International Journal of Advanced Research in Science, Engineering and Technology

Vol. 12, Issue 11, November 2025

ISSN: 2350-0328

IJARSET IMPACT FACTOR 7.150

Humus Mineral Fertilizers Based on Wastewater Sediments and Phosphogypsum

Baqoyev Xayrillo, **Urunova Xurshida**, **Toxirova Nargisa**, **Najmiddinova Marjona**, **Jurakulov Baxrom**, **Temirov Uktam**

Independent researcher, Navoi State University of Mining and Technologies, Uzbekistan
PhD, senior lecturer, Navoi State University of Mining and Technologies, Uzbekistan
Doctoral student, Navoi State University of Mining and Technologies, Uzbekistan
Student, Navoi State University of Mining and Technologies, Uzbekistan
PhD, senior lecturer, Navoi State University of Mining and Technologies, Uzbekistan
Professor, Navoi State University of Mining and Technologies, Uzbekistan

ABSTRACT: This study focuses on the utilization of wastewater treatment sludge and phosphogypsum as raw materials for producing environmentally friendly organomineral fertilizers. The chemical composition of both components was analyzed, and samples were prepared in varying weight ratios (80:20 to 60:40) under different pH conditions. The findings reveal that the weight ratio and pH of the medium have a significant impact on the transformation and stabilization of organic substances, humic and fulvic acids, and sulfate compounds. The optimal conditions for the formation and preservation of humic substances were found at pH 2–3, with 70–80% wastewater sludge content. Acidic treatment with nitric acid followed by ammonia neutralization not only enhanced the conversion of sulfur into assimilable sulfate forms but also improved the overall nutrient availability of the fertilizers. The proposed method ensures the effective recycling of industrial and municipal wastes into valuable agricultural products, contributing to improved soil fertility and sustainable environmental management.

KEYWORDS: wastewater sludge, phosphogypsum, organomineral fertilizers, humic acids, pH effect, sulfur transformation, soil fertility, sustainable agriculture.

I.INTRODUCTION

One of the most urgent challenges facing modern agriculture in Uzbekistan is the depletion of soil humus, which plays a decisive role in determining soil fertility, water retention, and the overall ecological balance of agricultural lands. Comparative data indicate a significant discrepancy in humus reserves between our soils and those of developed countries. In European and Russian soils, the top one-meter layer per hectare contains 350–700 tons of humus, while in our most fertile soils this value is only 65–85 tons. Such a deficiency not only limits crop productivity but also accelerates soil degradation and erosion. To restore the natural fertility of soils, it is necessary to enrich them with organic matter, particularly by introducing fertilizers containing humic substances. One of the most promising and cost-effective sources for obtaining such humus-based fertilizers is wastewater treatment sediments, which are rich in organic residues, mineral components, and microelements essential for plant nutrition [1-2].

Modern scientific research and practical developments have proposed several methods for the processing of wastewater sediments into safe, nutrient-rich organomineral fertilizers. According to recent patents and technological innovations, the sediments are first dried to a moisture content of 10–25%, then ground to a particle size of 0.1–1.0 mm, and subjected to magnetic separation in a strong magnetic field of at least 1000 E (80 kA/m). As a result, two fractions are obtained: the magnetic fraction, enriched with iron, nickel, and chromium compounds, and the non-magnetic fraction, which retains valuable humic and mineral components. In this process, the concentration of heavy metals such as Fe, Cr, Cu, Zn, Ca, and Mg is reduced by 20–30%, thereby significantly decreasing the toxicity of the material. The non-magnetic portion undergoes further purification through acidic washing in a 10% sulfuric acid solution at 40–60°C, after which the obtained sediment is washed, neutralized, and prepared for agricultural use[3-4].

