

VALORIZATION OF AZNEK PHOSPHORITE AND ACTIVATED SLUDGE FOR SUSTAINABLE ORGANOMINERAL FERTILIZER PRODUCTION

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Abstract:

This study investigates the feasibility of producing organomineral fertilizers based on Aznek phosphorite (AF) and activated sludge (AL) derived from biochemical wastewater treatment plants. The main objective was to determine the optimal component ratios and evaluate the effect of nitric acid activation on the transformation of phosphorus into plant-available forms. Laboratory experiments were carried out using AF:AL mass ratios ranging from 90:10 to 20:80 and nitric acid (55.6% HNO₃) dosages of 50–90% of the stoichiometric requirement relative to CaO content. The results showed that increasing acid dosage led to a decrease in total P₂O₅ content (from 13.16% to 10.44% at 90:10 ratio), while significantly enhancing the amount of assimilated P₂O₅ (from 6.07% to 8.51%). The relative availability of phosphorus increased up to 86.26% with increasing activated sludge content and acid dosage. A similar trend was observed for calcium, where assimilated CaO increased with acid treatment. The organic matter, including humic and fulvic acids, increased significantly with higher AL proportions, reaching up to 30.13%.

Keywords: Organomineral fertilizer; Aznek phosphorite; Activated sludge; Nitric acid activation; P₂O₅ availability; Calcium oxide; Humic substances; Wastewater treatment; Sustainable agriculture; Resource recycling

1. Introduction

The development of environmentally sustainable and resource-efficient fertilizers is one of the key challenges in modern agricultural and chemical technologies [1], [2]. In particular, the utilization of local mineral resources and industrial waste materials as raw components for organomineral fertilizers has gained increasing scientific and practical interest. This approach not only reduces environmental pollution but also enhances the economic efficiency of fertilizer production [3], [4], [5].

Aznek phosphorite (AF), a locally available phosphate raw material, represents a promising mineral source for phosphorus-containing fertilizers. However, the phosphorus in phosphorite is predominantly present in the form of calcium phosphates, which are poorly available for plant uptake. Therefore, chemical and technological activation methods are required to convert phosphorus into more soluble and plant-accessible forms [6, 7, 8].

At the same time, activated sludge (AL), generated as a by-product of biochemical wastewater treatment processes, contains a significant amount of organic matter, humic-like substances, nitrogen compounds, and micronutrients. The combined utilization of phosphorite and activated sludge creates favorable conditions for producing high-efficiency organomineral fertilizers with improved agrochemical properties [9], [10], [11].

In this context, the present study aims to investigate the possibility of obtaining organomineral fertilizers based on Aznek phosphorite and activated sludge. Particular attention is given to determining the optimal mass ratios of mineral and organic components, as well as evaluating the effect of nitric acid treatment on the transformation of phosphorus into plant-available forms [12].

2. Materials and Methods

Aznek phosphorite (AF), obtained from the Aznek deposit, was used as the primary mineral raw material. The phosphorite mainly consists of calcium phosphates, which are characterized by low plant availability. As an organic component, activated sludge (AL) collected from biochemical wastewater treatment facilities was used. The activated sludge contains organic matter, humic substances, nitrogen compounds, and micronutrients, making it a suitable component for organomineral fertilizer production.

Characterization of Raw Aznek Phosphorite

(Fig. 1) indicates a high content of phosphorus pentoxide (P_2O_5 – 23.39%) and calcium oxide (CaO – 44.78%), confirming its suitability as a promising raw material for phosphate fertilizer production. At the same time, the presence of silicon dioxide (SiO_2 – 9.14%) and carbon dioxide (CO_2 – 13.58%) should be considered as important factors affecting the processing efficiency.

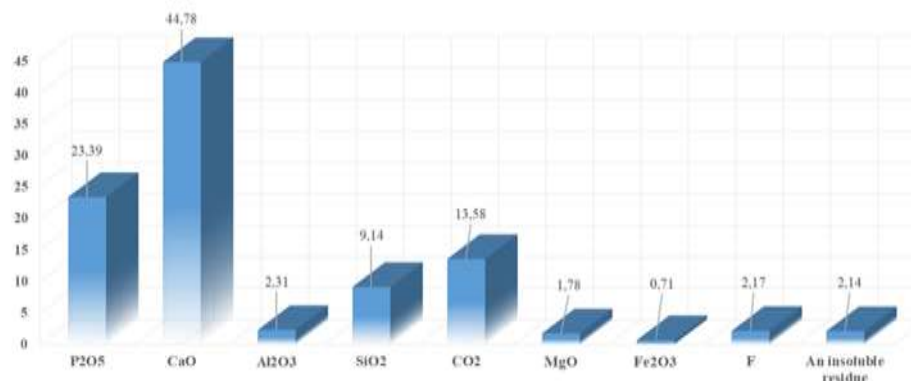


Figure 1. The chemical composition of the raw Aznek phosphorite

Minor components such as magnesium oxide (MgO – 1.78%) and aluminum oxide (Al_2O_3 – 2.31%) contribute to the physicochemical properties of the phosphorite. The relatively low iron oxide content (Fe_2O_3 – 0.71%) is considered a favorable factor for further chemical processing. However, the relatively high fluorine content (2.17%) requires special attention due to potential environmental and technological concerns. The insoluble residue (2.14%) also represents an additional parameter influencing the overall reactivity of the material.

