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Production of Bentonite-Enriched Superphosphate Fertilizer Based on Uzbekistan Phosphorites and Bentonite Raw Materials

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ABSTRACT: This article presents a technological approach to producing environmentally and economically efficient superphosphate fertilizer enriched with bentonite, using locally available natural phosphorite and bentonite raw materials from Uzbekistan. The mineral composition of phosphorites, the physicochemical properties of bentonite, the technological processes of fertilizer production, and the scientific basis for manufacturing are analyzed. The use of bentonite-enriched superphosphate improves plant nutrition and reduces water consumption while minimizing nutrient loss, thereby decreasing the environmental impact of conventional fertilizers. Furthermore, the article highlights current challenges and future prospects in this field, based on recent studies and relevant literature sources.

I. INTRODUCTION

In the Republic of Uzbekistan, the efficient use of land resources and the enhancement of domestic fertilizer supply remain urgent issues, particularly through the development and processing of natural phosphate deposits. Despite the abundance of low-grade phosphorites in the Qizilqum and other local deposits, their processing efficiency is currently insufficient. At the same time, the presence of large-scale bentonite reserves extracted at the industrial level within the country opens up opportunities to use this raw material as an auxiliary component in fertilizer production [1, 2].

The continuous growth of the global population necessitates increased food production, which in turn has led to the intensive production and application of various synthetic fertilizers. Among them, nitrogen, phosphorus, and potassium fertilizers are essential for cultivating agricultural products. However, most conventional fertilizers are inefficient because they dissolve easily in water and quickly leach due to irrigation or soil moisture. This results in excessively high concentrations of nutrients in the root zone, which plants are unable to absorb effectively [3, 4]. As a result, conventional fertilizers contribute to the accumulation of surplus nutrients in the soil, leading to environmental pollution through nutrient loss processes, particularly phosphorus and nitrogen leaching. Therefore, to increase agricultural productivity on a sustainable and environmentally responsible basis with minimal ecological and financial loss, it is crucial to explore the prospects of producing slow-release phosphorus fertilizers that also improve soil reclamation properties. This article discusses such prospects and the mechanisms of their effects.

The agricultural sector of the Republic of Uzbekistan requires approximately 525.2 thousand tons of P_2O_5 per year, while the domestic chemical industry produces only 130–150 thousand tons of P_2O_5, resulting in a significant shortfall of phosphate raw materials [5].

Since 2015, efforts have been made to increase the production of phosphate fertilizers. Within the framework of the project “Expansion of existing production capacity for phosphate ore beneficiation” at the Qizilqum Phosphorite Complex, the annual production capacity for washed and calcined phosphate concentrate containing at least 26% P_2O_5 has increased from 400 thousand tons to 716 thousand tons. The sole consumer of this washed and calcined phosphate concentrate is JSC "Ammofos-Maxam", which manufactures fertilizers such as ammophos (10% N, 46% P_2O_5) and suprefos (8–15% N, 20–24% P_2O_5) [5].

Currently, the use of mineral acids in the processing of phosphorites holds a central place in global practice, and this subject is widely covered in scientific and technical literature. Phosphate fertilizers rich in essential nutrients are mainly produced by reacting phosphate raw materials with sulfuric, phosphoric, hydrochloric, or nitric acids. In particular, sulfuric acid is commonly used to decompose phosphate raw materials such as phosphorites and apatites, resulting in the production of single superphosphate. Although this fertilizer contains a relatively low percentage of phosphorus (P_2O_5), it has agronomic value due to the presence of calcium and sulfur, which are beneficial to plant growth.

