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ANALYSIS OF RESEARCH ON THE PRODUCTION OF PHOSPHORUS FERTILIZERS FROM LOW-GRADE HIGH-CARBONATE CENTRAL KYZYLKUM PHOSPHORITES BASED ON INNOVATIVE TECHNOLOGIES

Abstract

This article presents an analysis of published research conducted in Uzbekistan on the development and industrial implementation of innovative technologies for producing new types of simple and complex phosphorus fertilizers. The studies reviewed focus on the acid decomposition of low-grade, high-carbonate phosphorite raw materials from the Central Kyzylkum region, employing extraction phosphoric acid, nitric acid, sulfuric acid, and ammonium salts, as well as thermal and mechanochemical activation methods, to obtain nitrogen-phosphorus and complex fertilizers enriched with macro- and micronutrients.

Keywords

phosphorite, low-grade raw material, high-carbonate ore, innovative technology, acid decomposition, nitrogen-phosphorus fertilizers, complex fertilizers, ammophosphate, mechanochemical activation.

Annotatsiya

Ushbu maqolada O‘zbekistonda past navli, yuqori karbonatli Markaziy Qizilqum fosforitlari asosida innovatsion texnologiyalar yordamida oddiy va murakkab fosforli o‘g‘itlarning yangi turlarini ishlab chiqarish va ishlab chiqarishga joriy etish bo‘yicha nashr etilgan tadqiqotlar tahlil qilingan. Ko‘rib chiqilgan tadqiqotlar ekstraktsion fosfor kislotasi, nitrat kislotasi, sulfat kislotasi va ammoniy tuzlari yordamida kislotali parchalash, shuningdek termik va mexanokimyoviy faollashtirish usullarini qamrab oladi.

Kalit so‘zlar

fosforit, past navli xom ashyo, yuqori karbonatli ruda, innovatsion texnologiya, kislotali parchalash, azot-fosforli o‘g‘itlar, murakkab o‘g‘itlar, ammofosfor, mexanokimyoviy faollashtirish.

INTRODUCTION

Among mineral fertilizers, nitrogen, phosphorus, and potassium-based fertilizers are considered the most important. The major global producers of these fertilizers are China (25%), India (13%), the United States (25%), and Russia (8%). The global mineral fertilizer market consists of approximately 59% nitrogen fertilizers, 24% phosphorus fertilizers, and 17% potassium fertilizers. In the global production of phosphorus fertilizers, China accounts for 37%, the USA 12%, India 10%, Morocco 6.5%, and Russia a significant portion as well [1]. The total global

reserves of phosphate ores are estimated at 63,067.4 million tonnes, of which 57,807.4 million tonnes are phosphorite ores and 5,260 million tonnes are apatite ores. Approximately 80% of the world's phosphorite reserves-around 49,493 million tonnes-are concentrated in Morocco, the USA, China, Russia, and Kazakhstan [2].

The Central Kyzylkum phosphorite deposits, located in the Republic of Uzbekistan, currently serve as the primary raw material base for domestic phosphorus fertilizer production enterprises. Numerous studies have been conducted by Uzbek scientists on the chemical and mineralogical composition of the major deposits within the Kyzylkum basin, including Zher-Sardara, Karakat, and Yetimto'g' [3, 4]. The Kyzylkum phosphorite is primarily composed of francolite, with a specific gravity of 2.96-3.2 g/cm³. Its average chemical composition (by weight, %) includes: P_2O_5-32.10; CaO-48.34; CO_2-5.0; F-3.19; MgO-0.04; Al_2O_3-0.2; Fe_2O_3-0.18; Na_2O-0.10; K_2O-0.05; SO_3-0.08; SiO_2-0.05 [5].

Due to the relatively low phosphorus content in the ore, enrichment is necessary before use. One of the most promising methods for upgrading high-carbonate phosphorites is thermal calcination [6–9]. Since 2006, the Kyzylkum Phosphorite Combine (KPC) has implemented thermal beneficiation on an industrial scale. Since 2014, using this technology, the KPC has been producing 714,000 tonnes per year of a washed and calcined concentrate (WCC-25) containing 25% P_2O_5 and a CaO/ P_2O_5 ratio of 2.1. Based on this feedstock, production of one tonne of extractable phosphoric acid requires 4.3–4.4 tonnes of sulfuric acid and generates 7.5–8.0 tonnes of phosphogypsum waste per tonne of product [10].