Overall, phosphorus in the Aznek phosphorite is strongly bound with calcium, forming stable mineral phases that constitute the primary structure of the ore.

Nitric acid (HNO_3) with a concentration of 55.6% was used as a chemical activating agent for the decomposition of phosphorite and conversion of phosphorus into more available forms.

To determine the optimal composition, AF and AL were mixed in different mass ratios: 90:10, 80:20, 70:30, 60:40, 50:50, 40:60, 30:70, and 20:80. Each mixture was prepared as a separate laboratory sample. Mechanical mixing was applied to ensure homogeneity and uniform

distribution of components.

The prepared mixtures were subjected to acid activation using 55.6% nitric acid. The acid dosage was calculated based on the stoichiometric amount required for calcium oxide (CaO) present in phosphorite. The experiments were carried out at 50%, 60%, 70%, 80%, and 90% of the stoichiometric acid norm.

The acid treatment was performed in laboratory reactors under continuous stirring to ensure effective interaction between the mineral and organic components. This process facilitated the partial decomposition of calcium phosphates and the formation of water- and citrate-soluble phosphorus compounds.

After completion of the reaction, the obtained mass was subjected to drying in laboratory ovens until a residual moisture content of 14–15% was reached. This moisture level was considered optimal for ensuring product stability and suitability for further processing, such as granulation and agrochemical evaluation.

3. Results and Discussion

The experimental results demonstrated that the composition of organomineral fertilizers based on Aznek phosphorite (AF) and activated sludge (AL) significantly depends on both the component mass ratio and the nitric acid dosage [13].

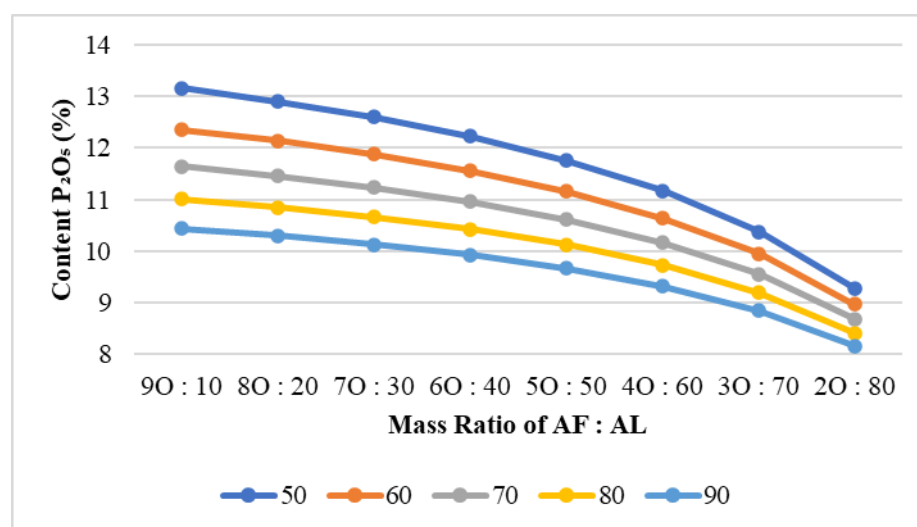


Figure 2. Dependence of the variation in total phosphorus pentoxide (P_2O_5 , %) during the production of organomineral fertilizers based on AF (Aznek phosphorite) and AL (activated sludge) on their mass ratio and acid dosage

It was observed that the total P_2O_5 content decreases with both increasing acid dosage and increasing proportion of activated sludge. For instance, at an AF:AL ratio of 90:10, the total P_2O_5 content decreased from 13.16% at 50% acid dosage to 10.44% at 90%. A similar trend was observed for other ratios: 12.90–10.30% (80:20), 12.60–10.13% (70:30), and 12.23–9.93% (60:40) [14].

With higher AL content, the P_2O_5 level further decreased, reaching 9.28–8.16% at a ratio of 20:80. This decrease is attributed to the dilution effect caused by the organic component and the formation of nitrate compounds during acid treatment.

