

**TECHNOLOGICAL AND ECONOMIC ADVANTAGES OF POTASSIUM SULFATE
PRODUCTION BASED ON LOCAL RAW MATERIALS OF UZBEKISTAN**

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Abstract

This article presents a scientific analysis of the technological and economic aspects of potassium sulfate (K_2SO_4) production based on locally available mineral raw materials in Uzbekistan. The study examines the types of potassium-bearing raw materials, their processing technologies, production efficiency, and key economic performance indicators. The results demonstrate that the utilization of local resources enables import substitution, reduces production costs, and ensures a stable supply of essential mineral fertilizers for agricultural use.

Keywords

potassium sulfate, local raw materials, mineral fertilizers, technological process, economic efficiency.

**ТЕХНОЛОГИЧЕСКИЕ И ЭКОНОМИЧЕСКИЕ ПРЕИМУЩЕСТВА
ПРОИЗВОДСТВА СУЛЬФАТА КАЛИЯ НА ОСНОВЕ МЕСТНОГО СЫРЬЯ
УЗБЕКИСТАНА**

Аннотация

В данной статье на научной основе проанализированы технологические и экономические аспекты производства сульфата калия (K_2SO_4) на основе местного минерального сырья, имеющегося на территории Республики Узбекистан. В ходе исследования рассмотрены виды калийсодержащего сырья, технологии их переработки, производственная эффективность, а также показатели экономической целесообразности. Полученные результаты показывают, что использование местных ресурсов позволяет обеспечить импортозамещение, снизить себестоимость производства и создать устойчивую систему обеспечения сельского хозяйства важными минеральными удобрениями.

Ключевые слова

сульфат калия, местное сырьё, минеральные удобрения, технологический процесс, экономическая эффективность.

Introduction: Potassium sulfate is an important mineral fertilizer widely used in agriculture, particularly valued for its low chloride content. It plays a crucial role in the cultivation of fruit and vegetable crops, cotton, and industrial crops. At present, the demand for potassium fertilizers in Uzbekistan's agriculture is steadily increasing. However, a significant portion of potassium sulfate consumed is still covered by imports.

Uzbekistan possesses potassium-rich salts, mirabilite, langbeinite, and other sulfate mineral resources, which can be processed to produce potassium sulfate. Utilizing local raw materials is not only technologically feasible but also economically and strategically important.

Literature Review: Scientific studies on the production and application of potassium sulfate (K_2SO_4) primarily focus on its agronomic efficiency, production technologies, as well as economic and environmental aspects. Research results indicate that potassium sulfate, as a low-chloride fertilizer, is preferable to potassium chloride for crops sensitive to salinity [1,2].

In international literature, the Mannheim process is widely described as a major industrial method for producing potassium sulfate, in which potassium chloride reacts with sulfuric acid. However, due to the high temperatures and significant energy consumption involved, many researchers have focused on developing alternative, lower-energy methods [3].

In recent years, technologies for obtaining potassium sulfate from natural potassium-magnesium and sulfate-containing mineral raw materials have emerged as a distinct field of research. Studies have shown that processing minerals such as langbeinite ($K_2SO_4 \cdot 2MgSO_4$) and similar compounds using selective crystallization achieves high product yield with relatively low environmental impact [4,5].

Research conducted by scientists from the Commonwealth of Independent States (CIS) has demonstrated that producing potassium sulfate from local potassium-magnesium deposits is economically efficient. In particular, reduced costs for raw material extraction and transportation have a direct positive effect on production costs [6].

Uzbek scientists have highlighted the complex processing of local mineral resources, as well as the production of mineral fertilizers from salt deposits and sulfate-containing raw materials [7,8]. Nevertheless, the analysis of existing studies indicates that the technological and economic advantages of producing potassium sulfate specifically from local raw materials have not been systematically and comprehensively addressed.

This study aims to fill this scientific gap by evaluating, on a scientific basis, the technological and economic advantages of producing potassium sulfate from local raw materials in Uzbekistan. The main objective of this research is to analyze the technological processes of potassium sulfate production under Uzbekistan's conditions and to assess their economic benefits scientifically.

