Effects of Microbial Activity on the Biochemical Alteration of KJ-II Bentonite Under Alkaline-Reducing Conditions

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1. Introduction

Bentonite has been considered as a buffer material for deep geological disposal of high-level radioactive wastes. Various kinds of microbe were found in pores of the bentonite. Sulfate-reducing bacteria (SRB) are one of representative native microbes that reduce sulfate (SO_4^{2-}) to sulfide (S^{2-}) in the bentonite. Such a microbial activity might make bentonite altered, affecting the behavior of radionuclides.

Bentonite can be affected by cement materials used as the construction for the repositories during the long-term disposal process. The cement can lead the environment to be alkaline. The pH of the cementitious condition is higher than that of the surrounding environment in which microbe can live. It has been reported that some microbes can survive and metabolize in an extreme environment like high temperature. However, it has not been known if indigenous microbes in the bentonite can survive in high alkaline conditions.

In this study, we investigated effect a microbial on the biochemical alteration of KJ-II (Gyeongju) bentonite by its indigenous microbe under alkaline-reducing conditions.

2. Materials and methods

2.1 Materials

The bentonite used in this study was taken from Gyeongju. We named it as “KJ-II bentonite”. It is a Ca-type bentonite with its ratio of CaO : Na_2O as 5.5:1, containing montmorillonite with > 65% in its total amount [1].

2.2 Methods

2.2.1 Bentonite. Distilled water sterilized was added to the KJ-II bentonite to make a solid-liquid ratio (S/L) to be 1g/30ml in a centrifuge tube of 50 ml. To remove some oxygen in the bentonite, it was saturated and shaken for 3 days (120 rpm, 30°C). Finally, the supernatant was removed after centrifugation (10,000 rpm, 5 minutes), then the centrifuge tube was placed in a glove box filled with N_2 gas.

2.2.2 Solutions. Under the clean bench, solutions were prepared by adding reagents into water. Before addition of the reagents, they were sterilized by 0.20 μm filtration (ADVANTEC). To investigate some microbial effects occurring in the KJ-II bentonite, some aqueous conditions such as 1) distilled water, 2) distilled water+10mM Na-lactate, and 3) distilled water+10mM Na-lactate+2mM sulfate were prepared respectively. All solutions were purged with N_2 gas for 40 minutes to remove oxygen in the solution and then moved to the glove box.

2.2.3 Experiments. All experiments were carried out in the glove box filled with N_2 gas (anaerobic condition). The prepared solutions were poured into centrifuge tubes with bentonite. NaOH solution was used to adjust the pH of the media as 9, 10, and 11, respectively (Table 1). The experiments were carried out for 5 months.

Table 1. Experimental solutions prepared for the study

Case	Solutions	pHs
1	distilled water	9, 10, 11
2	distilled water + 10mM Na-lactate	9, 10, 11
3	distilled water + 10mM Na-lactate + 2mM sulfate	9, 10, 11

3. Results and discussion

3.1 Color changes of bentonites

Initial color of the bentonites had not changed easily at any cases. However, a specific bentonite was changed to black at the pH 10 and 11 after 1 month for the case 3. A sample in the case 3 was completely blackened after 2 months at pH 9 (Fig. 1). It was assumed that this phenomenon was caused by the indigenous bacteria that were alive in the bentonite, if some electron donors (e.g., lactate) were supplied. The sulfate that was initially injected into the solution can be reduced to sulfide, which color is black as combined with metals (e.g., Fe). However, cases 1 and 2 showed a different color of light gray. It is assumed that it might be difficult to form sulfides due to the lack of sulfate for the cases 1 and 2.

The concentrations of sulfate in the natural groundwater are generally higher than about several tens ppm (mg/L) in Korea. In addition, it is reported that the sulfate concentrations in the groundwater near the sea shore are much higher. The repository sites could be placed near the sea shore in Korea, so the case 3 could be an example to study an effect of sulfate. According to a report, there are more than four kinds of SRB in the KJ-II bentonite [2]. In this study, the indigenous bacteria in the KJ-II bentonite were survived even in the strong alkaline conditions.

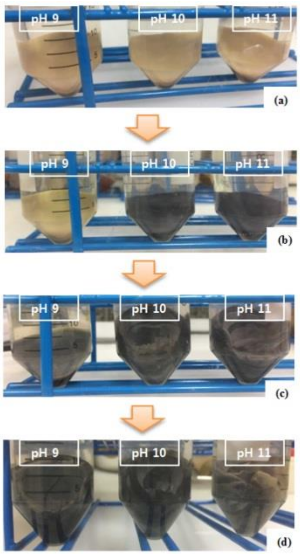

Fig. 1. Alteration of KJ-II bentonites in different pHs for the Case 3; (a) 1 week, (b) 1 month, (c) 2 months, and (d) 5 months.

3.2 Changes of chemical compositions

The supernatant of bentonite was extracted and analyzed to determine the concentrations of Al, Si and Ca using ICP-MS (inductively coupled plasma mass spectrometer). The result shows that the concentration of Ca increased at pH 11 for 2 month in all cases, and then decreased after that. Ca ions released from the bentonite by Na ions from the NaOH that was added for the pH adjustment. The concentration of Si increased steadily for 4 months at pH 11. It was 120~200 times higher than those of other samples. Finally, it also decreased after 4 months. The decreases of Ca and Si concentrations at pH 11 seemed that the ions may be combined to form a new mineral. In contrast, the concentrations of Al were lower than 0.1 mg/L in all cases. The dissolution of Si was superior to that of Al under our alkaline conditions.

4. Conclusion

The effect of microbial activity under alkaline-reducing conditions was investigated experimentally. In this study, the color of bentonite was changed by the activity of indigenous bacteria that are alive in the bentonite. It means that the indigenous microbe of KJ-II bentonite could survive under alkaline condition. In addition, the chemical compositions of bentonite supernatant were changed due to the chemical alteration of KJ-II bentonite.

The bentonite solid samples were analyzed by XRD (X-ray diffraction) to detect secondary minerals produced by the alteration of bentonite.

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