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Test of the Thermal-Hydro-mechanical Behaviors of Cherkasy Bentonite as Buffer Material of HLW Repository

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Abstract The principle of HLW disposal is based on the multiple-barrier system consisting of two basic components—a natural and an engineering barrier. The most common buffer material for engineering barrier systems (EBS) is compacted bentonite, which features low permeability and high retardation of radionuclide transport (Zlobenko et al. in Studies of clays from deposits in Ukraine as a barrier material for radioactive waste repositories, pp 857–861 [1]; International Atomic Energy Agency in Characterization of swelling clays as components of the engineered barrier system for geological repositories [2]; Zlobenko and Fedorenko in Ukrainian programme on characterization and evaluation of swelling clays for use in engineered barrier system of the geological repository [3]). The bentonite barrier should prevent the potential migration of radionuclides from the radioactive waste into the surrounding biosphere. Establishing the thermal limit for bentonite in a nuclear waste repository is potentially important, as the thermal limit plays on a major financial challenge requiring long-term strategic planning for used fuel management. Characterization of long-term mineralogical changes for EBS concerning the long-term geological evolution is needed for safety assessment purposes. To test the suitability and predicted functions of bentonite-based buffers under simulated repository conditions and to assess geochemical changes in minerals and porosity variations, thermal dehydration studies of bentonite were carried out at the temperature of 150 °C in "dry" and "wet" conditions. Commercial calcium bentonite (PBA-22 «Extra») was chosen as a clay component of the buffer materials as less sensitive to mineralized rock water. The connection between the structural peculiarities of bentonite and processes of heat treatment is considered. The montmorillonite shows changes induced by dehydration with temperature, there are changes and a decrease of the XRD profile intensity with heating to 150 °C. The predicting evolution of bentonite behaviour so as the degree of montmorillonite hydration is a very important parameter for cation behaviour as a function of the thermal load.

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Experiments with bentonite exposed to hot water vapour showed that the swelling pressure and hydraulic conductivity were not significantly changed for the investigated temperature of 150 °C. A slight increase in conductivity was recorded.

The method is based on ASTM standard D 5084-03 [14]. The permeameter has a diameter of 50 mm, while the diameter of the sample can vary between 50 mm. The height of the sample is 50–250 mm.

The test results showed that in thermal treatment (see Table 7), the hydraulic conductivities for all compacted bentonites with dry densities of 11,520, 1580, and 1650 kg/m^3 are very low K_s (ms^{-1})E−13. The hydraulic conductivities decrease with the increasing dry density of bentonite. The hydraulic conductivities decrease faster with increasing dry density at higher porosity. The change of hydraulic conductivities in bentonites at elevated temperatures is attributable to the change in the permeability factor and the density factor. At an elevated temperature, the adsorbed water may degenerate into bulk pore water [11], and this degeneration may lead to a higher amount of bulk pore water resulting in an increase of permeability due to an increase in flow channel volume.

A consequence of heating experiments, a continual decrease in ion exchangeability of the bentonite and S_{BET} values decreased due to the temperature treatment. Heat treatment has changed the structure of clays and their physicochemical properties.

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