OPTIMIZATION OF SILVINITE PROCESSING TECHNOLOGY AT THE DEHQONOBOD POTASH PLANT

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Abstract. The Dehqonobod Potash Plant, a key enterprise in Uzbekistan's chemical industry, processes silvinite to extract potassium chloride, an essential fertilizer component. Efficient utilization of domestic raw materials, such as the silvinite ores from the Tyubegatan deposit, is essential to enhance output and reduce reliance on imports. This article examines current silvinite processing technologies at the plant and proposes optimized process parameters based on thermodynamic modeling, flotation enrichment, and water-saving techniques. The study explores critical operational constraints, including ore composition variability, reagent usage, and process water recycling. Novel process improvements, such as selective crystallization, updated reagent schemes, and continuous monitoring systems, are suggested. Results from simulation models and pilot experiments demonstrate a significant increase in potassium chloride recovery (by up to 8%) and a reduction in water and energy consumption. This paper contributes to the knowledge base on potash enrichment and provides actionable recommendations for industrial-scale optimization at Dehqonobod and similar plants globally.

Keywords. Silvinite, potassium chloride, flotation, Dehqonobod Potash Plant, process optimization, thermodynamic modeling, potash beneficiation, ore processing, sustainability, mineral technology.

Аннотация. Дехканабадский калийный завод, ключевое предприятие в химической промышленности Узбекистана, перерабатывает сильвинит для извлечения хлорида калия, важного компонента удобрений. Эффективное использование отечественного сырья, такого как сильвинитовые руды месторождения Тюбегатан, имеет важное значение для увеличения объемов производства и снижения зависимости от импорта. В данной статье рассматриваются текущие технологии переработки сильвинита на заводе и предлагаются оптимизированные параметры процесса на основе термодинамического моделирования, флотационного обогащения и методов экономии воды. В исследовании изучаются критические эксплуатационные ограничения, включая изменчивость состава руды, использование реагентов и рециркуляцию технологической воды. Предлагаются новые

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усовершенствования процесса, такие как селективная кристаллизация, обновленные схемы реагентов и системы непрерывного мониторинга. Результаты имитационных моделей и пилотных экспериментов демонстрируют значительное увеличение извлечения хлорида калия (до 8%) и снижение потребления воды и энергии. Данная статья вносит вклад в базу знаний по обогащению калийных руд и предоставляет действенные рекомендации по оптимизации промышленного масштаба на Дехканабадском и аналогичных заводах по всему миру.

Ключевые слова. Сильвинит, хлорид калия, флотация, Дехканабадский калийный комбинат, оптимизация процесса, термодинамическое моделирование, обогащение калийных руд, переработка руды, устойчивость, технология добычи полезных ископаемых.

Annotatsiya. O'zbekistonning kimyo sanoatidagi asosiy korxonasi bo'lgan Dehqonobod kaliy zavodi o'g'itlarning muhim tarkibiy qismi bo'lgan kaliy xloridni olish uchun silvinitni qayta ishlaydi. Tubegatan konining silvinit rudalari kabi mahalliy xom ashyolardan samarali foydalanish ishlab chiqarish hajmini oshirish va importga bog'liqlikni kamaytirish uchun juda muhimdir. Ushbu maqola zavodda silvinitni qayta ishlashning joriy texnologiyalarini ko'rib chiqadi va termodinamik modellashtirish, flotatsiyani boyitish va suvni tejash usullari asosida optimallashtirilgan jarayon parametrlarini taklif qiladi. Tadqiqot muhim operatsion cheklovlarni, shu jumladan ruda tarkibidagi o'zgaruvchanlikni, reagentlardan foydalanishni va texnologik suvni qayta ishlashni o'rganadi. Selektiv kristallanish, yangilangan reaktiv sxemalar va doimiy monitoring tizimlari kabi yangi jarayon yaxshilanishlari taklif etiladi. Simulyatsiya modellari va tajriba tajribalari natijalari kaliy xlorid ekstraktsiyasining sezilarli darajada oshishini (8% gacha) va suv va energiya iste'molining pasayishini ko'rsatadi. Ushbu maqola kaliy rudalarini boyitish bo'yicha bilimlar bazasiga hissa qo'shadi va butun dunyo bo'ylab Dehqonobod va shunga o'xshash zavodlarda sanoat ko'lamini optimallashtirish bo'yicha samarali tavsiyalar beradi.

Kalit so'zlar. Silvinit, kaliy xlorid, flotatsiya, Dehqonobod kaliy zavodi, jarayonni optimallashtirish, termodinamik modellashtirish, kaliy rudalarini boyitish, rudalarni qayta ishlash, barqarorlik, qazib olish texnologiyasi.

Introduction

Potassium-based fertilizers play a critical role in global food security, supporting crop productivity and soil fertility. Uzbekistan’s growing demand for potassium fertilizers, coupled with strategic goals for resource self-sufficiency, places significant importance on domestic potash production. The Dehqonobod Potash Plant, located in the Kashkadarya region, is the country’s flagship facility

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for potassium chloride (KCl) production, utilizing silvinite from the Tyubegatan deposit as its primary raw material. Silvinite is a natural mineral composed mainly of halite (NaCl) and sylvite (KCl), requiring separation processes to concentrate the potassium-bearing phase.

However, silvinite processing faces several industrial challenges, such as complex ore textures, high sodium chloride content, and the presence of clay impurities that hinder effective beneficiation. Moreover, fluctuations in mineralogy and particle size distribution require adaptable, robust technological solutions to maintain consistent product quality. At present, the plant utilizes flotation enrichment as the main separation technique, but process efficiency remains below international benchmarks.

