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Water infiltration dynamics in bentonite-based engineered barrier systems investigated by time-lapse photography

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ABSTRACT

Understanding groundwater infiltration within engineered barrier systems (EBS) is crucial for safe and effective design of high-level radioactive waste (HLW) disposal systems, yet the complex interplay between thermal, hydraulic, and mechanical (THM) processes is not fully understood. This study investigates the water infiltration dynamics in compacted bentonite under various THM conditions through a series of laboratory infiltration tests with time-lapse photography. It is anticipated that the result of this study will contribute to the accurate prediction of the long-term performance of EBS.

1. INTRODUCTION

Water infiltration in EBS of geological repositories for HLW disposal is critical for containment integrity and long-term isolation of radioactive materials. These barriers, typically composed of bentonite, are designed to utilize the natural swelling capacity and low hydraulic conductivity of the clay to prevent radionuclide migration (Sellin & Leupin, 2013). The infiltration of water into the EBS is particularly critical as it triggers clay swelling that enhances its sealing properties by closing gaps.

However, characterizing the water infiltration process remains as a significant challenge due to the complexities of thermo-hydro-mechanical (THM) coupling in bentonite, which is mainly determined by the geological settings and the evolution of decay heat around the canisters. Consequently, experimental studies have been essential to provide insights for the design and safety assessment of HLW disposal systems. In this study, a series of laboratory infiltration tests under various THM conditions were performed to

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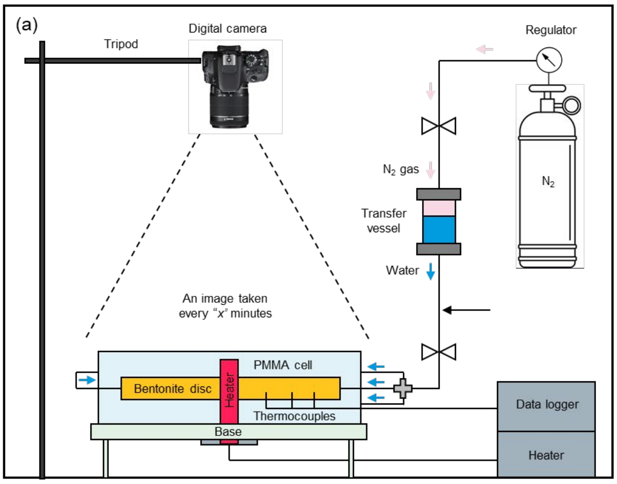
gain insights on the impact of temperature and gaps on the water infiltration dynamics.

2. Water infiltration tests

Bentonite discs of WRK bentonil were prepared by the cold isostatic pressure (CIP) method, targeting a water content of 14% and a dry density of 1.6 Mg/m^3. The prepared disc was mounted inside a transparent cell made of polymethyl methacrylate (PMMA) as illustrated in Fig. 1a. This setup reproduces the water infiltration into EBS; the decay heat around the canisters and the groundwater flow were replicated by a heater in the center and water injection to the edge, respectively. During water infiltration, time-lapse digital photographs were taken to infer the evolution of water content from the color changes as shown in Fig. 1b. Various THM conditions were considered by controlling the applied heat and configuring the bentonite buffer (e.g., presence of gaps, pellets/granule, etc.), and the propagation of the water front and the distribution of saturation was investigated.



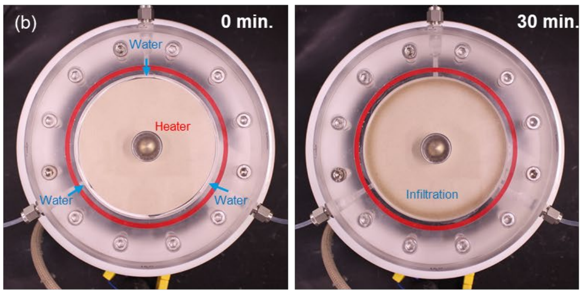


Fig. 1 (a) Experimental setup and (b) photographs taken at 0 and 30 minutes after the start of water infiltration showing the bentonite turning dark with saturation

3. CONCLUSIONS

The complex dynamics of water infiltration under THM conditions was visually investigated by a series of laboratory tests. It is anticipated that the obtained results, could help improve the prediction of long-term performance of EBS through upscaling.

REFERENCES

Sellin, P., & Leupin, O. X. (2013). "The use of clay as an engineered barrier in radioactive-waste management a review," Clays and Clay Minerals, **61**, 477-498.