Analysis of Thermo-Hydro-Chemical (T-H-C) Coupled Phenomena in Buffer Materials Focusing on the Clay mineral Montmorillonite

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High-level radioactive waste is disposed of at depths greater than 300 m below the surface in a multi-barrier system. The multi-barrier system consists of a natural barrier composed of bedrock and engineered barriers composed of vitrified waste (waste body), overpack (thick metal container), and buffer material (compacted bentonite with silica sand). The engineered barrier system must maintain its function over a long period of time. Factors that affect the function of the engineered barrier system include decay heat from the waste body, groundwater infiltration, and swelling of the buffer material, and those phenomena develop simultaneously. Therefore, a coupled analysis considering heat transfer, moisture transfer, stress, water quality, etc. is necessary to evaluate the long-term behavior of the engineered barrier system. The objective of this study is to develop a model to evaluate the type of bentonite used for geological disposal and the mixing ratio of silica sand in Thermo-Hydro-Chemical (T-H-C) coupled analysis of bentonite buffer material, focusing on the buffer material in the engineered barrier system. Firstly, a model was developed to derive the moisture diffusion coefficients of liquid water and water vapor based on Philip and de Vries, focusing on montmorillonite content, which is the main constituent of bentonite (Figs. 1-2). Then, time evolutions in temperature and moisture distribution in the buffer material were numerically analyzed by the difference method of cylindrical coordinate system one-dimensional diffusion equation in radial direction based on Fick's law. The validity of the distributions was confirmed by comparing to the measured data obtained from in-situ experiments at a depth of 350 m below ground level conducted in underground facility of the Horonobe Underground Research Center, Hokkaido, Japan (Fig. 3).

[1] JAEA, Buffer Material Database,” https://bufferdb.jaea.go.jp/bmdb/index_e.jsp”.
[2] NUMO, NUMO-TR-21-02, 2022.
[3] JAEA, JAEA-Data/Code 2019-003, 2019.

Keywords: HLW repository, Buffer, Montmorillonite, THMC coupling

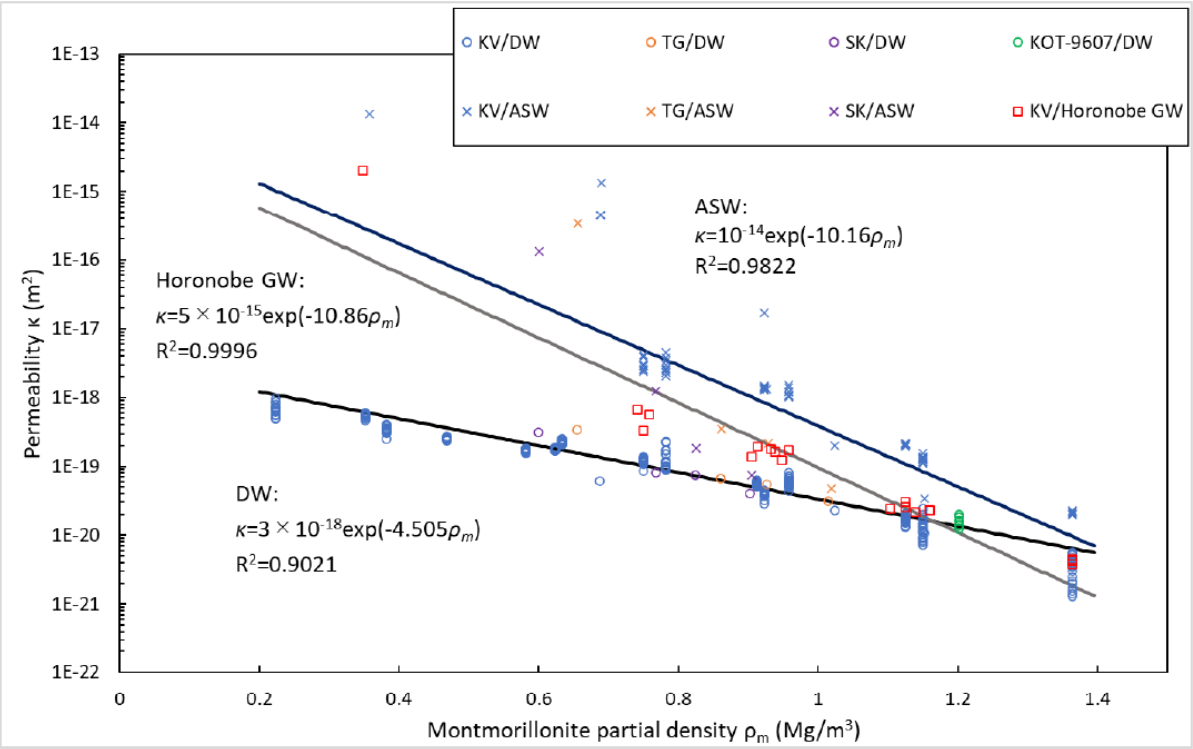

Fig. 1 Permeability versus montmorillonite partial density.

