

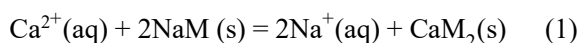
Effects of temperature on hydraulic and buffering performances of soil-bentonite mixture

○Rongguang YU, Atsushi TAKAI, Tomohiro KATO, Takeshi KATSUMI

1 Introduction

Bentonite is widely used in barriers around municipal solid waste landfills, contaminated fields, and high-level nuclear waste geo-repositories. The idea of soil-bentonite is to construct those barriers using the mixture of in-situ soil and bentonite, which could not only take advantage of the characteristics of bentonite but also effectively reduces costs (Kamon et al., 2002).

Many studies have reported that the osmotic swelling of bentonite secures the sealing of the barrier, and the contaminant water containing multivalent cations could inhibited the swell through the ion exchange behavior, e.g., Ca^{2+} against sodium bentonite:



Where M^- is the negative charged adsorption site in the interlayer of montmorillonite. As the inhibition of osmotic swelling proceeding, the impermeability of the barrier will also decreased (Katsumi et al., 2008).

On the other hand, various thermodynamic conditions will be met during the operation of soil-bentonite barriers as shown in Fig.1. Considering the long-term operation of the repository, the effect of the thermodynamic conditions on the functions of the barrier cannot be neglected. So far, the comprehensive understanding of the effects of temperature on the barrier performance of soil-bentonite mixtures is still insufficient.

In this study, batch tests for bentonite and soil at different temperatures were carried out separately, aiming to evaluate the effect of temperature on the barrier performance of soil-bentonite from the perspective of ion exchange and adsorption.

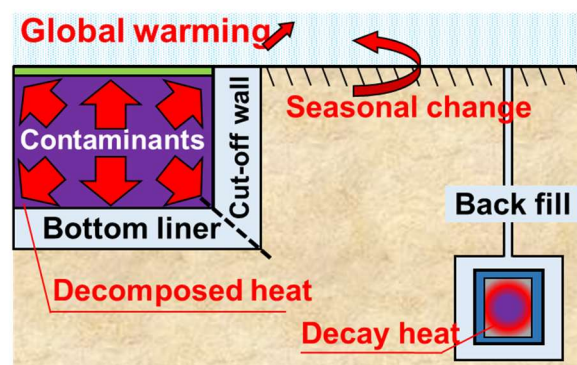


Fig. 1 Thermodynamic conditions during soil-bentonite barriers' operation

2 Methodology

For the batch test shown in Fig. 2, calcium chloride (CaCl_2) solution was used to simulate the multivalent condition in contaminated water. The liquid solid ratio of all batch tests was controlled at 20 ml/g and the oscillation was set at 200Hz for 24 h. The physical parameters of the solid materials used in this study is given in Table 1.

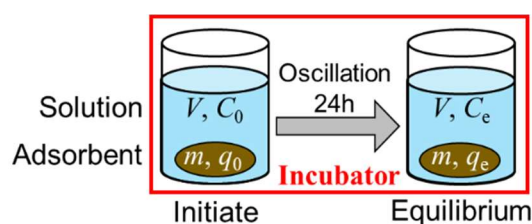


Fig. 2 Schematic drawing of batch test

Table 1 Physical parameters of the materials

	Decomposed granite soil	Sodium bentonite
Specific gravity (g/cm^3)	2.65	2.81
Particle diameter (mm)	< 2	-
Liquid limit (%)	< 30	426
Plastic limit (%)	-	33

All batch test conditions in this study are listed in Table 2. The supernatant was collected after 10 min centrifuge at 3000 rpm and 0.45 μm filtration. Then, the

concentrations of Ca^{2+} and Na^+ in all samples were measured by ICPE-9820 plasma atomic emission spectrometer.

Table 2 Discontinuous batch test conditions

Set	Type	Temperature (°C)	Initial CaCl_2 (mol/L)
1	Bentonite (B)	21.0	0.01/0.02/0.10/1.00
2		29.6	
3		37.0	
4		46.0	
5	Soil (S)	21.0	0.01/0.02/0.10
6		29.6	
7		37.0	
8		46.0	

3 Results

The adsorption and desorption isotherms of Ca^{2+} and Na^+ are shown in **Fig. 3** and **Fig. 4**. Note for **Fig 4**, Ca^{2+} concentration is set as X-axis for the convenient comparison with **Fig.3**.

