

INTEGRATED GEOTECHNOLOGICAL APPROACHES FOR EFFICIENT PROCESSING AND ENVIRONMENTAL MANAGEMENT OF POTASH DEPOSITS

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Abstract. Salt deposits belong to sedimentary rocks and are formed through long-term evaporation of seawater. They mainly consist of chlorides and sulfates of alkali and alkaline-earth metals. Potash deposits may contain either halogen-rich or sulfate-rich minerals, as well as mixed potassium-bearing rocks. Due to the high solubility of potash minerals, their development requires integrated geotechnological approaches that consider both mining conditions and ore processing methods for effective extraction and enrichment.

Keywords: Potash industry, Salt deposits, Geotechnological approaches, Sedimentary rocks, Mineral solubility, Ore processing, Potassium-bearing ores

Introduction

Potassium is one of the essential macronutrients required for plant growth and development, playing a key role alongside nitrogen and phosphorus in increasing agricultural productivity. In recent decades, the demand for potash fertilizers has increased significantly, with global consumption showing an average growth rate of approximately 8–10%. This growth is driven by the need to improve crop yields and ensure food security for the rapidly increasing world population.

Potash deposits have been exploited for more than a century, with mining depths typically ranging from 300 to 2000 meters depending on geological conditions. Traditional extraction methods include underground mining using drilling and blasting techniques, as well as solution mining applied in deeper ore horizons. The choice of mining method is largely determined by the mineral composition, structural characteristics, and solubility of the ore.

Global potash production has demonstrated steady growth, supported by advances in mining technologies and increased efficiency of ore processing. However, potash mining is associated with a range of environmental challenges. These include groundwater infiltration into mine workings, land subsidence, and the accumulation of solid and liquid waste. Studies indicate that mining activities can increase salinity levels in surface and groundwater systems, sometimes exceeding natural background concentrations by several times, while discharge of highly mineralized brines may reach tens of grams per liter.

Table 1. Global potash production and reserves

Country	Production (2011)	Production (2024)	Reserves
Belarus	5500	8000	750,000
Brazil	454	210	2,300
Canada	11,000	14,000	1,100,000
Chile	980	900	100,000
China	3700	6000	350,000
Germany	3010	2300	150,000
Israel	1960	2300	Large
Jordan	1380	1600	Large
Laos	-	300	75,000
Russia	6500	9000	400,000
Spain	420	400	68,000
United States	1000	480	220,000



Uzbekistan	-	200	Unknown
Other countries	-	370	300,000
World total	36,400	46,000	>3,500,000

The environmental impact of potash production also affects soil properties and vegetation, often leading to the formation of salt-affected areas and changes in ecosystem balance. At the same time, improper waste management and insufficient monitoring of mining processes can intensify these negative effects. Despite the availability of various mitigation measures, including backfilling technologies and improved waste disposal systems, comprehensive and integrated approaches to environmental protection in potash mining remain insufficiently developed.

Materials and Methods

This study is based on a comprehensive analysis of scientific literature, experimental data, and industrial practices related to potash mining and processing. A wide range of sources in the fields of mining engineering, mineral processing, environmental science, and waste management were reviewed to identify the key technological and environmental aspects of potash production.

The research methodology includes a comparative analysis of existing mining and beneficiation technologies, with a focus on underground extraction of water-soluble ores and subsequent processing methods such as flotation and halurgical treatment. Special attention is given to the physicochemical characteristics of potash ores, including their mineral composition, solubility, and behavior under different geological and hydrogeological conditions.