A number of published scientific sources [6–8] describe the theoretical and practical aspects of producing single superphosphate through a continuous technological process. These studies, in particular, present experimental work on the decomposition of Algerian phosphorites containing 29.10% P_2O_5 using sulfuric acid. Under experimental conditions, effective results were achieved using the following optimal parameters: phosphorite quantity – 1000 kg, acid concentration – 100%, acid amount – 850–900 kg, and reaction temperature – around 94–98°C. The acidic slurry formed as a result of mixing phosphorite and acid is neutralized with an aqueous solution of ammonia. This slurry, with a density of 1.55–1.65 g/cm³, is easily transferred to a rotary drum dryer, where the product is dried and granulated. The final product, single superphosphate, contains up to 16% water-soluble P_2O_5. These studies highlight that, compared to processing apatite concentrates, this method is more economically viable.

Scientific studies on the direct production of phosphorus fertilizers from phosphorites have also led to the development of a technology for producing complex phosphate fertilizers from sulfuric acid-decomposed materials without the need for a maturation stage in storage. These fertilizers also contain additional nutrients such as sulfur, calcium, and magnesium [9, 10]. The raw materials used in the research included: Russian phosphorites from the Yegoryevsk deposit containing 20.1% P_2O_5, 34.3% CaO, and 4.1% CO_2; talc enrichment waste with 36.2% MgO, 1.7% CaO, and 8.9% CO_2; extraction-grade phosphoric acid containing 37.2% P_2O_5; and 96% sulfuric acid. The optimal technological parameters for the process included 1000 g of phosphorite and 900 g of sulfuric acid. Under these conditions, the resulting superphosphate product had the following composition (by weight percentage): total P_2O_5 – 20.3–22.7%, citric acid-soluble P_2O_5 – 14.1–20.7%, and water-soluble P_2O_5 – 3.4–4.9%.

The implementation of an accelerated and cost-effective technology for producing single superphosphate from high-carbonate and low-grade phosphorites of the Central Kyzylkum region has demonstrated that the production cost of the resulting fertilizer can be reduced by 20–25% [11, 12].

Scientific research aimed at producing single superphosphate using a simplified technological scheme has thoroughly investigated the influence of process parameters during the two-stage acid decomposition of Central Kyzylkum phosphorites [13–15]. In the first stage, 70–80% of the phosphate raw material is decomposed using 93% concentrated sulfuric acid in a stoichiometric amount (100%) over 15–20 minutes, resulting in the formation of H_3PO_4 (phosphoric acid) and $CaSO_4$ (gypsum). In the second stage, the concentrated H_3PO_4 formed in the first step is reacted with the remaining 20–30% of phosphate raw material at a temperature of 122°C, leading to the formation of $Ca(H_2PO_4)_2$ (monocalcium phosphate).

However, unfortunately, under the new beneficiation scheme, there is no production of washed and dried concentrate or standard phosphorite powder. Given the current conditions, it is essential to utilize off-balance phosphorite ores, which are by-products of washed and dried phosphate concentrate production, as raw material for agricultural applications — specifically for the production of nitro-calcium phosphate fertilizers (6% N and 16% P_2O_5), standard nitro-calcium phosphate fertilizers (6% N and 16% P_2O_5), and ammoniated single superphosphate (1.5% N and 13.5% P_2O_5).

Bentonite, which is available in regions such as Navoi, Fergana, and Kashkadarya in Uzbekistan, is a clay mineral primarily composed of montmorillonite. It possesses a high capacity for water absorption and swelling, making it particularly useful in fertilizer formulations for enhancing granule strength, developing slow-release fertilizers, and reducing dust formation [16-18].

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II. RESEARCH METHODS

In this study, the composition of the initial phosphorite raw material, selected as a sample, was analyzed using the Scanning Electron Microscopy (SEM) method.