In the final stage of processing, the acidic wash solution is neutralized and alkalized to achieve a pH of 1.5–1.8, which promotes the precipitation of humate-bound heavy metals. This precipitate is then treated with ammonia solution until a pH of 10.5–11.0 is reached, forming an ammonium humate solution that serves both as a neutralizing and enriching agent for the processed sediment. The resulting material is subsequently dried to form a stable organomineral fertilizer suitable for use in agriculture. This technology not only allows for the recycling of waste materials but also contributes to the reduction of environmental pollution, the restoration of soil fertility, and the creation of a circular bioeconomy. Implementing such approaches in Uzbekistan's agro-industrial system can play a vital role in enhancing sustainable agricultural practices, improving crop productivity, and preserving the ecological health of our soils for future generations[5].

One of the pressing environmental and agricultural problems in Uzbekistan today is the large accumulation of phosphogypsum waste, a by-product of EFK (phosphate fertilizer) production. During the operation of "Ammofos-Maksam" JSC, more than 700,000 tons of phosphogypsum are generated annually. Currently, the total accumulated stockpile has exceeded 65 million tons, posing serious environmental and land management challenges. However, global experience in the utilization of phosphogypsum demonstrates that this by-product can be an environmentally safe and effective soil amendment. It improves soil's physicochemical properties, enhances structure, and increases nutrient content. For instance, applying 1 ton per hectare of phosphogypsum introduces approximately 265 kg of calcium (Ca), 215 kg of sulfur (S), 20 kg of phosphorus pentoxide (P_2O_5), and 9.8 kg of silicon dioxide (SiO_2) into the soil — all of which play a vital role in maintaining soil health and fertility [6-8].

Considering these beneficial properties, the combined use of phosphogypsum with mineral and organic fertilizers represents a promising direction for sustainable agriculture. This practice not only improves the fertility and structure of degraded soils but also contributes to the reclamation of saline and alkaline lands, which are common in the arid regions of Uzbekistan. The reuse of phosphogypsum as a soil conditioner aligns with the principles of resource efficiency, circular economy, and environmental safety, significantly reducing industrial waste accumulation and transforming it into a valuable agricultural input.

In light of these findings, we have conducted experimental research on developing organomineral fertilizers based on wastewater sediments and phosphogypsum. The purpose of these studies was to identify optimal processing conditions and composition ratios that maximize nutrient availability while minimizing heavy metal content. The resulting organomineral fertilizer demonstrates high agronomic efficiency, combining the nutrient richness of treated wastewater sediments with the calcium and sulfur content of phosphogypsum.

II.METHODOLOGY

To investigate the process of obtaining organomineral fertilizers, the chemical composition of the initial raw materials—wastewater sediments and phosphogypsum—was first analyzed. The composition of wastewater sediments (%) was as follows: moisture – 62.06; ash – 9.03; organic matter – 28.91; humic acids – 4.05; fulvic acids – 7.47; water-soluble organic substances – 3.13; insoluble organic substances – 14.26; P_2O_5 – 1.39; N – 1.17; K_2O – 0.81; and CaO – 4.14. The composition of phosphogypsum (%) was as follows: total P_2O_5 – 0.71; total CaO – 33.46; free CaO – 15.92; water-soluble CaO – 11.26; total SO_3 – 47.98; water-soluble SO_3 – 13.93; and the ratio SO_3 (water-soluble)/SO_3 (total) was 29.03%.

Based on these compositions, several experimental samples were prepared using different mass ratios of wastewater sediments to phosphogypsum: 80:20, 75:25, 70:30, 65:35, and 60:40. Each prepared mixture was treated with nitric acid (HNO_3) until the pH reached between 2.0 and 5.5, promoting partial mineralization and dissolution of calcium phosphates and organic complexes. The resulting suspension was then neutralized with 25% aqueous ammonia to a pH of 7.0, encouraging the formation of ammonium humates and phosphates—key components of the organomineral fertilizer. After neutralization, the samples were dried at 80–90°C until their moisture content reached 15–20%, producing a stable, granulated product ready for analytical and agronomic evaluation.