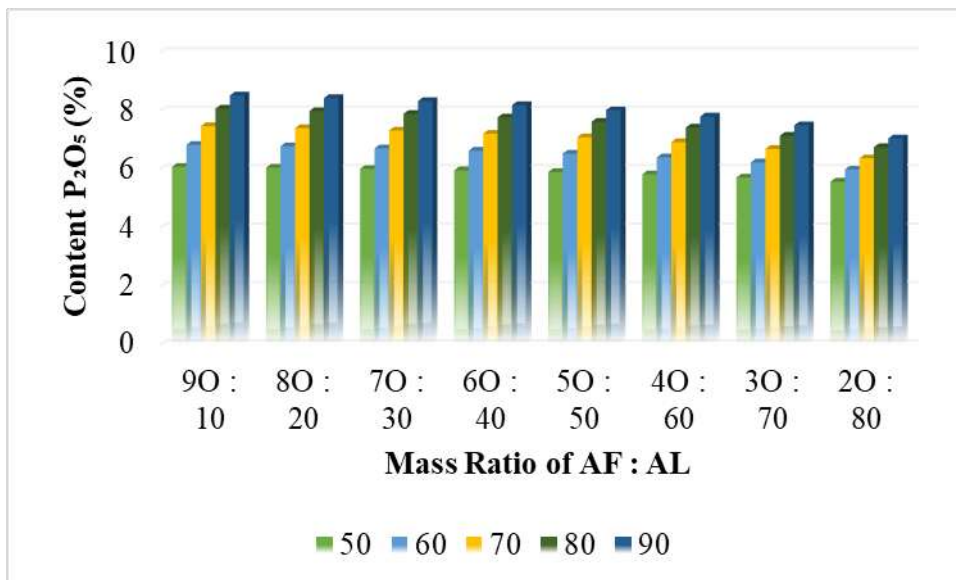


Figure 3. Dependence of the variation in assimilated phosphorus pentoxide (P_2O_5 , %) during the production of organomineral fertilizers based on AF and AL on their mass ratio and acid dosage.

In contrast, the content of assimilated (plant-available) P_2O_5 increased consistently with increasing acid dosage. At an AF:AL ratio of 90:10, the assimilated P_2O_5 increased from 6.07% at 50% acid dosage to 8.51% at 90%. Similar trends were observed across all compositions, with values ranging from 6.04–8.42% (80:20), 6.00–8.32% (70:30), and 5.95–8.18% (60:40) [15]. Although a slight decrease in assimilated phosphorus was observed with increasing AL content, the overall increase with acid dosage confirms the effectiveness of nitric acid in converting phosphorus into available forms.

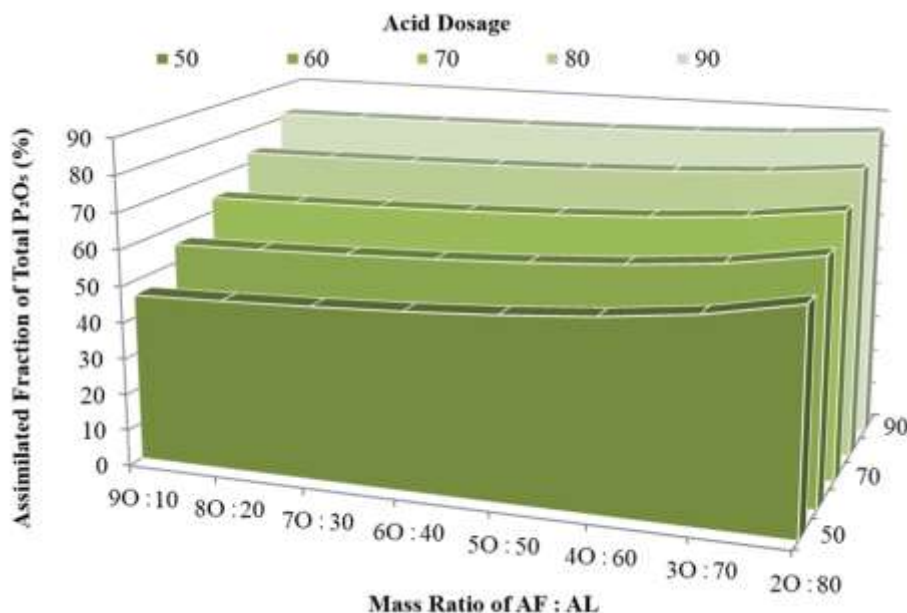


Figure 4. Dependence of the variation in the ratio of assimilated phosphorus pentoxide to total phosphorus pentoxide ($P_2O_5_{\text{assim}} \times 100 / P_2O_5_{\text{total}}$, %) during the production of organomineral fertilizers based on AF and AL on their mass ratio and acid dosage.

The ratio of assimilated P_2O_5 to total P_2O_5 showed a significant increase with both acid dosage and AL content. For example, at a 90:10 ratio, this value increased from 46.15% to

81.55% as the acid dosage rose from 50% to 90%. With increasing AL proportion, the relative availability further improved, reaching up to 86.26% at a 20:80 ratio [16]. This indicates that both acid activation and organic matter contribute to enhancing phosphorus bioavailability.

4. Conclusion

The results of this study demonstrate that the production of organomineral fertilizers based on Aznek phosphorite and activated sludge can be effectively optimized through a balanced combination of mineral and organic components together with controlled nitric acid treatment. Under the selected conditions, a nutrient-rich product with favorable agrochemical properties and improved bioavailability was obtained, confirming the efficiency of the proposed approach. These findings scientifically validate the feasibility of utilizing local raw materials for the production of high-performance organomineral fertilizers and highlight the potential of the developed technology for practical implementation as a resource-efficient and environmentally sustainable solution.

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