Problems of natural environment preservation of transboundary territories in uranium mining

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Abstract. Within the transboundary territories of Far Eastern Russia, China and Mongolia, various non-ferrous and expensive rare earth metals are actively mined, with uranium being most actively developed among all of them. The extraction of radioactive ores creates an increased threat to population of transboundary territories and forms the problem that requires coordinated solution to life safety issues. Establishing unified extraction and mineral processing complex within these territories could potentially reduce danger to the environment and increase economic efficiency of metal mining. Decontaminated ore utilisation can become an effective factor in strengthening raw material resource base of metallurgy in both, mining and processing within consolidated regions of the Far Eastern regions. Leaching technology options are a real step towards creation of low and waste-free mining based on combination of physical and technical & chemical processes of metal mining. Peculiarities of natural resource localization and extraction within territories of Russian Far East, China and Mongolia create favorable conditions in establishing environmentally safe and highly profitable metal mining cluster development of deposits of exposed metal ores. Collective use of modern equipment, based on leaching processes can significantly improve environmental, economic and social indicators of regional metal deposits development.

1. Introduction

Mineral deposits of Russia, China and Mongolia contain significant reserves of non-ferrous metals and ores, and especially ores and minerals that are used in fastest growing industry – energy industry. Russia, China and Mongolia together produce 16% of the world uranium mining [1]. Uranium resides within a significant majority of complex ores of non-ferrous metals. In addition to the environmental threats during an extraction of non-ferrous metals, mining of radioactive ore has specific features that should be taken into consideration for environmentally oriented resource supply planning for transboundary territories [2].

The problem lies in the increase of the lost reserves amount due to the lack of cost - effective enrichment technologies. The rate of extraction of base metals from ores does not exceed 60%, and associated elements – 30%. Selective mining of rich ore in a market economy impoverishes remaining reserves and leads to an increased number of radioactive tailings on the surface. Tailings of radioactive ore and ore from underground mining contain valuable and dangerous metals, and constitute a significant portion in chemical pollution of the biosphere by natural leaching.
When in the process of production and economic activity arise contradictions between economic interests of industrial enterprises and ecosystems state, technogenic load reduction on the environment becomes an objective necessity. Key role in that – new technical policy where environmental interest of production and disposal of waste is of utmost importance.

Traditional development systems exclude off-balance reserves from production sphere. The emission for processing of all rock mass on the Earth's surface, separated from the array, meets modern conditions and leaving stocks, not meeting the requirements, in the depths creates conditions for natural leaching with migration of natural leaching solutions into the environment.

Cumulative impact of mining on the environment is carried out at all stages of mining, especially in stowage of substandard mineral raw materials, which are not subject to immediate processing, as although they contain valuable minerals they are too toxic to use.

Substandard mineral raw materials, located on the surface, are subject to dusting, and quite often concentration of dust in the air can repeatedly exceed sanitary standards at a distance of up to 10 km. Settling on the soil and water, dust generates excess concentration of heavy metals and toxic elements with negative consequences for living matter.

Current means to neutralize harmful effects of metals on living matter are ineffective, so the only real way to minimize danger of chemical and radiation pollution is waste-free metals extraction by means of “leaching” extracted minerals in underground blocks and disintegrators [3].

The purpose of present research is to substantiate creation of a “single cycle” mining and processing of mineral ore, that operates in a closed circuit.

2. Models and Methods

The object of research are methods of extraction and processing of substandard uranium ores to produce metals and components of hardening mixtures.

Present research aims to create technological basis for rational usage of technogenic waste in order to improve environmental situation of the Far Eastern enterprises.

To prove the possibility of achieving this goal, a retrospective analysis of leaching technologies practical application in the uranium mining Russian enterprises is conducted. Experimental leaching of metals in disintegrator is implemented. Based on the analysis of the modern concepts of radioactive ore mining, organizational and technological measures for nature and resource-saving technologies are proposed. A complex method of research is applied, including: system analysis and scientific generalization of literature sources, previous research results and production experience, data array processing, obtained as a result of researches using statistical methods and probability theory, mathematical modeling.

Comparative evaluation of possible solution options of the problem under study, taking into account results of predictive studies, conducted on similar topics, is carried out; research studies and selection of methods & tools, research directions and ways of solving problems; theoretical research of creation ways of highly effective innovative mining and ore processing technologies of ore recycling.

3. Results and Discussion

Traditional enrichment processes do not provide full minerals disclosure, therefore they cannot be claimed in the elimination of tailings enrichment by extracting metals from them. Combination of magnetic, gravitational and electrochemical separation and enrichment methods allows to emit metals from tailings into commercial products, but differs in complexity and increased costs. Therefore, for disposal of substandard reserves for today's technology, fundamentally new technologies are developed.