The chemical analysis of the obtained samples focused on the determination of organic matter, humic acids, fulvic acids, and water-soluble organic substances. The analyses were carried out using standard GOST methodologies: moisture content was determined according to GOST 26712-85, ash content by GOST 26714-85, and organic matter by GOST 27980-80. Humic acids were isolated using 0.1 N alkaline solution treatment, followed by neutralization of the extracted solution with mineral acid, as described in the methods of references. These analytical results form the scientific basis for assessing the efficiency and stability of organomineral fertilizers derived from wastewater sediments and phosphogypsum, offering an environmentally sustainable way to recycle industrial and municipal waste into valuable agricultural inputs.

International Journal of Advanced Research in Science, Engineering and Technology

ISSN: 2350-0328

IJARSET IMPACT FACTOR 7.150

Vol. 12, Issue 11, November 2025

III.RESULTS

According to the obtained data, the content of organic matter in the samples prepared on the basis of wastewater sludge and phosphogypsum depends directly on both the weight ratio and the pH of the medium. As the pH value increases from 2.0 to 5.5, the amount of organic matter in all samples gradually decreases. The highest value was observed in the 80:20 ratio sample at pH 2.0 (22.51 %), while at pH 5.5 it dropped to 19.28 %. Conversely, as the share of phosphogypsum increased — meaning a lower proportion of wastewater sludge — the organic matter content significantly decreased: in the 60:40 ratio, the values were 16.99 % at pH 2.0 and 15.08 % at pH 5.5. This indicates that under strongly acidic conditions, the decomposition of organic compounds occurs more intensively, while the presence of phosphogypsum acts as an inert component that reduces their stability.