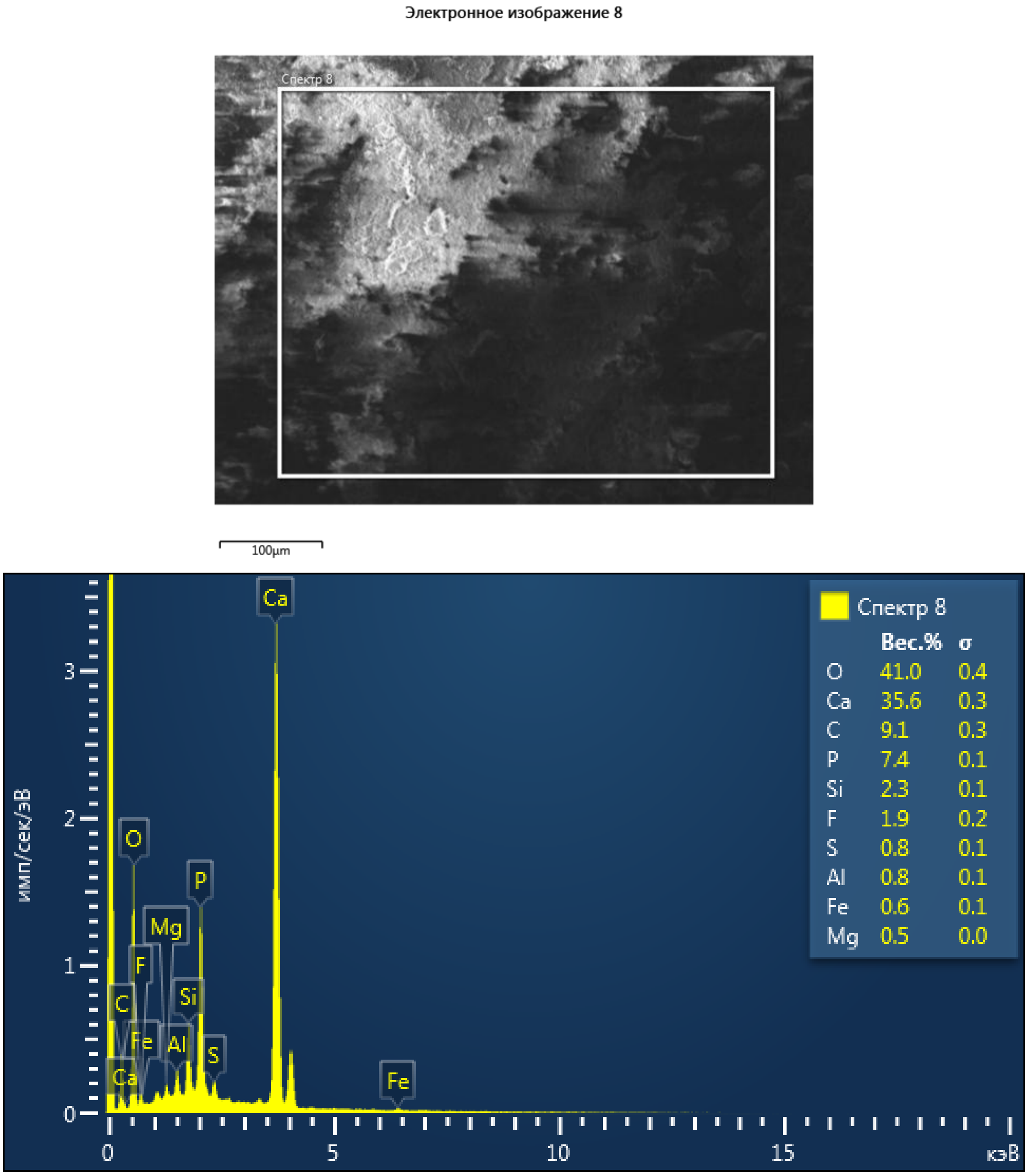

Fig. SEM Analysis of Phosphorite Raw Material

The Scanning Electron Microscopy (SEM) analysis of the phosphorite raw material revealed the following elemental composition (in %): O – 41.0%, Ca – 35.6%, C – 9.1%, P – 7.4%, Si – 2.3%, F – 1.9%, S – 0.8%, Al – 0.8%, Fe – 0.6%, Mg – 0.5%.

The chemical composition of the bentonite sample added to the superphosphate slurry was determined to be as follows (in %): Al_2O_3 – 9.15, Fe_2O_3 – 4.01, MgO – 2.41, CaO – 15.76, P_2O_5 – 0.19, SO_3 – 1.73, SiO_2 – 17.56, TiO_2 – 0.35, and moisture content – 5.31.