For soil (S) cases, neither Ca^{2+} adsorption nor Na^+ desorption have shown clear temperature dependency. The Ca^{2+} adsorption and Na^+ desorption amounts of the decomposed soil were always lower compared to the bentonite cases, but the difference in Ca^{2+} adsorption is reduced at high concentrations.

For bentonite (B) cases, Ca^{2+} adsorption isotherms and Na^+ desorption isotherms have shown opposite temperature dependencies. As temperature rising, more Ca^{2+} was adsorbed while less Na^+ was desorbed, indicating that the Ca^{2+} adsorption is an endothermic reaction and Na^+ desorption is an exothermic reaction.

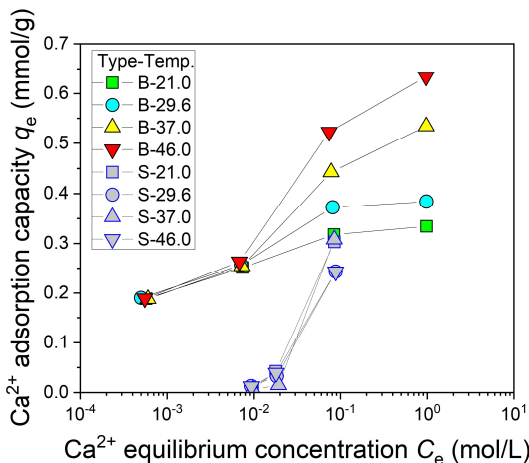


Fig. 3 Ca^{2+} adsorption Isotherms

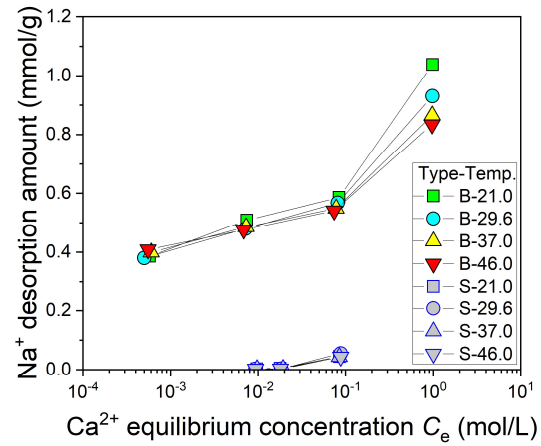


Fig. 4 Na^+ desorption amount vs Ca^{2+} concentration

4 Discussion

The results of batch tests have illustrated a kind of unbalanced ion exchange in bentonite. As **Fig. 5** shows, at the same initial CaCl_2 concentration (C_0), more positive charges will tend to get into the montmorillonite interlayer, which theoretically would facilitate the inhabitation of osmotic swelling.

On the other hand, the adsorption of soil part is found to be non-negligible at high CaCl_2 concentrations. This means multivalent cations will have more chances to be adsorbed by the soil rather than by the bentonite.

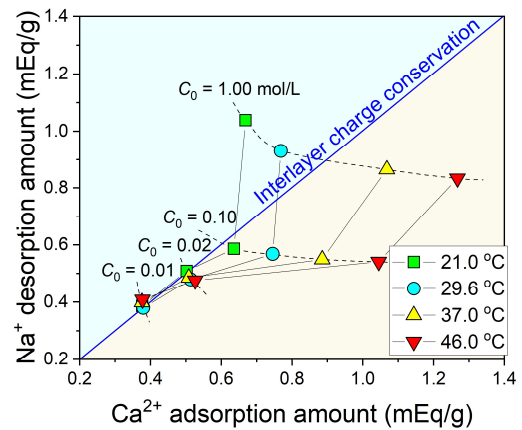


Fig. 5 Ionic change for bentonite after batch tests

References

- Kamon, M. et. al., (2002). Suitability Assessment of Bentonite-Soil Mixtures as the Landfill Bottom Liner Material. *J. Soc. Mat. Sci. Japan*, 51(1), 36–41.
- Katsumi, T. et. al., (2008). Long-term barrier performance of modified bentonite materials against sodium and calcium permeant solutions. *Geotext. Geomembr.*, 26(1), 14–30.