87	3.37
1 : 0.7	31.76	22.21	96.13	94.68	90.95	3.40
1 : 1	28.01	28.02	96.57	94.72	91.43	3.51
Based on the WPA with concentration 46.41% P_2O_5						
1 : 0.5	34.93	17.46	96.68	94.96	93.07	3.14
1 : 0.7	31.86	22.27	97.12	95.19	93.13	3.16
1 : 1	28.09	28.08	97.25	95.23	93.23	3.27
Based on the WPA with concentration 51.07% P_2O_5						
1 : 0.5	35.09	17.55	97.15	95.21	93.11	3.07
1 : 0.7	32.04	22.42	97.32	95.27	93.22	3.12
1 : 1	28.27	28.36	97.32	95.70	93.51	3.15

Urea-phosphate with such indicators is in great demand. A similar pattern is observed for the remaining concentrations of WPA. It should be noted that the concentration of WPA practically does not impact on the composition of the product, only its increase slightly increases the relative content of digestible and water-soluble forms of phosphorus, while reducing the strength of its granules. Depending on the concentration of WPA and the ratio N: P_2O_5, the strength of granules of urea-phosphate is within 3.07-3.51 MPa.

Whereas, close in terms of their composition and properties, NP-fertilizers are obtained on the basis of DAP and urea slurry (Table 2). Thus, at the studied WPA concentrations (35.92-51.07% P_2O_5) and N: P_2O_5 ratios (1: 0.5-1), the obtained samples of urea-phosphate are characterized by the following parameters: 29.21-35.99% N,17.89-29.52% P_2O_{5total}, $P_2O_{5deg.}$ by citric acid : P_2O_{5total} = 96.42-97.36%, $P_2O_{5deg.}$ by EDTA : P_2O_{5total} = 94.13-96.21%, P_2O_{5water} : P_2O_{5total} = 92.57-95.12% with the sum of nutrients equal to 53.64-59.05% and the strength of the granules ranged 2.94-3.42 MPa. The maximum strength of the granules (3.42 MPa) is obtained when the acid concentration is 40.85% P_2O_5 and the ratio N: P_2O_5 = 1: 1. In any event, all the fertilizers prepared in terms of the strength of the granules meet the requirements of agriculture.

Table 3 shows the composition of urea-phosphate-potassium on the basis of MAP slurry (at pH = 5.3), urea and potassium chloride, and in Table. 4 on the basis of DAP slurry (at pH = 5.3), urea and potassium chloride with weight ratios N: P_2O_5: K_2O from 1: 0.7: 0.3 to 1: 1: 1. The overall picture of the results of the interaction of MAP and DAP with nitrogen and potassium additives is similar. Only the absolute values of the components in the products differ only slightly. It also shows that the concentration of evaporated WPA does not affect the composition of the finished product. The main parameter affecting the process is the ratio of N: P_2O_5: K_2O. From the data it follows that the more potassium chloride is introduced into the urea-phosphate-potassium slurry, the higher the strength of the product granules. The highest strength of granules (4.42 MPa) is observed at an acid concentration of 40.85% P_2O_5 and a ratio of N: P_2O_5: K_2O = 1: 1: 1 (Table 3). For example, when using MAP slurry and an acid concentration of 35.92% P_2O_5 with a change in the ratio N: P_2O_5: K_2O from 1: 0.7: 0.3 to 1: 1: 1, the composition of the product changes (wt.%): From 23.04 to 18.95 N, 16.13 to 18.96 $P_2O_{5total,}$ from 7.14 to 18.97 K_2O, P_2O_{5deg}. by citric acid : P_2O_{5total} from 95.72 to 97.26, $P_2O_{5deg.}$ by EDTA : P_2O_{5total} from 95.10 to 95.57, P_2O_{5water} : P_2O_{5total} from 93.80 to 95.20 and the strength of granules from 3.34 to 4.32 MPa. At an acid concentration of 51.07% P_2O_5, these figures range from

Table 2. Composition and strength of granul models carboammoposhos, obtained based on diammophos pulps and carbomide (pH = 7.0)