III. EXPERIMENTAL RESULTS

This study aims to investigate the process of producing bentonite-enriched superphosphate fertilizer through the decomposition of phosphorite samples with the addition of bentonite, as well as to evaluate the efficiency and effectiveness of the resulting fertilizer.

The procedure for conducting the decomposition process and obtaining the final product was as follows: the calculated amount of sulfuric acid, with a concentration of 60% (within an acceptable range of 60% to 100%), was heated to a temperature of 50–60°C and then slowly added to a thermostatically controlled glass beaker containing the phosphorite raw material sample. The mixture was thoroughly stirred using a mechanical stirrer. In the production of superphosphate, the decomposition of the phosphate raw material occurs according to the following general reaction equation:

$$2Ca_5(PO_4)F + 7H_2SO_4 + 3H_2O = 3Ca(H_2PO_4)_2\cdot H_2O + 7CaSO_4 + 2HF$$

In practice, the decomposition process occurs in two stages:

$$Ca_5(PO_4)F + 5H_2SO_4 + 2{,}5H_2O = 3H_3PO_4 + 5CaSO_4\cdot 0{,}5H_2O + HF$$

$$Ca_5(PO_4)F + 7H_3PO_4 + 5H_2O = 5Ca(H_2PO_4)_2\cdot H_2O + HF$$

Along with the decomposition of the phosphate raw material, the decomposition of other minerals also takes place. For example, calcite decomposes according to the following reaction:

$$CaCO_3 + H_2SO_4 = CaSO_4 + CO_2 + H_2O$$

When free P_2O_5 is neutralized with gaseous ammonia, monoammonium phosphate is formed:

$$H_3PO_4 + NH_3 = NH_4H_2PO_4$$

As a result of the exothermic neutralization, the temperature rises to 80–90°C, causing partial drying of the superphosphate product.

Processing of Phosphorite Raw Material and Production of Bentonite-Enriched Superphosphate Fertilizer

The phosphorite raw material was treated with sulfuric acid for 60 minutes. Upon completion of the reaction, bentonite was added to the superphosphate mass. The bentonite was introduced at 5–10% by weight relative to the superphosphate. The resulting mixture was then stirred for 30 minutes and neutralized to pH 4–4.5 using a 25% aqueous ammonia solution. Drying was carried out at a temperature of 80°C, and granulation was performed using a rolling (pelletizing) method. The chemical composition of the fertilizer granules was analyzed, and their mechanical strength was measured. The granule strength of 2–3 mm particles was determined using the IPG-1M device. The results are presented in Table 1.

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Table 1. Composition of Bentonite-Enriched Superphosphate Fertilizer

№	H_2SO_4, %	Bentonite (%)	N	$P_2O_{5total.}$	$P_2O_{5citric.}$	$P_2O_{5water.}$	CaO	SO_3	Granule strength MPa
1	90	5	0,77	11,25	9,15	6,86	33,35	39,71	3,05
2		10	0,71	11,10	8,82	6,28	32,91	39,18	3,29
3	100	5	1,63	10,85	9,31	7,81	32,14	42,44	3,44
4		10	1,56	10,72	9,16	6,84	31,79	41,97	3,72

At a 90% sulfuric acid dose, the composition of superphosphate fertilizer with 5% bentonite addition was as follows (in %): $P_2O_{5total.}$ – 11.25; $P_2O_{5citric.}$ – 9.15; $P_2O_{5water.}$ – 6.86; $P_2O_{5citric.}$ / $P_2O_{5total.}$ – 81.33%; $P_2O_{5water.}$ / $P_2O_{5total.}$ – 60.98%; N – 0.77. The granule strength was 3.05 MPa. For superphosphate fertilizer with 10% bentonite addition, the composition was: $P_2O_{5total.}$ – 11.10; $P_2O_{5citric.}$ – 8.82; $P_2O_{5water.}$ – 6.28; $P_2O_{5citric.}$ / $P_2O_{5total.}$ – 79.46%; $P_2O_{5water.}$ / $P_2O_{5total.}$ – 56.58%; N – 0.71. The granule strength was 3.29 MPa.