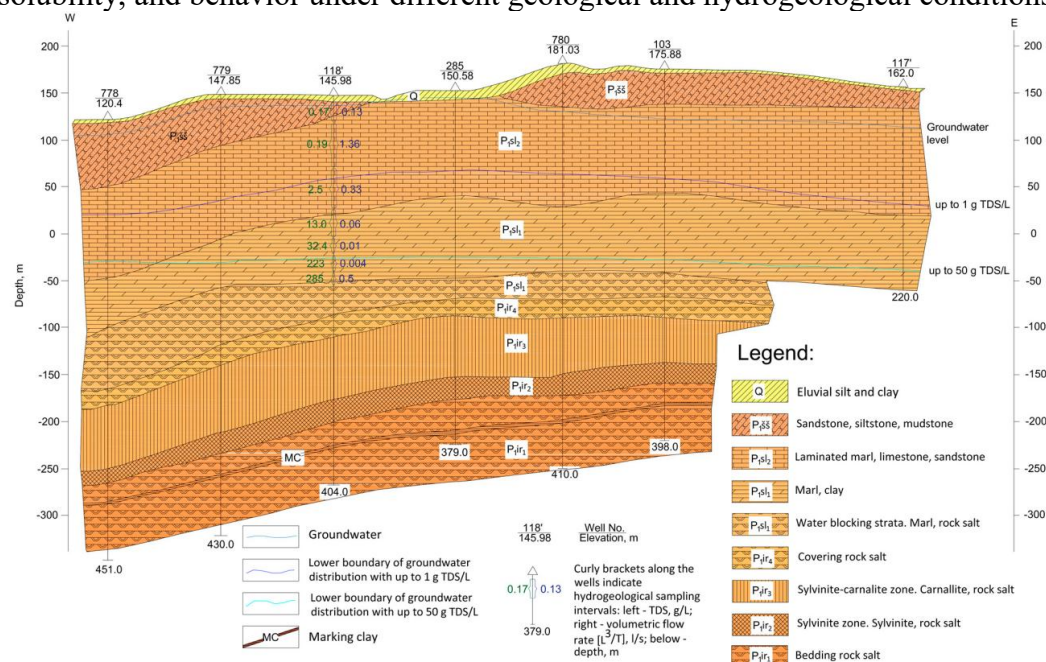


Fig. 1. Geological structure of a typical potash-bearing sedimentary basin

A systems-based approach was applied to assess the environmental impact of potash mining. This includes the evaluation of solid and liquid waste generation, their composition, and disposal techniques such as tailings storage, brine accumulation, and subsurface injection. Both natural and anthropogenic factors affecting environmental safety were considered, including groundwater contamination, surface water salinization, and land subsidence.

Geomechanical and hydrogeological analyses were used to assess the stability of rock masses and the risks associated with water inflow into mine workings. Particular emphasis was



placed on the processes of fluid migration through fractured and porous media, which are critical for understanding flooding mechanisms and the integrity of protective geological layers.

In addition, monitoring-based methods were considered, including the analysis of environmental indicators and operational parameters. These approaches allow for evaluating the effectiveness of mitigation measures such as hydraulic backfilling, improved waste management systems, and environmentally sustainable mining technologies.

Results and Discussion

The analysis of potash mining and processing technologies demonstrates that the efficiency of potassium chloride production largely depends on the mineralogical composition of the ore and the selected beneficiation method. The obtained results indicate that flotation processing ensures a high recovery rate of potassium chloride, typically exceeding 85%, while maintaining product purity at the level of 95–96%. The effectiveness of this method is primarily associated with the selective separation of sylvite from halite based on differences in surface properties.

The evaluation of technological stages shows that the highest efficiency is achieved during the flotation and leaching processes, whereas lower performance indicators are observed in drying and mechanical preparation stages. This variation is explained by differences in energy consumption, process control, and material losses at each stage. Optimization of these processes leads to improved overall recovery and reduced operational costs.

The results of environmental assessment reveal that potash mining activities generate significant amounts of solid and liquid waste. The ratio of waste to final product may reach several tons per ton of potassium chloride produced, depending on the processing technology. These wastes, including halite residues, clay-salt slurries, and concentrated brines, contribute to changes in the chemical composition of surrounding environmental components.