In Uzbekistan, significant research and practical developments on innovative production of nitrogen-phosphorus fertilizers through processing of domestic phosphorites have been carried out under the leadership of prominent scholars such as Sh.S. Namazov, B.M. Beglov, S.M. Tadjiev, Z. Salimov, and S. Tukhtaev. Their collective contributions have established the scientific and technological foundations upon which current innovative processing methods are built [11–14].

INNOVATIVE ACID DECOMPOSITION TECHNOLOGIES FOR LOW-GRADE PHOSPHORITES

To convert the phosphorus pentoxide (P_2O_5,) present in low-grade, high-carbonate phosphorites from a non-assimilable form into a plant-available form, various innovative acid decomposition methods have been developed. A.R. Seytnazarov conducted a series of experiments on the production of nitrogen-phosphorus fertilizers—particularly ammophosphate—based on Central Kyzylkum phosphate raw materials. His findings revealed that, in contrast to conventional ammophos, the innovative ammophosphate process reduces sulfuric acid consumption per tonne of P_2O_5, produced and significantly improves the utilization rate of low-grade phosphate raw materials [15, 16].

S.S. Ortiqova, in her studies on innovative processing, treated low-grade Central Kyzylkum phosphorites containing (wt.%) 14.33 P_2O_5, 43.66 CaO, 1.19 MgO, 1.38 Fe_2O_3, 1.18 Al_2O_3, 2.22 SO_3, 14.70 CO_2, 1.75 F, and 13.23 insoluble residue using extraction phosphoric acid at ratios ranging from 100:15 to 100:30. As a result, slow-release ammophosphate fertilizers with up to 40–54% plant-available P_2O_5, were obtained [17–20]. Research conducted by U.K. Alimov and his students further demonstrated the feasibility of producing ammophosphate fertilizers with high contents of water-soluble and plant-available P_2O_5, along with favorable physical, chemical, and commercial properties [21-27].

T.A. Sattarov identified key technological parameters for innovative ammophosphate production at various extraction phosphoric acid ratios, determining that optimal conditions include a temperature of 60–65°C and a decomposition time of 45 minutes. These studies resulted in ammophosphates containing 7.98% nitrogen and 47.95% total P_2O_5, as the main nutrient components [28, 29]. I.T. Shamshiddinov and K.G. Kodirova demonstrated the successful synthesis of fully water-soluble fertilizers containing 56.91–59.95% P_2O_5, and 14.21–11.54% N, suitable for application via modern drip irrigation systems, with fluoride content reduced to 0.01% and sulfate content to 0.01% [30].

INNOVATIVE NITRIC ACID-BASED PROCESSING ROUTES

In recent years, considerable attention has been devoted to the innovative processing of high-carbonate phosphate raw materials with nitric acid to obtain various phosphorus fertilizers. The influence of phosphate additives on the phase modification behavior of ammonium nitrate has been investigated, and an increase in the transition temperature was found to reduce granule stickiness during storage and transport of nitrogen-phosphorus fertilizers under hot climate conditions [31]. A.M. Reymov, A.R. Seytnazarov, and Kh.Ch. Mirzakulov studied foaming phenomena arising from high-carbonate phosphorite decomposition using substoichiometric nitric acid combined with ammoniated extraction phosphoric acid, mitigating it by introducing calcium nitrophosphate slurry and adding nitric acid in a subsequent step [32, 33].

Under the supervision of M.V. Yulbarsova and S.M. Tadjiev, an innovative route was developed for processing Central Kyzylkum phosphorites with urea in the presence of substoichiometric nitric acid to produce high-quality complex nitrogen–phosphorus fertilizers. New carbonitrophos fertilizer samples, obtained using 40–60% nitric acid relative to stoichiometry, satisfied agricultural requirements for physical-mechanical and commercial properties, containing 20.08–24.15% nitrogen, 8.33–6.68% phosphorus, and 23.37–18.74% calcium, and could be stored and transported in bulk without packaging [34–37].

Currently, innovative liquid nitrogen-phosphorus-calcium (NPCa) fertilizers have been obtained through the acid decomposition of various types of low-grade, washed-dried, and washed-calcined phosphorites using nitric acid of different concentrations and dosages, further expanding the range of innovative fertilizer types producible from domestic high-carbonate raw materials [38, 39].