At a 100% sulfuric acid dose, the composition of superphosphate fertilizer with 5% bentonite addition was: $P_2O_{5total.}$ – 10.85; $P_2O_{5citric.}$ – 9.31; $P_2O_{5water.}$ – 7.81; $P_2O_{5citric.}$ / $P_2O_{5total.}$ – 85.81%; $P_2O_{5water.}$ / $P_2O_{5total.}$ – 71.98%; N – 1.63. The granule strength was 3.44 MPa. For superphosphate fertilizer with 10% bentonite addition, the composition was: $P_2O_{5total.}$ – 10.72; $P_2O_{5citric.}$ – 9.16; $P_2O_{5water.}$ – 6.84; $P_2O_{5citric.}$ / $P_2O_{5total.}$ – 85.45%; $P_2O_{5water.}$ / $P_2O_{5total.}$ – 63.81%; N – 1.56. The granule strength was 3.72 MPa.

The decrease in available P_2O_5 content can be explained by the following reaction that occurs as the degree of ammonization increases:

$$2CaHPO_4 + CaSO_4 + 2NH_3 = Ca_3(PO_4)_2 + 2(NH_4)_2SO_4$$

The strength of unammoniated acidic superphosphate granules does not exceed 0.3 MPa, while that of ammoniated superphosphate granules reaches 2–3 MPa. The addition of 5–10% bentonite to the superphosphate led to an increase in granule strength to 3.05–3.72 MPa.

For the obtained phosphorus fertilizer samples, the water-soluble phosphorus pentoxide (P_2O_5) content should not be less than 50% of the total phosphorus pentoxide content. When phosphorites are decomposed using 90–100% sulfuric acid, with the formation of monocalcium phosphate, the proportion of water-soluble P_2O_5 is higher. However, further scientific research is required to obtain detailed information on the availability of phosphorus pentoxide and other elements in fertilizers enriched with bentonite.

IV. CONCLUSION

Thus, the application of bentonite-containing superphosphate undoubtedly increases the availability of macro- and micronutrients in the soil, improves the structure, physico-chemical, and mechanical properties of the soil, and enhances the nutrient uptake efficiency of the applied fertilizers. As a result, crop yields increase. In addition, the use of bentonite-enhanced superphosphate fertilizers improves plant nutrition, helps reduce irrigation frequency, and minimizes nutrient loss, thereby reducing the environmental impact of conventional fertilizers.
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REFERENCES

[1]. Beglov B.M., Namazov Sh.R. Phosphorites of the Central Kyzylkum and Their Processing. – Tashkent, 2013. – 460 p.
[2]. Doniyarov N.A., Tagaev I.A. Development and Improvement of the Processing Technology of Low-Grade Phosphorite Ores of the Central Kyzylkum. – Navoi, 2018. – 144 p.
[3]. Mohammad M. Almutari. Synthesis and modification of slow-release fertilizers for sustainable agriculture and environment: a review. // Arabian Journal of Geosciences. Published: 16 August 2023. V.16, article number 518, (2023)
[4]. Priya E., Sudipta Sarkar, Pradip K. Maji. A review on slow-release fertilizer: Nutrient release mechanism and agricultural sustainability // Journal of Environmental Chemical Engineering. V.12, I.4, August 2024.

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ISSN: 2350-0328

Vol. 12, Issue 7, July 2025

[5]. Badalova O.A., Otaboev Kh.A., Namazov Sh.S., Seytnazarov A.R., Radjabov R.R. Simple Ammoniated Superphosphate Based on Off-Balance Phosphorite Ore – Mineralized Mass. // Universum: Technical Sciences, Electronic Scientific Journal. 2018, No. 9(54). URL: http://7universum.com/ru/tech/archive/item/6350

[6]. Kharikov A.M., Smetana V.V. On the Problems of the Phosphate Raw Material Base of Ukraine. // Chemical Industry of Ukraine. – Kyiv, 1999. – No. 4. pp. 3–7.