Table 2. Waste generation and utilization

Year	Waste Generation (thousand tons)	NaCl Solution Use	Hydraulic Backfilling	Total Utilization (%)	Uzbekistan (Qashqadaryo Plant)
2024	33500	-	24000	71.0	1200
2023	33000	-	23500	70.2	1100
2022	32800	-	23000	69.5	1000
2021	32925	-	22994	68.84	900
2020	30521	-	20935	68.59	850
2019	30213	-	1176	3.9	800
2018	32386	2185	16624	58.08	750
2017	32697	990	13480	44.25	700
2016	30153	910	11306	40.52	650
2015	31272	910	9560	33.48	600
2014	34767	857	6010	19.75	550
2013	28145	842	10000	38.52	500
2012	26705	10200	-	38.20	450
2011	30059	400	8300	28.94	400

Hydrogeological analysis shows that the migration of saline solutions plays a key role in environmental impact formation. Increased salinity levels in groundwater and surface water systems were observed in areas affected by mining operations. The transformation of water chemistry toward chloride-dominated compositions indicates the influence of potash processing activities.



Geomechanical observations confirm that improper management of underground voids and water-protective layers can lead to ground subsidence and the formation of deformation zones. The results demonstrate that the implementation of hydraulic backfilling significantly improves the stability of rock masses and reduces the risk of flooding and surface deformation.

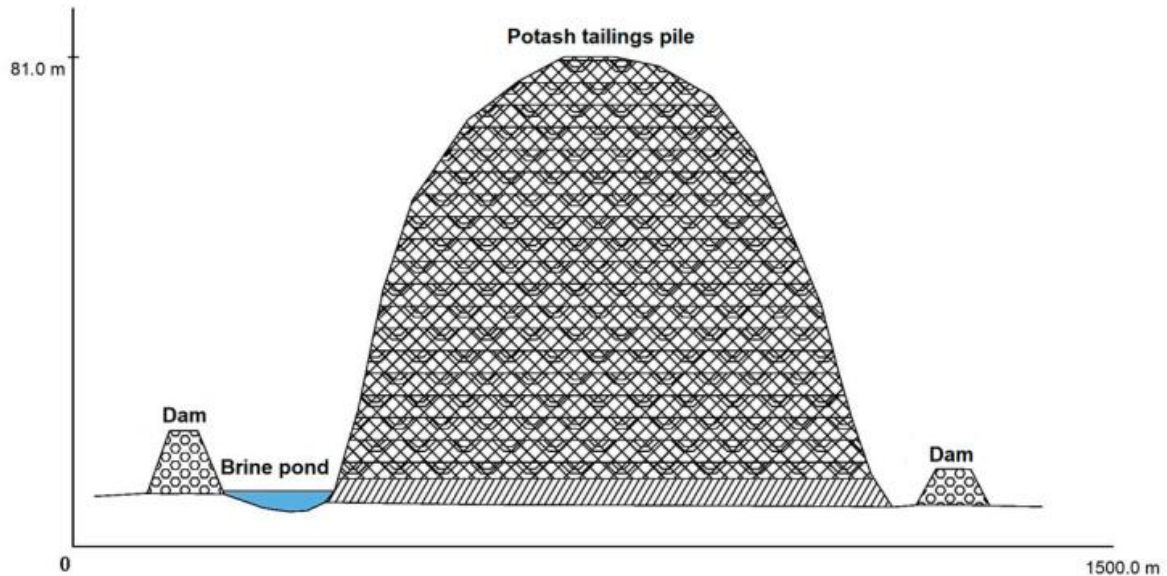


Fig. 1. Schematic cross-section of a potash tailings pile with brine pond and protective dams

Conclusion

The results of this study demonstrate that the effective development and processing of potash deposits depend on the integration of advanced geotechnological approaches with optimized beneficiation technologies. Flotation and halurgical methods provide high recovery rates and product quality when properly adapted to the mineralogical composition of the ore. At the same time, the efficiency of technological stages varies, highlighting the importance of process optimization, especially in mechanical preparation and drying operations. The application of modern processing techniques contributes to improved resource utilization and reduced production losses. However, potash mining is accompanied by significant environmental challenges, including the accumulation of solid and liquid waste, salinization of groundwater and surface water, and land subsidence. These impacts are largely associated with the high solubility of salt minerals and the migration of saline solutions within geological formations. The findings confirm that the implementation of measures such as hydraulic backfilling, effective waste management, and continuous environmental monitoring significantly reduces environmental risks. Therefore, ensuring a balance between technological efficiency and environmental protection remains a key condition for the sustainable development of the potash industry.

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