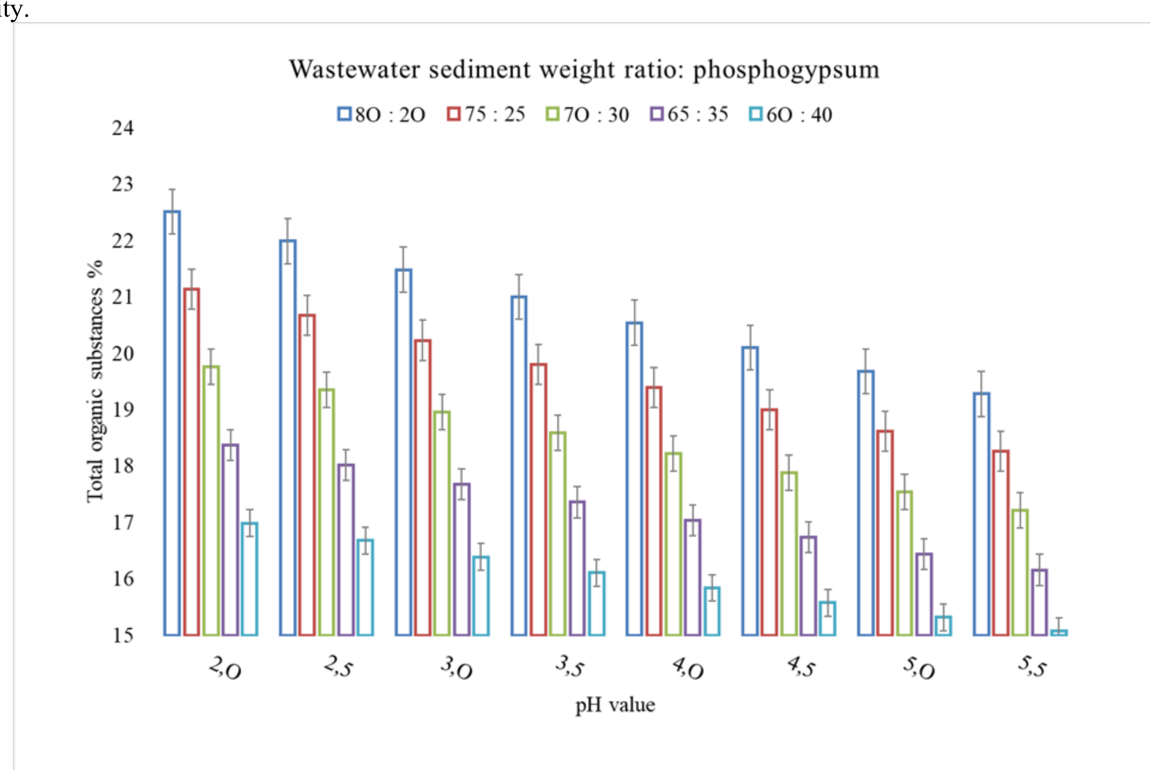

Figure 1. Dependence of the organic matter content in samples prepared from wastewater sludge and phosphogypsum on the weight ratio and pH of the medium.

According to the results shown in Figure 2, the content of humus substances in the samples prepared from wastewater sludge and phosphogypsum is directly influenced by both the weight ratio of the components and the pH of the medium. As the pH increased from 2.0 to 5.5, the humus content consistently decreased across all compositions, indicating the gradual decomposition or transformation of humic substances under less acidic conditions. The highest humus content was observed in the 80:20 ratio sample at pH 2.0 (11.4 %), while the lowest value appeared at pH 5.5 (9.8 %). When the phosphogypsum fraction increased and the proportion of wastewater sludge decreased, the overall humus content dropped markedly — for instance, in the 60:40 ratio, the humus content declined from 8.6 % (pH 2.0) to 7.7 % (pH 5.5). This demonstrates that humic substances mainly originate from the organic-rich wastewater sludge, while phosphogypsum acts as a mineral diluent, reducing organic enrichment.

International Journal of Advanced Research in Science, Engineering and Technology

