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LEACHING OF URANIUM DEPOSITS IN MONGOLIA

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The paper outlines the results of field, laboratory, and theoretical studies on geotechnical parameters of uranium in-situ leaching (ISL) for hydrogenous deposits located in eastern Mongolia. The field and laboratory studies included drilling, geophysical surveying, testing and evaluation of mechanical and flow properties of uranium-bearing rocks, and evaluation of chemical compositions of rocks and water samples. Theoretical studies included mathematical modelling of coupled flow and mass transport of leaching fluids and dissolved uranium on the example of an ore body at the well-studied “Ul’zit” deposit. The proposed horizon-oriented approach to preparing and leaching separate ore bodies at different depths takes into account rocks structure of varying permeability, which allows successive leaching of ore bodies using wells of varying diameters and specific filter design.

Based on field study results obtained for the opened hydrogenous deposits of Mongolia we described the properties of uranium ores and ore bodies varying horizontally and vertically. Ore body structure, origin, chemical composition, shape and size as well as uranium content and hydrogeological conditions have identical origin for studies sites and completely satisfy the conditions of in-situ leaching. Ore-body parameters are typical for hydrogenous deposits and characterized by the uranium content of 0.036 to 0.066%. Typically, ore bodies of up to 7.0 m thickness lay at 3-7 elevations located within the range from 18 to 300 m below the ground surface. All ore bodies are located in aquifers of highly variable conductivity which change from 0,2 to 370 m^2/d.

Groundwater chemical composition and radiological properties of uranium satellite elements studied in the laboratory showed low and medium water mineralization of 0,7-7,0 g/l, the absence of ferric oxide, the presence of hydrogen sulphide to 10.2 mg/l. The content of ferrous iron ranges from 2.8 to 7.3 mg/l, and uranium from $3{\cdot}10^{-5}$ to $3{\cdot}10^{-4}$ g/l. Under these conditions acidification of ores to be performed by the solutions with sulphuric acid concentration of 10 to 15 g/l should be followed by leaching with solutions of acid concentration from 8 to 12 g/l. Uranium extraction under continuous supply of hydrogen peroxide at the average concentration of 0.06 g/l and ferric iron as oxidizers can be fitted with a time-dependent power-law correlation.

Based on the finite-difference method implemented in software “Modflow” a mathematical model of uranium leaching has been developed and validated under hydrogeological conditions of the “Ul’zit” deposit. The model describes coupled flow and transport of leaching solution and dissolved uranium in a part of the aquifer that contains uranium ore bodies and covered by geotechnological wells arranged hexagonally. In simulations we focused on successive leaching of four neighbouring sections that cover ore body nr. 1 located at the highest elevation close to the ground surface. Sinking water level in wells reaches 3 m with flow velocity at the vicinity of wells up to 2 m/d. Based on the average concentration of uranium in leaching solution we evaluaed the expected output of 9 to 10 tons of uranium from the ore body nr. 1 at the uranium recovery rate estimated under laboratory conditions. The recommended well-to-well distance in a hexagonal cell for ISL ranges from 12.5 to 44.3 m.

The maximum resource saving is achieved when drilling the wells to the deepest ore bodies. The use of the horizon-oriented approach for preparing isolated ore bodies at the “Ul’zit” deposit may reduce drilling costs by combining the wells up to $2.508 Mio. In addition, this approach allows shortening time to be spent on ISL mining of deposits in Mongolia more than 2 times on the average. Following the recommendation on the radius of an ISL cell with a hexagonal well arrangement at the “Kharaat”, “Khairkhan” and “Gurvan-Sayhan” sites makes it possible to save up to $0.9 Mio for mining of each deposit.

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