

5-9 How Long Does a Repository Confine Radionuclides? –Modeling of Long-Term Alteration of Bentonite Buffer Material–

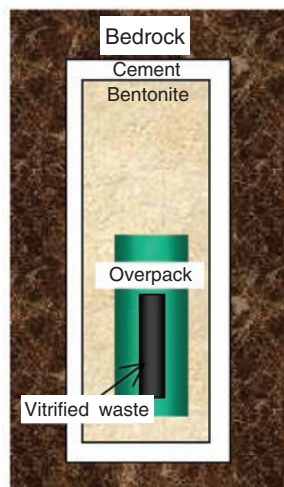


Fig.5-17 A conceptual view of high-level radioactive waste (HLW) disposal system

Vitrified HLW is encapsulated in an iron container (overpack), surrounded by engineered buffer material (bentonite) and placed in a shaft contained in stable bedrock. Cement is used for mechanical support of the shafts, but it causes surrounding water to become highly alkaline, which is likely to deteriorate the properties of the bentonite buffer over a long period.

In the Japanese program, high-level radioactive waste (HLW) is vitrified, encapsulated in a metal container called overpack, surrounded by engineered bentonite buffer material, and placed in a repository cut out from stable bedrock as shown in Fig.5-17. Cement is expected to be applied for the mechanical support of the repository.

Besides its mechanical buffer function, bentonite prevents groundwater from intruding into the waste and retards radionuclide movement outwards by adsorbing them. It is necessary to estimate the long-term changes of such properties of bentonite confining long-lived radionuclides in HLW.

Radioactive decay of radionuclides in HLW increases the temperature of the surrounding bentonite up to 90°C right after the emplacement, and an alkaline environment is likely to be induced by the cement used in the repository. The temperature and alkaline condition possibly accelerate alteration of bentonite.

Because the radionuclide confining property of the bentonite arises from its main constituent montmorillonite, dissolution of montmorillonite in contacting groundwater results in deterioration of the confinement. Several researchers have obtained the dissolution rates of pure pulverized montmorillonite in free water with high water/solid-ratio, which are far from the repository condition where bentonite is

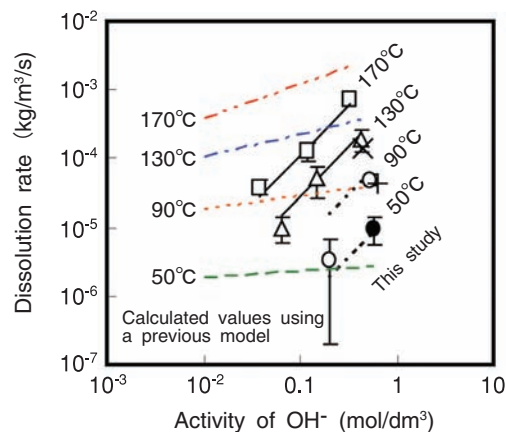


Fig.5-18 Dissolution rate of montmorillonite in highly alkaline solutions

The dissolution rate of montmorillonite, the main constituent of bentonite, was investigated using compacted bentonite. The dependence of the rate on activity of hydroxide ions, a_{OH^-} , and on the temperature is shown here. There is higher dependence on a_{OH^-} than a model based on results of experiments using pulverized bentonite. The rate is sensitive to the alkalinity.

in a compacted state. The property of water filling the narrow pore spaces (porewater) in the compacted bentonite may be different from that of free water. We performed the dissolution experiments of montmorillonite in a compacted state simulating the repository condition.

The dissolution rate of montmorillonite we obtained was a function of activity of hydroxide ions, a_{OH^-} (mol/dm³), and temperature, T (K), as shown in Fig.5-18. The rate, R_A (kg/m³/s), could be formulated as:

$$R_A = 3.5 \times 10^3 (a_{\text{OH}^-})^{1.4} \exp(-51000/RT) [\text{kg/m}^3/\text{s}]$$

where R is the gas constant. The dissolution rate obtained for a compacted state has a higher dependence on the a_{OH^-} than that of previous models that were based on high water/solid-ratio dissolution experiments using pulverized materials.

The a_{OH^-} of porewater is an important factor determining the dissolution rate, and this is determined by both chemical reactions with minerals and mass transport. We developed a coupled mass-transport/ chemical-reaction code for predicting the a_{OH^-} and the long-term alteration of the bentonite.

Further investigation is necessary to understand the mechanisms of the dissolution of compacted montmorillonite and to verify the model by comparing results of the model calculation with laboratory experiments or field observations.

Reference

Yamaguchi, T. et al., Experimental and Modeling Study on Long-Term Alteration of Compacted Bentonite with Alkaline Groundwater, *Physics and Chemistry of the Earth*, vol.32, no.1-7, 2007, p.298-310.