3D REACTIVE TRANSPORT SIMULATION 0F URANIUM IN SITU RECOVERY. LARGE-SCALE WELLFIELD APPLICATIONS IN SHU SARYSSU BASSIN, TORTKUDUK DEPOSIT (KAZAKHSTAN)

By

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ABSTRACT

Uranium in situ recovery (ISR) is the most widely used uranium mining technique worldwide. It consists in dissolving the ore by a leaching solution, directly within the deposit. The absence of mechanical extraction gives ISR the advantage of being quick to deploy, but also of being less expensive and of lower surface environmental impact than open-pit and underground mining. However, as in the oil and gas industry, it offers an indirect view of the deposit and presents a high degree of uncertainty on the estimate of future production. By predicting flows and geochemical reactions within the reservoir, reactive transport (RT) is a powerful and suitable tool for understanding and managing an ISR operation. Therefore, ORANO Mining and the Centre of Geoscience of MINES ParisTech have been developing for the past ten years a deterministic RT modeling approach dedicated to the simulation of ISR operations. The modeling is done with the HYTEC reactive transport code developed at MINES ParisTech and is based on i) a geological model (porosity / permeability fields and distribution of reactive mineral phases), ii) a geochemical model describing the interactions between the injected solution and mineral phases, iii) a geometric configuration of the wells and an operating scenario. This study illustrates a large-scale application of RT modeling at the Tortkuduk wellfield (Kazakhstan), one of the largest ISR mines in the world, operated by KATCO (subsidiary of ORANO Mining).

This study highlights the robustness of the modeling workflow and its added value for the operator. First, the robustness demonstration is performed on 2394 wells covering 39 different production areas (blocks). The model reproduces the observed uranium concentration and pH of pumped solution over time scales up to 12 years. Only three parameters are manually adjusted to calibrate the model: global initial grades in clays (beidellite), calcite, and iron hydroxide (goethite). The discrepancy between simulated and observed uranium production and acid consumption decreases as the observation scale widens, showing that local errors compensate for each other. These deviations are mainly explained by the uncertainties of the 3D geological models and not by the RT simulations. Second, a case study of four of the simulated blocks illustrates how this modeling helps decision making and becomes a key asset for the operator. In 2019, after 10 years of production, the study area was redeveloped to target the remaining uranium. Several scenarios have been tested and sequentially improved through simulations. In the first two years alone, the final design adopted predicted a 28% increase in uranium production and a 35% increase in economic gains over the usual empirical approach. Comparison between the 2019 forecast and the 16-month observations showed a difference of less than 10% for total uranium production. This difference drops to 2% using the actual operating conditions observed, which validates the predictability of the workflow and confirms the expected gains.

Keywords: In situ recovery, Uranium, Reactive transport, History matching, Optimisation, HYTEC