Materials and Methods: In this study, potassium- and sulfate-containing mineral raw materials found in Uzbekistan - including potassium-magnesium salts, mirabilite, gypsum, and other minerals - were selected as the primary research objects. The evaluation of production technologies was carried out using the following methods:

- Analysis of the chemical and mineralogical composition of local raw materials;
- Comparative assessment of existing industrial technologies for potassium sulfate production, including sulfatization, ion-exchange, and crystallization;
- Calculation of the energy consumption and material balance of technological processes;
- Economic evaluation, including determination of production cost, capital and operational expenditures, and profitability indicators.

The data analysis was based on publicly available scientific sources, industry statistics, and technical-economic calculations [9]. In this study, potassium- and sulfate-containing minerals from Uzbekistan were selected as the main raw materials.

Table 1.

Mineral Raw Materials Studied and Their Characteristics

Type of Mineral Raw Material	Main Components	Problematic Features (Heterogeneity)	Impact on Technology
Potassium-	K^+ , Mg^{2+} , Cl^- ,	High Mg^{2+} and Cl^-	Complicates separation;

magnesium salts	SO ₄ ²⁻	content	additional purification required
Mirabilite	Na ₂ SO ₄ ·10H ₂ O	High moisture, mixed phases	Increases evaporation energy
Gypsum	CaSO ₄ ·2H ₂ O	Carbonate and silicate impurities	Reduces reactivity
Other sulfate minerals	SO ₄ ²⁻ -based salts	Variable mineral composition	Affects process stability

Model calculations were based on the average chemical composition of raw materials and the assumed process yields. However, the high heterogeneity of the raw materials—such as elevated Mg²⁺ and Cl⁻ ions in potassium-magnesium salts, moisture and mixed phases in mirabilite and gypsum deposits, and the presence of carbonate and silicate components - can lead to significant deviations under real industrial conditions [10].

The evaluation of production technologies was carried out using the following approaches:

- **Sulfatization:** Characterized by a low production cost, but the separation of by-products was not fully reflected in the model; additional filtration and precipitation may be required.
- **Ion-exchange:** A technology with high yield and low energy consumption; however, chemical degradation of resins and waste generation during regeneration were considered [11,12].
- **Crystallization:** Equipment design is simple and relatively insensitive to raw material composition, but the evaporation stage is highly energy-intensive.

Energy consumption was calculated only for the main technological processes; in actual production, stages such as neutralization of waste solutions, water recycling, and drying of residues can significantly affect the overall energy balance.

Table 2.

Comparative Analysis of Potassium Sulfate Production Technologies

Technology type	Advantages	Disadvantages	Energy requirement
Sulfatization	Low production cost, relatively simple technology	By-products require separation; additional filtration needed	Medium
Ion-Exchange	High yield, energy-efficient	Resin degradation; waste generation during regeneration	Low
Crystallization	Simple equipment, less sensitive to raw material composition	Evaporation stage is highly energy-intensive	High

The economic assessment in the model assumes stable prices for raw materials and energy. However, under real conditions, price fluctuations, dependence on imported reagents, and logistical constraints must be taken into account.

This approach highlights the necessity of critically considering raw material variability, process stability, and environmental constraints when selecting a technology for potassium sulfate production based on local raw materials.

Results: The study results indicate that potassium sulfate production based on local raw materials in Uzbekistan is technologically feasible. In particular, processing potassium-magnesium salts via the sulfatization method was found to be highly efficient [13].

Technological analysis revealed the following:

- Utilizing local raw materials significantly reduces logistics costs;

- Energy consumption in production is 10–15% lower compared to technologies based on imported raw materials;
- The yield of potassium sulfate can reach approximately 85–90%.
Economic analysis showed that:
- The production cost of potassium sulfate from local raw materials is lower than that of imported products;
- Substituting imports can save foreign currency;
- Local production contributes to the creation of new jobs and the development of regional industry.

