

Comparative Study on the Colloid Formation by Chemical Erosion of Compacted Bentonite

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1. Introduction

Colloids generated from buffer material play a role as mediators that accelerate the migration of radionuclides in the high-level waste repository [1]. Therefore, evaluating the generation mechanism and behavior of colloids from buffer material candidates is an essential procedure for ensuring disposal safety [2]. This study aims to evaluate the mechanism of colloid generation by the chemical erosion of bentonite, which is used as a buffer material in deep geological repositories, by designing a colloid generation device consisting of artificial fractures and comparing the characteristics of colloids that could be generated from Na and Ca-type bentonite.

2. Methods and Results

2.1 Design of the Artificial Fracture System

To evaluate the chemical erosion and colloid generation under low ionic strength conditions, an experimental system simulating artificial fractures in compacted bentonite erosion and colloid generation was prepared based on work by previous studies [2,3]. The colloid generation experimental device was designed as a circular system with a diameter of 250 mm (Fig. 1). It was configured to position compacted bentonite (density: 1.6 g/cm³) in the center of the system. The material of the experimental device was made of acrylic to observe the swelling and colloid generation of the externally compacted bentonite. The circular colloid generation device was composed of an inlet for fluid injection and an outlet for sample collection at both ends, with the inlet and outlet positioned at the bottom of the reaction device to minimize sample loss due to the location of the inlet. A film-type sensor was installed at the bottom where the compacted bentonite is located to measure the swelling pressure due to bentonite swelling. The artificial fracture in the experimental device was maintained at a size of 1 mm by installing spacers at the bolt fastening part, and the experimental conditions were set to inject a constant flow rate (6 mL/day) using a syringe pump. To compare the colloid generation characteristics depending on the type of bentonite, Na-type bentonite (Wyoming bentonite) and

Ca-type bentonite (Bentonil WRK) were used. The specifications of the compacted bentonite produced were the same ratio as the In-DEBS experiment conducted by the Korea Atomic Energy Research Institute, with a diameter of 30 mm and height of 87.6 mm. The solutions used in the experiment were distilled water and synthetic groundwater simulating KURT groundwater to evaluate the effects of ionic strength. Colloid samples were collected every 24 hours using a fraction collector, and the experiment was conducted over 30 days. Colloid concentration and particle size in the samples were measured by collecting 6 mL of sample from the automatic sampler. The chemical properties of the solution in the sample were evaluated by measuring pH and electrical conductivity, and colloid particle size distribution was analyzed using Dynamic Light Scattering. The concentration of colloids in the sample was analyzed using a turbidimeter through its calibration curve. To compare the mineralogical characteristics according to bentonite swelling, particle size distribution, and X-ray Diffraction analysis conducted on dried samples to compare mineralogical characteristics.

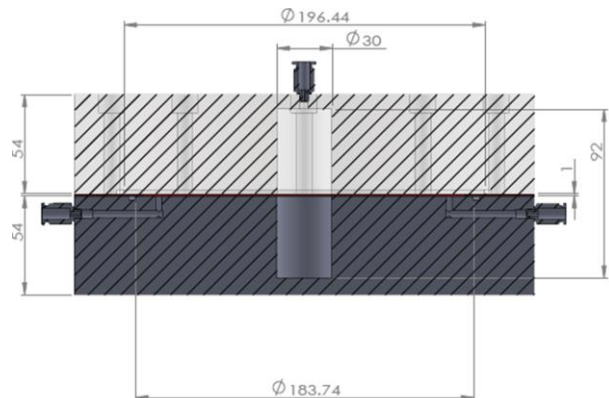


Fig. 1. Design of the artificial fracture system

2.2 Generation of Colloids

Colloids generated from Wyoming bentonite showed relatively distinct colloid generation characteristics compared to WRK bentonite (Figure 2d). In the condition of distilled water, the concentration of colloids began to increase from the third day of the

reaction, and a constant concentration of colloids of about 100 mg/L was observed to be continuously generated. On the other hand, in the condition of synthetic groundwater, colloids began to generate after five days, and the amount of generated colloids showed a maximum value of about 45 mg/L on the 15th day of monitoring, then started to decrease continuously, and no colloid concentration was generated on the 30th day. This is considered to be due to the effects of ionic strength in synthetic groundwater, as mentioned earlier, resulting in less colloid generation, and it is assumed that they aggregated and did not move outside the reaction device during the migration process. Wyoming bentonite was found to have light-colored colloid particles distributed in the direction of the outlet throughout the reaction device. However, in synthetic groundwater, the distribution width was confirmed to be less. The generation and migration characteristics of colloids can be influenced by the spacing, length, and gradient of the flow path, so further research is needed to specifically elucidate this.

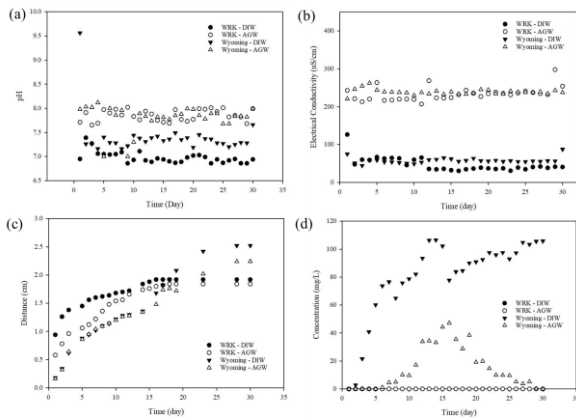


Fig. 2. Monitoring of pH(a), electrical conductivity(b), distance of bentonite expansion(c), colloid concentration (d) of the effluent

2.3 Surface Characterization

As shown in the figure 3, samples were collected by dividing the inside of the experimental device into three zones based on bentonite swelling and colloid generation points. SEM analysis of the bentonite surface collected from each point showed that the compaction of Wyoming and WRK bentonite decreased from S1 to S3, and particle separation due to repulsive forces between bentonite particles was expected to occur toward the outer edge. Similar to the trend in previous colloid generation experiments, a more distinct decrease in compaction was observed on the surface of Wyoming bentonite. Analyzing the samples collected from the S3 area, it was found that nano-sized colloid particles were partially separated in both Wyoming and WRK, with the size of particles observed in WRK showing a relatively

more significant tendency compared to Wyoming. However, a comparison of elemental composition by EDS analysis at each point did not reveal any significant differences.

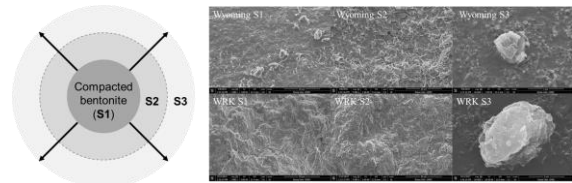


Fig. 3. Sampling area of compacted bentonite and SEM images

3. Conclusions

This study substantiates that colloid generation characteristics are contingent upon the type of compacted bentonite employed, with the stability of the generated colloids being significantly influenced by the ionic strength of the ingress water. The findings serve as a foundational corpus for future interpretations of colloid characteristics emanating from buffer materials. This underscores the necessity for continued investigative efforts into the detailed mechanisms governing these phenomena.

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