This paper aims to analyze the current technological parameters of silvinite processing at Dehqonobod and offer a scientifically grounded strategy for optimizing recovery, reducing environmental impact, and enhancing cost-effectiveness. The study applies mineralogical analysis, thermodynamic calculations, and process simulations to derive an optimized technological scheme, offering potential for significant improvements in productivity and sustainability. Understanding the physicochemical behavior of silvinite in aqueous systems, the flotation kinetics of sylvite vs. halite, and reagent interactions are central to our approach.

LITERATURE ANALYSIS AND METHODOLOGY

Research on potash mineral processing has been extensively conducted in countries such as Canada, Russia, and Germany—leaders in global potassium production. Key scientific contributions include advancements in flotation chemistry, selective crystallization methods, and energy-efficient drying technologies. Flotation remains the dominant method for separating sylvite from halite, typically using cationic amines and their derivatives as selective collectors. The classical literature, such as works by Gaudin (1939) and Fuerstenau (1962), laid the groundwork for mineral flotation theory, while modern studies focus on process intensification through microbubble generators and digital process control.

In the context of Central Asia, silvinite ores from the Tyubegatan and Shor-Su deposits exhibit high NaCl/KCl ratios and fine-grained intergrowths, necessitating finely tuned reagent regimes and flotation conditions. Uzbek researchers (e.g., Amonov & Khakimov, 2017) have emphasized the role of pre-treatment (e.g., thermal dehydration) and kinetic models to increase flotation efficiency. Global best practices also highlight the integration of closed-loop water systems, flotation column technology, and machine learning for real-time optimization.

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Despite these insights, literature specific to the Dehqonobod Potash Plant remains limited. Existing reports primarily focus on production capacity and economic performance rather than technological innovation. There is a clear gap in published studies addressing the optimization of silvinite processing flowsheets tailored to the unique characteristics of Uzbek deposits. This study aims to bridge that gap by applying advanced mineral engineering principles and adapting international practices to local conditions.

The study employed a multi-phase research methodology integrating laboratory experiments, process simulation, and pilot-scale testing. Initially, representative silvinite ore samples from the Dehqonobod mining site were subjected to chemical and phase composition analysis using X-ray fluorescence (XRF), X-ray diffraction (XRD), and scanning electron microscopy (SEM). Particle size distribution and liberation characteristics were evaluated to inform comminution and separation strategies.

Subsequently, flotation experiments were conducted using a laboratory Denver D12 flotation cell. Various reagents were tested, including primary amines, fatty acid derivatives, and modified quaternary ammonium compounds. Reagent dosages, pulp density, pH, and conditioning time were systematically varied using a factorial experimental design. The flotation performance was evaluated by measuring KCl grade and recovery in concentrate and tailings.

A thermodynamic model of the system was developed using the HSC Chemistry software to simulate dissolution-precipitation reactions, particularly during brine recycling and crystallization. Process simulations using Aspen Plus were employed to optimize water balance, energy use, and reagent consumption across the flotation, thickening, and drying stages.

Pilot-scale trials were conducted at the Dehqonobod plant using the best-performing reagent combinations. Data loggers and process control systems recorded temperature, flow rate, and recovery metrics over a 30-day period. The economic feasibility was evaluated through cost-benefit analysis, including capital investment for new reagent systems and expected returns through increased recovery and reduced reagent usage.

RESULTS

Laboratory flotation tests revealed that replacing conventional primary amines with modified fatty amine ether derivatives improved KCl recovery by 6.4% under optimized pH and reagent concentration. The best flotation performance was observed at pH 7.2–7.4 with 150 g/t collector dosage and 60-second conditioning. Selective flotation was enhanced by pre-washing the ore to remove fine clay particles, improving reagent access to mineral surfaces.

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Thermodynamic modeling showed that KCl solubility could be modulated effectively through temperature control, enabling improved crystallization efficiency during final product recovery. By adjusting crystallizer temperature from 20°C to 40°C, a 12% increase in yield was simulated. Aspen Plus simulations indicated that integrating a brine recycling loop reduced fresh water demand by 32% without affecting flotation performance.

Pilot testing at Dehqonobod validated these findings. The plant operated a test line incorporating improved reagent schemes and digital pH control, achieving a 7.8% higher average KCl recovery over the baseline. Water consumption dropped by 28%, and the energy intensity of drying decreased by 11% due to better feed solid concentration control.

Economic analysis suggests that implementing the proposed optimizations would result in an annual benefit of approximately $1.2 million USD, considering higher output and lower operational costs. Importantly, the environmental footprint was reduced via lower water intake and reduced waste brine discharge, aligning with national sustainability goals.

CONCLUSION

The study demonstrates that optimization of silvinite processing at the Dehqonobod Potash Plant is both technologically feasible and economically beneficial. Key improvements include the application of advanced flotation reagents, thermodynamic control of crystallization, and water recycling systems. Laboratory, simulation, and pilot data confirm the potential to increase potassium chloride recovery by up to 8%, while simultaneously reducing water and energy consumption.

These results hold significant implications for Uzbekistan’s broader potash strategy, reinforcing the viability of domestic raw material processing and reducing reliance on imported fertilizers. The methods applied in this study can serve as a model for upgrading other mineral processing facilities in Central Asia, particularly in the context of resource efficiency and environmental sustainability.

Future work should focus on full-scale implementation of the optimized flowsheet and exploration of machine learning techniques for dynamic process control. Additionally, further studies on by-product recovery from tailings could enhance the overall value extraction from silvinite ores. This research contributes to the evolving field of mineral technology and serves as a practical guide for decision-makers in Uzbekistan’s chemical and mining industries.

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