Prediction of degassing from groundwater caused by shaft excavation in Mizunami Underground Research Laboratory, Japan

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Starting in 2004, the Japan Nuclear Cycle Development Institute (JNC) has been excavating shafts in Mizunami, Gifu Prefecture, for construction of an Underground Research Laboratory. In order to predict hydrochemical effects, especially degassing due to shaft excavation, reactive chemical transport simulation is performed using the modified TOUGHREACT code (Xu and Pruess, 1998 and 2001) and PHREEQC (Parkhurst and Appelo, 1999). Thermodynamic data is based on modified EQ3/6 and LLNL database. The shaft excavation is modeled using cylindrical symmetry; the model domain has a diameter of 8 km and a depth of 2 km. At the vertical direction, the model domain is divided into 29 layers (thickness: 2 m - 500 m). At the horizontal direction, each layer is divided into 23 ring elements (5 cm - 1600 m), for a total of 667 elements. The water pressure at the top of the model domain is maintained at a constant one bar, and the initial condition of pressure distribution is hydrostatic. The side boundary of the model domain is considered permeable and a constant temperature boundary. The bottom boundary of the model domain is considered impermeable and insulated. The model in this study contains Na-Ca-HCO3 type groundwater in the shallow sedimentary rocks and Na-Ca-Cl type groundwater in the deeper sedimentary rocks and granites. Shaft excavation with a diameter of 6.5 m, is employed at the center of cylindrical volume to a depth of 1000 m over 6 years. In the simulation, changes in groundwater conditions are calculated from natural state to 10 years after shaft completion.

After several months from start of shaft excavation, the water pressure below the impermeable layers goes down below 100 kPa because of water discharge from the shaft, reaching 43 kPa absolute after one year of excavation. The calculated pressure match well with the measured pressure of MSB-2 (change from 120 to 38 kPa). Due to the pressure decline, air invades the sedimentary formations from the shaft at shallow depths and water saturation decreases with time. The discharge rate of groundwater into the shaft is calculated as about 4 kg/s after completion of shaft excavation, and the pressure continues to decline near shaft. It is predicted that degassing of methane, carbon dioxide and hydrogen sulfide will occur in a region of up to 20 m from shaft due to pressure depletion. The chemical changes including pH and Eh were also calculated. JNC will verify the simulation prediction by in-situ measurements from the tunnels at hundred meter intervals in the near future.