BENEFICIATION OF SILVINITE ORES BY HALURGICAL METHOD

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Abstract

The halurgical method, also known as the thermal-solution treatment, represents an alternative route for potash extraction from silvinite ores, especially in deposits where flotation efficiency is limited due to fine intergrowths or high halite content. This approach involves dissolving potassium chloride selectively from crushed ore by manipulating temperature, solution concentration, and crystallization conditions. The present thesis examines the principles, process flow, and technological parameters of silvinite beneficiation through halurgical processing. The study outlines key stages including ore dissolution in saturated brine, selective crystallization of KCl, and recovery of high-purity potassium salts. Special attention is paid to thermodynamic modeling, energy requirements, and brine recycling. The halurgical method is evaluated in terms of its industrial applicability, energy efficiency, and environmental impact. The findings show that with appropriate control over temperature and brine composition, the halurgical method can achieve over 90% KCl recovery, offering a viable complement to flotation-based techniques in specific geological settings.

Keywords. Silvinite, halurgical method, potash beneficiation, potassium chloride, thermal-solution treatment, crystallization, brine processing, KCl recovery.

Аннотация

Галургический метод, также известный как термическая обработка раствором, представляет собой альтернативный путь извлечения калия из сильвинитовых руд, особенно в месторождениях, где эффективность флотации ограничена из-за мелких сростков или высокого содержания галита. Этот подход включает селективное растворение хлорида калия из измельченной руды путем манипулирования температурой, концентрацией раствора и условиями кристаллизации. В настоящей диссертации рассматриваются принципы, технологический процесс и технологические параметры обогащения сильвинита посредством галургической обработки. В исследовании излагаются ключевые этапы, включая растворение руды в насыщенном рассоле, селективную

кристаллизацию KCl и извлечение высокочистых калийных солей. Особое внимание уделяется термодинамическому моделированию, энергетическим потребностям и переработке рассола. Галургический метод оценивается с точки зрения его промышленной применимости, энергоэффективности и воздействия на окружающую среду. Результаты показывают, что при соответствующем контроле температуры и состава рассола галургический метод позволяет достичь извлечения более 90% KCl, что является эффективным дополнением к методам, основанным на флотации, в определенных геологических условиях.

Ключевые слова. Сильвинит, галургический метод, обогащение калийных солей, хлорид калия, терморастворная обработка, кристаллизация, переработка рассола, извлечение KCl.

Introduction. Potassium chloride, extracted from potash ores such as silvinite, plays a vital role in global agriculture as a primary nutrient in compound fertilizers. Conventionally, silvinite is processed using flotation techniques to separate sylvite (KCl) from halite (NaCl). However, flotation efficiency diminishes significantly when the ore contains fine-grained intergrowths, excessive clay content, or variable mineral textures. In such cases, the halurgical method—based on differential solubility and temperature control—presents a viable alternative for potash extraction.

The halurgical approach leverages the contrasting solubility behaviors of sylvite and halite in saturated brines at varying temperatures. Unlike flotation, which relies on surface chemistry and reagent interaction, halurgical processing employs controlled dissolution, cooling crystallization, and mechanical separation to recover potassium salts. This method is particularly suitable for silvinite ores that are difficult to float or for processing tailings from flotation plants.

This thesis explores the technological stages, thermodynamic fundamentals, and operational variables of the halurgical method. By analyzing its potential for integration into existing processing systems, this study evaluates whether halurgical beneficiation can enhance overall potash recovery and support more sustainable mineral resource management.

Main part. The halurgical method consists of several key stages designed to dissolve and selectively recrystallize potassium chloride from silvinite ores. These stages include:

1. *Ore Preparation and Crushing*. The silvinite ore is first crushed to particles smaller than 5 mm. This size range facilitates rapid and uniform dissolution of the

mineral components in brine. Pre-treatment also includes screening and removal of insoluble components such as clays and carbonates.

2. *Preparation of Saturated Brine*. A saturated NaCl brine is prepared to act as a solvent medium. This brine minimizes unwanted dissolution of halite while promoting the selective solubilization of KCl. Temperature control is critical, as KCl solubility increases with temperature, while halite solubility remains relatively stable.

3. *Thermal Leaching (Hot Dissolution)*. The crushed ore is leached with hot brine at temperatures ranging from 70°C to 100°C. At these temperatures, potassium chloride readily dissolves into the solution, leaving most of the NaCl undissolved due to its lower solubility differential.

4. *Cooling and Crystallization*. The KCl-rich solution is then cooled under controlled conditions (typically 20–40°C), prompting the crystallization of sylvite. The rate of cooling and agitation determines the size and purity of the formed crystals. Nucleation and crystal growth kinetics are managed to favor KCl over NaCl.

5. *Solid-Liquid Separation and Drying*. The KCl crystals are separated using hydrocyclones, centrifuges, or vacuum filters. Residual brine is recycled, and the KCl product is dried to obtain fertilizer-grade material.

6. *Brine Recycling and Waste Management*. Spent brine is re-concentrated and reused in the cycle to reduce environmental discharge. Insoluble tailings are either neutralized or disposed of in dry form. Modern halurgical systems integrate heat exchangers and closed-loop brine systems to improve thermal efficiency.

Thermodynamic Considerations. Using HSC Chemistry modeling, the solubility of KCl and NaCl was calculated across a range of temperatures. The data confirm a favorable window for selective dissolution and crystallization. The energy demand of the process depends largely on the thermal gradient and the efficiency of the crystallization step.

Industrial Applicability. Halurgical beneficiation is already used in regions with high-salinity ores, including parts of China and Russia. It is particularly useful when the ore is too fine-grained or impure for flotation. The method can be integrated into existing flotation plants to treat tailings or low-grade ores.

Conclusion. The halurgical method of potash beneficiation presents an effective, technically viable alternative to traditional flotation, particularly for silvinite ores with complex mineralogical characteristics. By utilizing temperature-controlled dissolution and crystallization, this process can achieve high recoveries of potassium chloride with minimal environmental burden.

Key advantages of the halurgical approach include its adaptability to fine-grained ores, potential for high product purity, and compatibility with closed-cycle brine systems that conserve water and minimize waste. Moreover, thermodynamic control allows precise targeting of KCl solubility zones, enhancing process predictability and product consistency.

While the energy requirements are significant, especially for heating and cooling stages, modern heat recovery systems and renewable energy integration offer pathways for improving sustainability. When applied strategically, halurgical processing can complement flotation to maximize potash recovery and support comprehensive resource utilization strategies.

Future directions include the integration of real-time monitoring tools, machine learning-based crystallization control, and hybrid schemes that combine halurgical and flotation processes. With further refinement, the halurgical method may play an increasingly prominent role in global potash production.

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