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Studying the influence of technological factors on the process of ammoniation of the carbamide sulfate-water system.

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Annotation. In this work, the possibility of obtaining water-soluble, highly effective, and environmentally safe fertilizers by ammoniating an 80% solution of urea sulfate containing 2CO (NH2) 2·H2SO4 with ammonia was studied. Ammonization was carried out at various pH values, and the chemical composition, physicochemical, and rheological properties of the formed liquid and solid phases were analyzed. The obtained results showed the possibility of developing agrochemically balanced fertilizers based on urea-sulfate.

Keywords: urea sulfate, ammoniation, ammonia, nitrogen-sulfur fertilizers, pH effect, physicochemical properties, rheological properties

Currently, one of the urgent scientific and practical tasks is the efficient use of mineral fertilizers in agricultural production, reducing nitrogen losses, and enhancing the uptake of nutrients by plants. Although urea is widely used among nitrogen fertilizers due to its high nitrogen content and versatility, its rapid hydrolysis in soil and liquid environments under the influence of the urease enzyme leads to ammonia volatilization, nitrogen loss, and environmental pollution [1,2].

Literature indicates that under unfavorable chemical and temperature conditions, urea decomposition results in the formation of biuret, cyanuric acid, and other phytotoxic compounds. This phenomenon reduces fertilizer efficacy and adversely affects plant development. Experimental studies have demonstrated the negative impact of biuret on plant growth and internal nitrogen metabolism [3].

Methods for processing urea in an acidic environment to stabilize it and reduce nitrogen loss are extensively documented in scientific literature. Specifically, it has been demonstrated that in an acidic environment, the conversion of ammonia to ammonium ions leads to decreased volatility and improved nitrogen retention [2].

The formation of ammonium sulfate resulting from the interaction of urea with sulfuric acid, as well as the kinetic and thermal characteristics of this process, were investigated using mathematical modeling in the works of Beltrán-Prieto and Kolomazník. The authors demonstrated that the reaction rate in the urea-sulfate system depends on the excess amount of acid, the process occurs at relatively low temperatures, and technological safety is ensured. This indicates the potential for using urea-sulfate complexes as a highly effective and environmentally safe form of fertilizer [4].

The importance of ammonium sulfate and other sulfur-containing fertilizers in plant nutrition, as well as the role of sulfur in protein synthesis and efficient nitrogen utilization, has been highlighted in numerous studies. Research has shown that in cases of sulfur deficiency, plants experience reduced nitrogen assimilation, disruption of the N:S ratio, and decreased crop yield [5].

At the same time, the literature lacks a sufficiently deep and systematic study of the physicochemical stability of urea-sulfate complexes, their transformation in soil environments, and the technological foundations for their application as slow-release fertilizers. In particular, research on the scientific basis and practical effectiveness of the integrated use of urea-sulfate systems as sources of nitrogen and sulfur remains limited [4, 5].

Therefore, by ammoniating an 80% urea sulfate solution ($2CO(NH_2)_2 \cdot H_2SO_4$) with ammonia, water-soluble, highly effective, environmentally safe, and agrochemically balanced fertilizers were obtained.

Initially, an 80% solution of urea sulfate (US) was prepared. The chemical composition, physicochemical and rheological properties of the liquid and solid phases formed after ammoniation of this solution with ammonia at various pH values were studied (Tables 1, 2).

1. When ammonizing a US solution with ammonia to a pH of 2.05, the process proceeded with the separation of the solid phase, and the solid phase was filtered to separate it from the liquid phase. The filtration rate was 1808 kg/m2·s, and the L:S phase ratio was 36.11:63.89.

The rheological properties of the liquid phase at 20°C were studied. It was found that its viscosity is 6.5709 mm2/s and its density is 1.3031 g/cm3. Temperature crystallization 23°C.

Table 1

Physicochemical and rheological properties of the liquid phase formed after ammoniation of an 80% US solution

№	pH	Reological properties at 20°C		Filtration rate, kg/m^2·s	S:L	Crystallization temperature of the solution, t, °C
		Viscosity, ν, mm^2/s	Density, ρ, g/cm^3			
1	2,05	6,5709	1,3031	1808	36,11:63,89	23
2	4,10	-	-	3582	66,71:33,29	-
3	6,04	3,4631	1,2457	8201	56,53:43,47	23
4	7,17	-	-	3827	45,37:54,63	-

Table 2

Chemical composition of the solid and liquid phases formed after ammonization of an 80% solution of US, %.

№	pH	N,%			SO_3,%
		total	amide.	amm.	
Solid phase					
1	2,05	21,68	16,21	5,48	47,85
2	4,10	26,69	15,90	10,79	29,15
3	6,04	28,42	17,20	11,22	28,13
4	7,17	28,73	16,68	12,05	28,87

Liquid phase					
1	2,05	37,67	27,13	10,54	23,73
2	4,10	46,99	35,64	11,35	36,03
3	6,04	40,04	29,31	10,73	35,73
4	7,17	37,44	27,26	10,18	33,54

When studying the chemical composition of the liquid phase, it was found that of the total nitrogen content of 37.62%, 10.54% is in the form of ammonium and 27.13% is in the form of amides. The sulfur content was 23.73%. In the solid phase, the content of only total nitrogen was 21.68%, its ammonium and amide forms were 5.48 and 16.21%, respectively, and the value of the nutrient element sulfur was 47.85%. This means that, according to the composition, a mixture of bicarbamide sulfate, ammonium sulfate, and monoammonium sulfate salts is formed in the solid phase.

Consequently, when the pH range is in the range of 1.0-2.0, the product is in a strongly acidic environment. At this stage, urea sulfate is formed. With ammoniation (addition of ammonia), when the pH range is in the range of 4.5-6.5, ammonia neutralizes the product, converting the H+ ions of sulfuric acid into NH4+. At this stage, ammonium sulfate is formed. When the pH range of the final ammonization is in the range of 6.5-7.5, this is a "neutralized" medium, which is optimal for granulation. Therefore, it is advisable to recommend maintaining the pH in the reaction within the range of 6.04-7.17.

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