All data were downloaded from JAEA Buffer Material Database[1] and NUMO-TR-21-02[2]

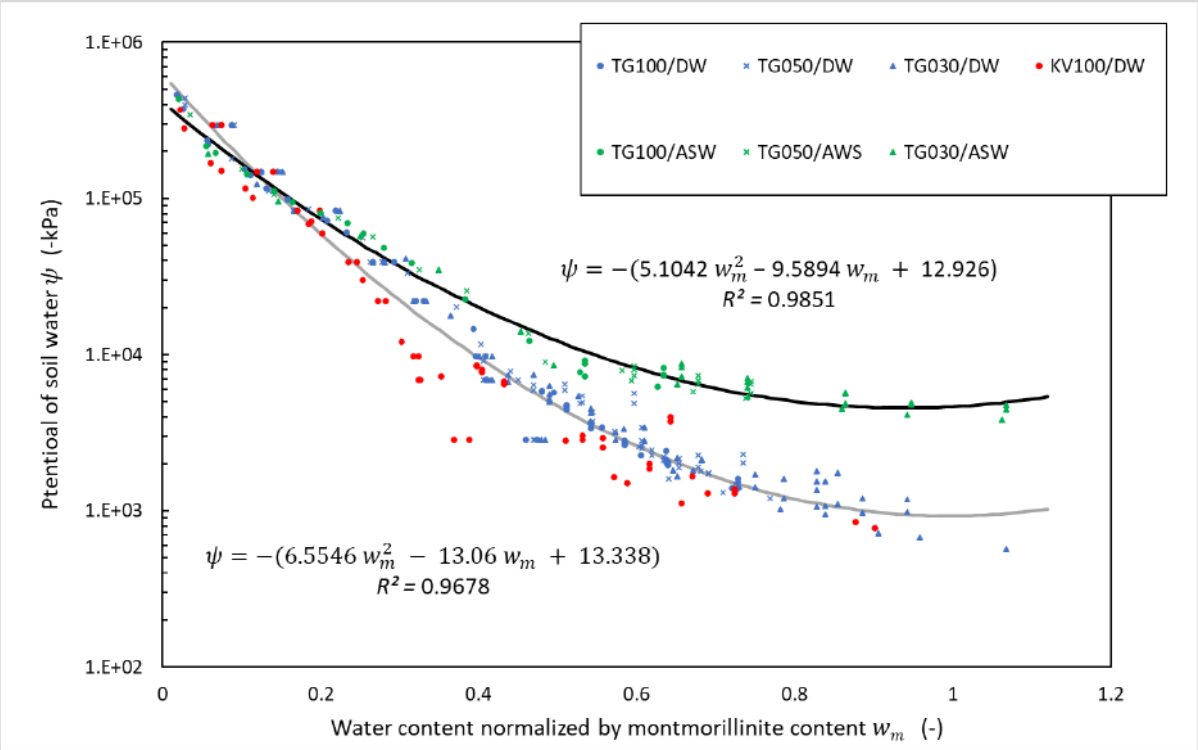

Fig. 2 Potential of soil water versus water content normalized by montmorillonite content.

All data were downloaded from NUMO-TR-21-02[2]

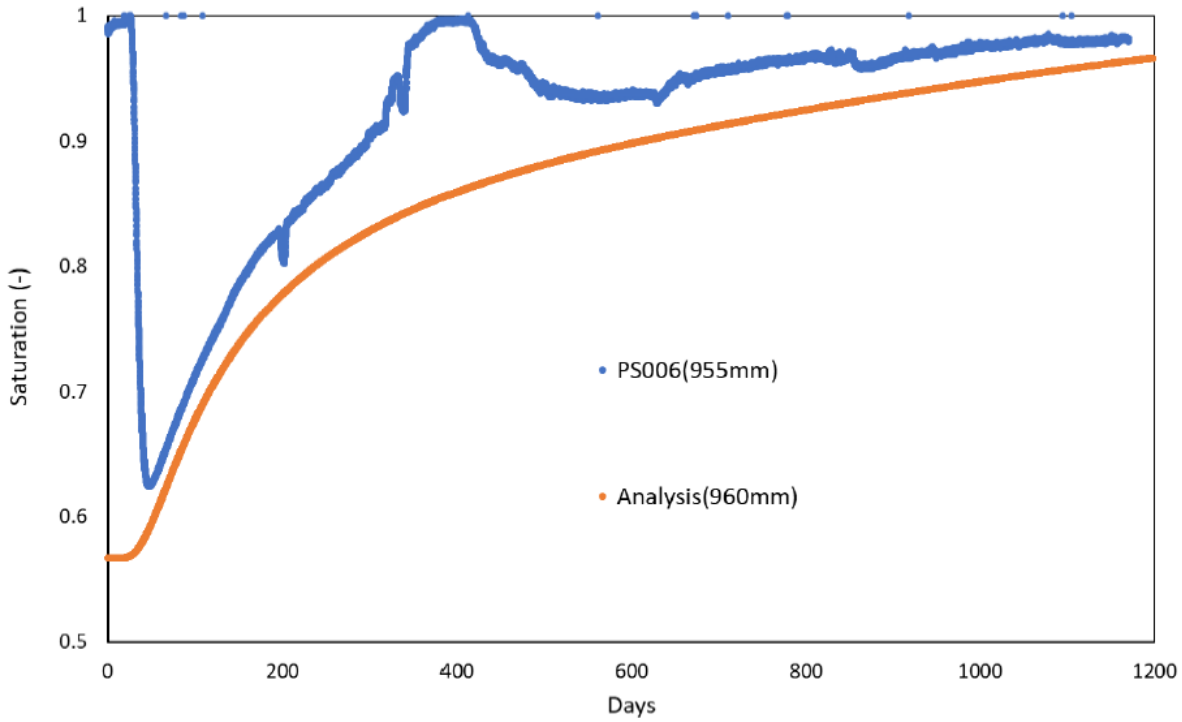

Fig. 3 Comparison of measurement results and T-H-C coupled analysis results (saturation). PS006 data were downloaded from JAEA-Data/Code 2019-003[3]