[7]. Kharikov A.M., Toshinsky V.I. On the Problems of Providing Phosphate Raw Materials to Ukrainian Enterprises. // Bulletin of the Kharkiv State Polytechnic University. – Kharkiv: HGPU, 1999. – No. 39. p. 24–27.

[8]. Kharikov A.M., Nishporenko N.N., Vakal S.V. Physicochemical Properties and Kinetic Studies of Algerian Phosphorites as an Alternative Raw Material for Ammoniated Superphosphate Production. // Bulletin of Cherkasy State Technological University. – Cherkasy, 2004. No. 4. pp. 109–115.

[9]. Angelov A.I., Sobolev N.V., Syrchenkov A.Ya., Al'mukhametov I.A. Production of Enriched Superphosphate from Low-Grade Phosphate Raw Materials of the Yegoryevsk Deposit. // Chemical Industry Today. – Moscow, 2006. – No. 1. pp. 13–21.

[10]. Angelov A.I., Sobolev N.V. Development of Enriched Superphosphate Technology from Phosphate Meal of the Yegoryevsk Deposit. // Conference Abstracts "Advances in Chemistry and Chemical Technology." – Vol. XVII, Moscow, 2003, D.I. Mendeleev Russian Chemical Technical University. pp. 39–41.

[11]. Tajiev S.M., Akbarova M.G., Maksudova Z.I. New Technology for Producing Simple Superphosphate from High-Carbonate Phosphorites. // Proceedings of the International Scientific Conference "Modern Problems of Chemistry and Chemical Technology. Current Issues of Natural and Humanitarian Sciences." – Osh. Bulletin, 2001. – No. 2. pp. 227–230.

[12]. Tadzhiev S.M., Namazov Sh.S., Beglov B.M. Development of a Flow Technology for Simple Superphosphate from Phosphorites of Tashkura. // Chemical Industry Today. – Moscow, 2004. – No. 4. – pp. 32–38.

[13]. Otaboev Kh., Radjabov R., Sherkuziev D., Namazov Sh., Seytnazarov A. Technological features of the production of granulated simple superphosphate according to the flow scheme // International Journal of Advanced Science and Technology. – India, 2020. - Vol. 29. – №. 8. – pp. 1418-1430.

[14]. Otaboev Kh.A., Badalova O.A., Namazov Sh.S., Radjabov R., Seytnazarov A.R., Beglov B.M. Two-Stage Processing of Phosphate Meal with Sulfuric Acid – A Basis for the Flow Technology of Simple Superphosphate Production. // Chemical Industry Today. – Moscow, 2020. – No. 3. pp. 32–41.

[15]. Otaboev Kh.A., Seytnazarov A.R., Sherkuziev D.Sh., Namazov Sh.S., Radjabov R. Composition and properties of fertilizers based on simple superphosphate, potassium chloride and ammonium nitrate // Scientific and technical journal of Namangan institute of engineering and technology. – Namangan, 2021. V.6, I.1. pp. 179-187.

[16]. Myachina O.V., Aliev A.T., Kim R.N., Rakhmonov A.Kh., Narzullaev O.S. Activity of Soil Hydrolases Under the Influence of New Slow-Acting Fertilizers. // Uzbek Chemical Journal. – 2017. – No. 2. pp. 42–47.

[17]. Eshqurbonov, Furqat, Hamidov Azim. Methods for determining the chemical composition of natural Guliophosphate raw material. Fergana State University 6 (2024): pp. 107-107.

[18]. Eshqurbonov Furqat, Hamidov Azim. Industrial significance and physical and chemical analysis of Khovdag bentonite. Mechanics and Technology 2 (9) Special Issue (2024): pp. 149-153.