Table 3.

Comparison of Logistics and Energy Consumption for Technologies Based on Imported and Local Raw Materials

Parameter	Technology Based on Imported Raw Materials	Technology Based on Local Raw Materials	Difference
Raw material transport distance, km	1500–3000	100–300	5–10 times shorter
Logistics cost, \$/t product	40–50	10–15	↓ 65–75 %
Energy consumption, GJ/t K ₂ SO ₄	7.5	6.4–6.7	↓ 10–15 %
Energy cost, \$/t	75	63–67	↓ 8–12 \$

Table 4.

Generalized Technological and Economic Indicators of Potassium Sulfate Production Based on Sulfatization of Potassium-Magnesium Salts

Assessment Area	Key Indicator	Value	Overall Evaluation
Raw Material Base	Type of raw material	K–Mg salts (local)	Stable and available
Technology	Processing method	Sulfatization	Industrially reliable
	Yield, %	85–90	High efficiency
Economic Indicators	Raw material consumption, t/t K ₂ SO ₄	1.15–1.25	Standard
	Additional stages	Filtration, precipitation	Technologically simple
	Product cost, \$/t	232	Competitive
Macroeconomic Impact	Cost of imported product, \$/t	370	High
	Cost difference, \$/t	≈138	≈37% lower
	Import substitution, thousand t/y	100	Strategically significant
Overall Evaluation	Foreign currency savings, \$ mln/y	13–14	Positive
	New jobs created	80–120	Social benefits
Overall Evaluation	Economic efficiency	Positive	Sustainable profitability

The generalized data presented in Table 4 indicate that processing local potassium-magnesium salts in Uzbekistan via the sulfatization method is both technologically and

economically feasible. The technology has been tested in industrial practice and ensures a potassium sulfate yield of 85–90%, demonstrating the high efficiency of the process.

Economic analysis shows that potassium sulfate produced from local raw materials has a production cost of \$232/t, which is approximately 37% lower than that of imported products. This difference is primarily explained by the significant reduction in raw material and logistics costs.

Furthermore, under production conditions of 100,000 tons per year, foreign currency savings of \$13–14 million can be achieved, and 80–120 new jobs can be created. This highlights the not only economic but also social significance of this technology.

Overall, the results of the generalized table confirm that potassium sulfate production based on local raw materials is an import-substituting, competitive, and sustainably profitable technology.

Discussion: The results of this study indicate that the production of potassium sulfate from locally available potassium-magnesium raw materials in Uzbekistan is technologically feasible. In particular, processing potassium-magnesium salts via the sulfatization method demonstrates high efficiency and is considered a reliable technology in industrial practice.

According to the data in Table 3, the use of local raw materials significantly reduces the raw material transport distance and lowers logistics costs by 65–75%. At the same time, energy consumption is 10–15% lower compared to technologies based on imported raw materials, thereby enhancing the energy efficiency of the process.

The generalized indicators presented in Table 4 show that the potassium sulfate yield in the sulfatization process is approximately 85–90%. The raw material consumption of 1.15–1.25 t/t K_2SO_4 confirms that the technology is both normative and economically feasible. A product cost of \$232/t indicates that locally produced potassium sulfate is approximately 37% cheaper than imported products.

From a macroeconomic perspective, an annual production of 100,000 tons of potassium sulfate could save \$13–14 million in foreign currency. Moreover, establishing local production would create 80–120 new jobs, positively impacting regional industrial development.

Overall, the results confirm that potassium sulfate production based on local raw materials is an import-substituting, energy-efficient, and economically viable solution.

Conclusion: The production of potassium sulfate based on locally available mineral raw materials in Uzbekistan is both technologically and economically efficient. The study results demonstrate that this approach is of significant importance for supplying agriculture with high-quality mineral fertilizers, substituting imports, and enhancing the stability of the national economy.

Future work should focus on improving these technologies, implementing them at an industrial scale, and enhancing their environmental sustainability through additional scientific research.

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