Underground leaching of uranium dates back to the second half of the last century. In the Charcase, Kiik-Tal, Taboshar, etc. mines uranium was leached in the underground blocks of ore containing 0.015-
0.017% [4]. From 1963 Bykogorsky deposit (Northern Caucasus) was developed by underground and heap leaching of off-balance ores. Technologies from leaching when developing Streltsovsky uranium deposits have been used since the 80s of the last century with the increase of their share to 30%. Leaching is carried out with sulfuric acid solution with 65% extraction. Off-balance ores heap leaching is conducted since 1974 to year-round operation extracting up to 50%. In heaps balance ores are leached with extraction of 85% with uranium content up to 0.15 %. In Tselinny mining and chemical plant leaching of uranium ore was carried out in a complex way (figure 1).

![Figure 1. Scheme of complex metals leaching: 1-plant of solute preparation and processing; 2-pile; 3-leaching unit; 4-disintegrator; 5-pond-tailing; 6-concentrate.](image)

The block of balance ores leaching of Vostok deposit in Kazakhstan is prepared according to the scheme (figure 2). Uranium extraction was 72% [5].

![Figure 2. Block of underground leaching: 1, 2-drifts; 3-ort; 4-ort; 5-boundary of the ore body; 6-fracture; 7-rising; 8-dimple; 9-installation layer; 10-subsea layer; 11-solutions bore; 12-blast holes.](image)
The reason for the increase in the number of substandard mineral raw materials in the storage is the prevailing trend of gross ore extraction from the subsoil in the expectation of technological progress for their enrichment on the surface, which in practice does not occur.

The possibilities of traditional enrichment technologies are limited by the use of solely mechanical energy. Modernization of traditional enrichment processes is carried out by involving hydrometallurgical and chemical processing operations, that increase efficiency of enrichment through the use of other energy types, but there are no real achievements in this direction yet.

The new direction of metals extraction from substandard metal-containing mineral raw materials is a combined chemical enrichment and activation in working body of disintegrator [6].

Leaching in disintegrator increases a general efficiency indicator-extraction of metals into solution, and processes combination of off-balance ores preparation and tailings in disintegrator and leaching further increases metals extraction into solution.

Elimination of chemical pollution sources radically changes present dangerous impact of mining on the environment and cannot be estimated due to the lack of reliable methods of calculation.

Mechanochemical technology of metals extraction from enrichment tailings is based on the phenomenon of their properties change at the speed of 250 m/s (figure 3).

![Figure 3. Disintegrator work scheme.](image)

When processing substance with an overload of up to four hundred million free-fall accelerations, kinetic energy is accumulated in it, which is used not only for mechanical components activation, but also for chemical processes. Disintegrator plant creates electrically non-equilibrium charged centers in the mineral. Mineral is destroyed on crystals surfaces, processes of phase separation are simplified, and the yield of the activated product increases. The leaching solution is pressed into cracks, and metal is extracted into the solution along with mineral destruction [7].

Experimental lead and zinc extraction from enrichment tailings allows to conclude that leaching of tailings in disintegrator under identical conditions is significantly more effective than agitation leaching. It provides the same extraction, but reduces process duration by 2 orders, and reduction in residual metal content in secondary tailings is reached by increase in the multiplicity of processing.

Metals extraction from solution can be carried out by the option of membrane technology with salts and metals deposition.

Towards leaching technologies realization there is a number of problems: metals extraction from collective leaching solution, effective neutralization of uterine solutions, increase in mechanical and chemical durability of disintegrator working body, etc. constitute the second phase of innovative technology industrial development [8].
The fundamental difference of innovative technology consists in localization of mining products. When using the traditional technology non-conforming on the content of metals, separated from the array, and crushed ores remain in the mined-out space, while with underground leaching, the metals concentration is significantly reduced, less risk of metals migration beyond the mining circuit. The accumulated and current enrichment tailings after leaching are converted into environmentally friendly raw materials for related industries.

Technologies with metals leaching from ores allow extracting from substandard ores up to 70% of metals at the place of occurrence. Rich ores are produce to the surface and processed at the plant, and the rest are leached in blocks, stacks and disintegrators. By-products of the combined technology are metals, construction raw materials, gases, acids and alkalis.

Elimination of chemical pollution sources radically changes present dangerous impact of mining on the environment and cannot be properly assessed due to the lack of reliable methods of calculation [9].

Joint use of mining and processing cluster equipped with modern machinery for hydrometallurgical processes implementation in comparison with separate production of member countries will cut down expenses and will increase the enterprise competitiveness. The technology ensures minimization of load on the environment not by limiting the impact of pollutants at certain production stages, but by eliminating the source of chemical pollution [10].

4. Conclusion

Problems of preserving natural environment of transboundary territories in uranium mining can be solved by using leaching technologies that allow to limit the territory of production processes and increase safety of raw radioactive material management.

Common conditions of mineral localization, geographical proximity of deposits and possession of experience in the development of uranium deposits by breakthrough technologies allow to establish a powerful cluster for extraction and processing of chemically uncovered ores on transboundary territories of Russia, China and Mongolia.

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