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Integrated Numerical Simulation of Thermo-Hydro-Chemical Phenomena Associated with Geologic Disposal of High-Level Radioactive Waste

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A series of numerical simulations was performed using a multiphase thermo-hydro-chemical numerical model to predict integratedly and evaluate quantitatively thermo-hydro-chemical phenomena due to heat generation associated with geologic disposal of high-level radioactive waste. The average mineralogical composition of the fifteen unweathered igneous rock bodies, which were classified as granite, in Republic of Korea was adopted as an initial (primary) mineralogical composition of the host rock of the repository of high-level radioactive waste in the numerical simulations. The numerical simulation results show that temperature rises and thus convective groundwater flow occurs near the repository due to heat generation associated with geologic disposal of high-level radioactive waste. Under these circumstances, a series of water-rock interactions take place. As a result, among the primary minerals, quartz, plagioclase (albite), biotite (annite), and muscovite are dissolved. However, orthoclase is initially precipitated and is then dissolved, whereas microcline is initially dissolved and is then precipitated. On the other hand, the secondary minerals such as kaolinite, Na-smectite, chlorite, and hematite are precipitated and are then partly dissolved. In addition, such dissolution and precipitation of the primary and secondary minerals change groundwater chemistry (quality) and induce reactive chemical transport. As a result, in groundwater, Na+, Fe2+, and HCO_3- concentrations initially decrease, whereas K+, AlO_2-, and aqueous SiO_2 concentrations initially increase. On the other hand, H+ concentration initially increases and thus pH initially decreases due to dissociation of groundwater in order to provide OH-, which is essential in precipitation of Na-smectite and chlorite. Thus, the above-mentioned numerical simulation results suggest that thermo-hydro-chemical numerical simulation can provide a better understanding of heat transport, groundwater flow, and reactive chemical transport including dissolution and precipitation of minerals and groundwater quality changes due to heat generation associated with geologic disposal of high-level radioactive waste. Therefore, it is expected that the thermo-hydro-chemical numerical simulation approach suggested in this study can be utilized reasonably and widely in optimization, improvement, cost reduction, potential risk analysis, mitigation, and policy establishment related to geologic disposal of high-level radioactive waste. This work was supported by the Radioactive Waste Management Program funded by the Korea Institute of Energy Technology Evaluation and Planning (KETEP), Ministry of Trade, Industry and Energy, Republic of Korea.