ISSN: 2350-0328

Vol. 12, Issue 11, November 2025

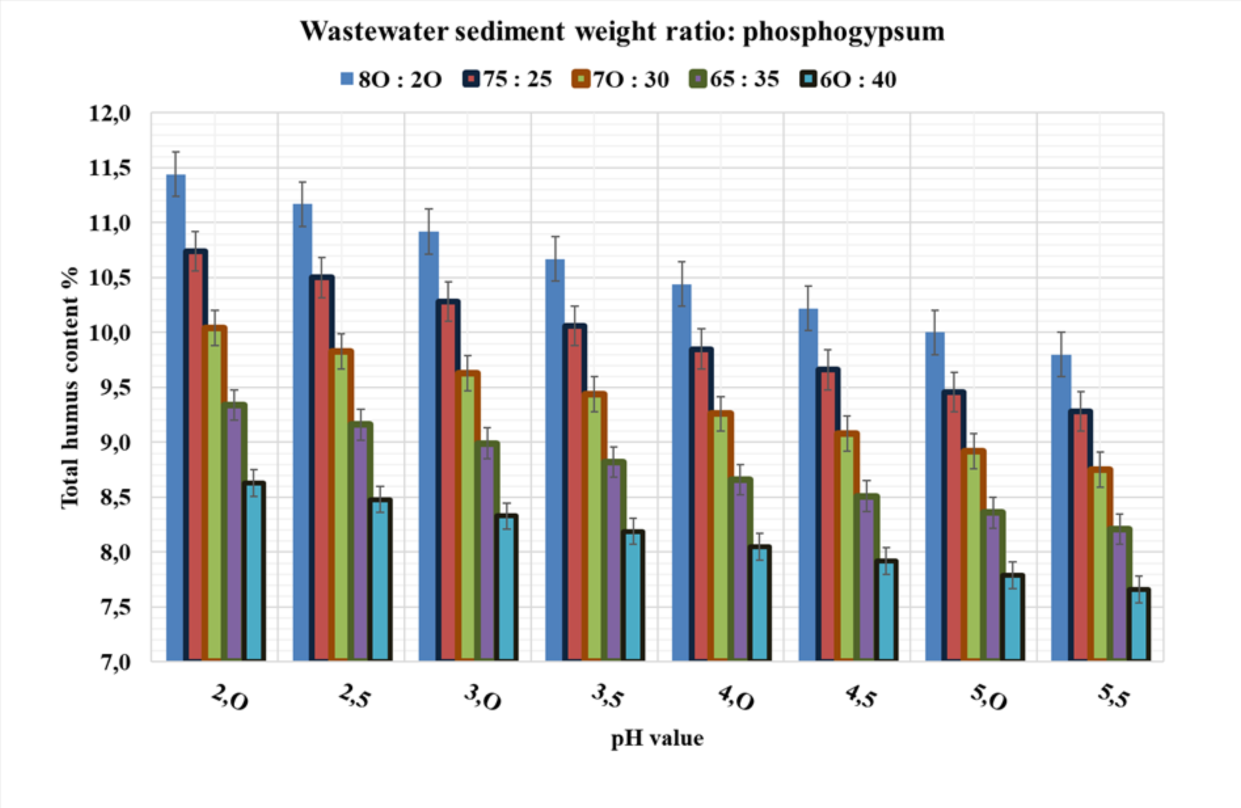

Figure 2. Dependence of the humus content variation in samples prepared from wastewater sludge and phosphogypsum on the weight ratio and pH of the medium.

IV.CONCLUSION

The results of the conducted research showed that the combined processing of wastewater sludge and phosphogypsum makes it possible to obtain nutrient-rich, environmentally friendly organomineral fertilizers. The analysis of the samples revealed that both the weight ratio and the pH of the medium have a direct impact on the transformation degree of organic matter and humus compounds: as the proportion of phosphogypsum increased, the content of organic substances decreased, while the optimal conditions were observed at a pH range of 2–3 and with a wastewater sludge share of 70–80%. Under these conditions, the stability of humic and fulvic acids was higher, which enhanced the agrochemical and biological activity of the resulting organomineral fertilizers. Moreover, acid treatment with nitric acid followed by neutralization with ammonia ensured the conversion of sulfur into sulfate forms, thereby increasing its bioavailability. Overall, this technology demonstrates significant potential for improving soil fertility and protecting the environment through the efficient recycling of wastewater sludge and phosphogypsum.

REFERENCES

1. Kulikowska, D., & Bernat, K. Sewage sludge composting: A review on process monitoring, stability and maturity // *Applied Sciences*. – 2020. – T.10. – №13. – P. 1–25.

2. Bouhia, Y., Oukarroum, A., & Elghnidi, Y. Organo-mineral fertilizers: Current knowledge on their agronomic efficiency and environmental behavior // *Agronomy*. – 2022. – T.12. – №10. – P. 1–18.

3. Food and Agriculture Organization (FAO). Voluntary Guidelines for Sustainable Soil Management (VGSSM). – Rome: FAO, 2017. – 123 p.

4. Rather, I. A., Khan, S. A., & Ahmad, M. Organomineral vs. synthetic fertilizers: Agronomic performance and environmental implications – A systematic review // *Soil Systems*. – 2024. – T.8. – №2. – P. 1–21.

5. Rühlmann, J., Körschens, M., & Zeyer, J. Organo-mineral fertilizers in European agriculture: State of the art and perspectives // *Agronomy*. – 2024. – T.14. – №3. – P. 1–20.

6. Santos, J. A., Dinis, P. A., & Figueiredo, B. R. Phosphogypsum amendments in agriculture: A review on effects, risks, and management // *Frontiers in Environmental Science*. – 2021. – №9. – P. 1–15.

7. Nasr, A., El-Deeb, M., & Ibrahim, A. Phosphogypsum as a soil amendment: Environmental risks and opportunities – A review // *International Journal of Agronomy*. – 2022. – №2022. – P. 1–12.

8. Łapiński, M., Grabowski, M., & Wysocka, I. Phosphogypsum-based soil amendments co-applied with organic manures: Effects on nutrient availability and trace elements // *Chemical Engineering Journal Advances*. – 2024. – T.17. – P. 1–12.