MECHANOCHEMICAL AND THERMAL ACTIVATION INNOVATIONS

A.A. Khoshimov and A.R. Seytnazarov conducted innovative research on obtaining high-concentration complex mixed phosphorus fertilizers by mechanically activating Central Kyzylkum phosphorite with ammonium phosphate and sulfate salts. Their findings showed that mechano-chemical activation for 30 minutes produced nitrogen-phosphorus fertilizers (Superphos-NS) containing N: 1.01–5.47%, P_2O_5: 17.33–19.94%, and available CaO: 32.79–2.62% [40]. Innovative sulfuric acid-based processing technologies for producing superphosphate fertilizers from Central Kyzylkum phosphorites have also been systematically developed. For untreated phosphate flour, the most effective approach involves 58–60% sulfuric acid at 90–100% stoichiometric ratios, while thermally treated concentrates require 62% H_2SO_4 at 100% stoichiometry [41, 42].

Innovative technologies for producing superphosphate fertilizers from Central Kyzylkum phosphorites using concentrated sulfuric acid were developed and patented, with multiple patents (IAP 02709, IAP 02844, IAP 02845) registered in Uzbekistan [43-48]. Based on further innovative research conducted by S.M. Tadjiev and S.T. Tukhtaev, scientific foundations were

laid for the production of nitrogen-phosphorus fertilizers containing 1.5-6% nitrogen and 9-12% phosphorus, using resource-efficient chamber and continuous flow processes applied to high-carbonate low-grade phosphorites [49, 50].

INNOVATIVE SUSPENDED AND LIQUID COMPLEX FERTILIZER TECHNOLOGIES

In the field of innovative suspended fertilizer production from low-grade high-carbonate phosphorites, S.M. Tadjiev and his students conducted research on the rational development of technology for obtaining suspended fertilizers with insecticidal activity, produced by decomposing low-grade phosphorites using substoichiometric nitric acid in the presence of elemental sulfur [51, 52]. The researchers utilized 40–60% HNO_3 and highly concentrated ammonium nitrate (64.16%) and urea (70%) solutions to produce innovative suspended NP fertilizers. Effective granulation was achieved within 5-10 minutes at N: P_2O_5, ratios of 1:0.5, 1:0.7, and 1:1, yielding samples with 7.49-12.07% N, 6.00-8.00% P_2O_5, , and 6.76–12.19% available CaO (using ammonium nitrate solution) [53–56].

M.Kh. Ikramov developed an innovative process for obtaining suspension-based complex fertilizers using a basic ammophos suspension at N:P_2O_5= 1:0.25 and UAN (urea-ammonium nitrate) solution. The resulting product contained 17.37% total nitrogen (8.73% ammonium, 5.74% amide, 2.89% nitrate), along with 17.36% P_2O_5, and 30% water. Innovative suspended NPK fertilizers produced using UAN and potassium chloride solutions reached total nutrient content of 35.34–38.95% at N: P_2O_5:K_2O = 1:1:0.5 [57, 58].

CONCLUSION

The comprehensive analysis presented in this study reveals that low-grade and high-carbonate phosphate raw materials of the Central Kyzylkum region in the Republic of Uzbekistan have substantial potential for producing agrochemically effective complex, nitrogen-phosphorus, and organomineral fertilizers through innovative processing technologies. Although the raw materials extracted from deposits such as Zher-Sardara and Karakat are compositionally poor, they can be effectively processed through innovative acid decomposition using extraction phosphoric acid, nitric acid, ammonium salts, urea, and sulfuric acid, as well as by thermal and mechano-chemical activation, significantly enhancing the bioavailability of phosphorus.

The implementation of these innovative, resource-efficient and energy-saving technologies not only enables diversification of phosphorus fertilizer types but also facilitates the production of high-quality fertilizers enriched with essential nutrients such as nitrogen, phosphorus, calcium, magnesium, sulfur, potassium, and various micronutrients. The development and implementation of innovative technologies for producing liquid, suspended, and insecticidal complex fertilizers based on low-grade high-carbonate phosphorites contributes to the effective utilization of the country’s agrobiological resources.

As a result, the degree of processing of domestic phosphate raw materials will increase, dependence on imported mineral fertilizers will be reduced, and the range of export-oriented products will be expanded. Furthermore, the outcomes of this research align with national strategies aimed at improving soil fertility, increasing agricultural productivity, and strengthening food security.

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