Weight correlation N : P_2O_5	N, %	P_2O_{5total}, %	P_2O_{5deg} / P_2O_{5total} by 2 %-citric acid %	$P_2O_{5deg.}$ / P_2O_{5total} by 0.2 M EDTA, %	P_2O_{5water} / P_2O_{5total} %	Strength of granules MPa
Based on the WPA with concentration 35.92% P_2O_5						
1 : 0.5	35.75	17.89	96.42	94.13	92.57	3.11
1 : 0.7	32.85	22.09	96.46	94.48	94.07	3.13
1 : 1	29.21	29.23	96.51	94.53	94.12	3.38
Based on the WPA with concentration 40.85% P_2O_5						
1 : 0.5	35.81	17.90	96.54	94.19	92.91	3.25
1 : 0.7	32.88	23.05	96.57	94.75	94.19	3.30
1 : 1	29.25	29.26	96.62	94.77	94.22	3.42
Based on the WPA with concentration 46.41% P_2O_5						
1 : 0.5	35.98	17.98	97.11	95.16	93.16	3.16
1 : 0.7	32.97	23.14	97.19	95.25	94.25	3.17
1 : 1	29.51	29.50	97.28	95.29	94.31	3.22
Based on the WPA with concentration 51.07% P_2O_5						
1 : 0.5	35.99	18.00	97.28	96.00	93.89	2.84
1 : 0.7	33.01	23.15	97.36	96.19	95.08	2.86
1 : 1	29.53	29.52	97.36	96.21	95.12	2.94

Table 3. Composition and strength of urea-phosphate-potassium's granul models based on ammophos and carbamide slurry (pH = 5.3)

Weight correlation $N : P_2O_5 : K_2O$	N, %	P_2O_{5total}, %	K_2O, %	$\frac{P_2O_{5deg}}{P_2O_{5total}}$ by 2 %-citric acid %	$\frac{P_2O_{5deg.}}{P_2O_{5total}}$ by 0.2 M EDTA, %	$\frac{P_2O_{5water}}{P_2O_{5total}}$ %	Strength of granules MPa
Based on the WPA with concentration 35.92% P_2O_5							
1 : 0.7 : 0.3	23.04	16.13	7.14	95.72	95.10	93.80	3.34
1 : 0.7 : 0.5	23.01	16.16	11.55	95.79	95.17	94.12	4.23
1 : 1 : 1	18.95	18.96	18.97	97.26	95.57	95.20	4.32
Based on the WPA with concentration 40.85% P_2O_5							
1 : 0.7 : 0.3	23.22	16.30	7.20	95.83	95.15	93.87	3.94
1 : 0.7 : 0.5	23.17	16.31	11.59	96.69	95.22	94.18	4.37
1 : 1 : 1	19.07	19.08	19.09	97.38	95.60	95.28	4.42
Based on the WPA with concentration 46.41% P_2O_5							
1 : 0.7 : 0.3	23.27	16.34	7.27	96.08	95.22	93.88	3.29
1 : 0.7 : 0.5	23.21	16.35	11.63	96.76	95.29	94.19	3.30
1 : 1 : 1	19.11	19.12	19.10	97.44	95.76	95.29	4.10
Based on the WPA with concentration 51.07% P_2O_5							
1 : 0.7 : 0.3	23.41	16.39	7.33	96.16	95.24	94.14	3.07
1 : 0.7 : 0.5	23.39	16.42	11.67	96.83	95.31	94.21	3.00
1 : 1 : 1	19.22	19.21	19.20	97.55	95.84	95.37	4.04

Table 4. Composition and strength of urea-phosphate-potassium granul models based on ammophos and carbamide slurry (pH = 7.0)

Weight correlation $N : P_2O_5 : K_2O$	N, %	P_2O_{5total}, %	K_2O, %	$\frac{P_2O_{5deg}}{P_2O_{5total}}$ by 2 %-citric acid %	$\frac{P_2O_{5deg.}}{P_2O_{5total}}$ by 0.2 M EDTA, %	$\frac{P_2O_{5water}}{P_2O_{5total}}$ %	Strength of granules MPa
Based on the WPA with concentration 35.92% P_2O_5							
1 : 0.7 : 0.3	23.21	16.30	7.22	95.89	95.28	94.11	3.21
1 : 0.7 : 0.5	23.19	16.33	11.63	96.75	95.34	94.43	3.22
1 : 1 : 1	19.64	19.65	19.63	97.81	95.78	95.27	3.29
Based on the WPA with concentration 40.85% P_2O_5							
1 : 0.7 : 0.3	23.28	16.34	7.31	95.96	95.34	94.19	3.31
1 : 0.7 : 0.5	23.27	16.37	11.66	96.82	95.42	94.50	3.33
1 : 1 : 1	19.66	19.67	19.65	97.97	95.73	95.37	3.57
Based on the WPA with concentration 46.41% P_2O_5							
1 : 0.7 : 0.3	23.33	16.37	7.39	96.76	96.15	95.05	3.18
1 : 0.7 : 0.5	23.31	16.39	11.70	96.83	96.16	95.36	3.19
1 : 1 : 1	19.67	19.68	19.69	98.12	97.31	96.44	3.25
Based on the WPA with concentration 51.07% P_2O_5							
1 : 0.7 : 0.3	23.43	16.40	7.41	96.89	96.28	95.30	2.91
1 : 0.7 : 0.5	23.42	16.44	11.72	96.90	96.35	95.38	2.93
1 : 1 : 1	19.76	19.75	19.74	98.13	96.61	96.25	3.01

23.41 to 19.22%, from 16.39 to 19.21%, from 7.33 to 19.20%, from 96.16 to 97.55%, from 95.24 to 95.84%, from 94.14 to 95.37% and from 3.07 to 4.04 MPa, respectively. In them, the sum of nutrient components (N + P_2O_5 + K2O) ranges from 47.13-57.63%.

When using DAP slurry, a similar composition of NPK-fertilizers is obtained, as in the case of MAP (Table 4), but with relatively low granule strength (2.91-3.57 MPa). In fact, that all brands of urea-phosphate-potassium contain a high concentration of nutrients (nitrogen, phosphorus and potassium). Phosphorus in them is in a form digestible for plants. The strength of the granules of both NP- and NPK-fertilizers satisfies the requirements of agriculture (must be at least 2 MPa).

Improving strength NP and NPK fertilizers using urea is much stronger than NPK based on ammonium nitrate [13]. Agglomeration process in presence with urea promotes increase in yield of product. Although there is approach for preparation of a double-coated slow-release NPK compound fertilizer possessing 8.47% K_2O, 8.51% P_2O_5 and 15.77% N but they require poly(acrylic acid)/diatomite as binders [14].

Thus, the results of the conducted studies show the possibility of using equipment to produce concentrated NP and NPK fertilizers based on WPA, ammonia, urea and potassium chloride based on the processing of washed calcined phosconcentrate containing 26% P_2O_5. In this regard, JSC "Ammophos-Maxam" has such high-performance facilities, such as vacuum evaporators, speed ammonizator evaporator (SAE) that is, high-speed ammoniation-evaporator, mixing reactors, and DGD-drum granulator-dryer, that is, everything necessary for the production of urea-phosphate and urea-phosphate-potassium.

4. CONCLUSION

1. It was established that the concentration of phosphoric acid and the pH of ammoniated phosphate slurry practically does not affect the composition of urea-phosphate. An increase in the mass fraction of urea in the slurry, on the one hand, increases the nitrogen content in the product, on the other hand, reduces the total P_2O_5 content, without affecting the relative contents of digestible and aqueous forms of phosphorus.
2. Using the slurry of both MAP and DAP including urea and chloride, NPK-fertilizers similar in composition are obtained, containing high concentrations of nutrients (up to 19.7% nitrogen, 19.7% phosphorus and 19.7% potassium). In terms of composition and properties, they meet the requirements of Specification 6-08-285–74 for an urea-phosphate-potassium fertilizer.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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