Mineralogical study on the consistency property of bentonite mixed soil

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Introduction

Bentonite is being used as a cushioning material because its primary component, Smectite, is expected to offer water cutoff, self-sealing properties, delayed sorption or migration of nuclides, and chemical buffering properties .

This study used X-ray diffraction and near-infrared spectroscopy to measure the crystal structure of high-purity homo-ionic Smectite and the vibratory motion of water molecules under controlled humidity. To compare the experimental results in detail, measurements were taken at intervals of 5% relative humidity (RH) between 0 and 100% RH on adsorption and desorption processes.

Materials and methods

Materials

Kunipia-F (Kunimine Industries Co., Ltd.), whose primary component is sodium Smectite. we refined Kunipia-F to produce high-purity homo-ionic (Na^+, K^+, Mg^{2+}, Ca^{2+}) Smectite.

Water content adjustment

The humidity control unit is composed of a saturation chamber, a temperature, pressure, and flow rate controller, and an experimental chamber. The temperature of the experimental chamber was set to room temperature (25℃).

X-ray diffraction

The Ultima IV horizontal multipurpose sample X-ray diffractometer (manufactured by Rigaku) was used to take measurements. The measurement conditions were as follows. X-rays: Cu (40 kV, 40 mA), measurement method: FT measurement, step width: 0.0600°, gate time: 1 s, scanning range: 2θ=2.000-50.000°.

Near-infrared spectroscopy

The Spectrum 400 Fourier transform infrared spectrometer (manufactured by Perkin Elmer) was used to take measurements. The measurement conditions were as follows. Measurement method: diffuse reflection, resolving power: 4 cm^{-1}, number of additions: 100 times, measurement range: 4000-7800 cm^{-1}.

Crystal structure of Smectite

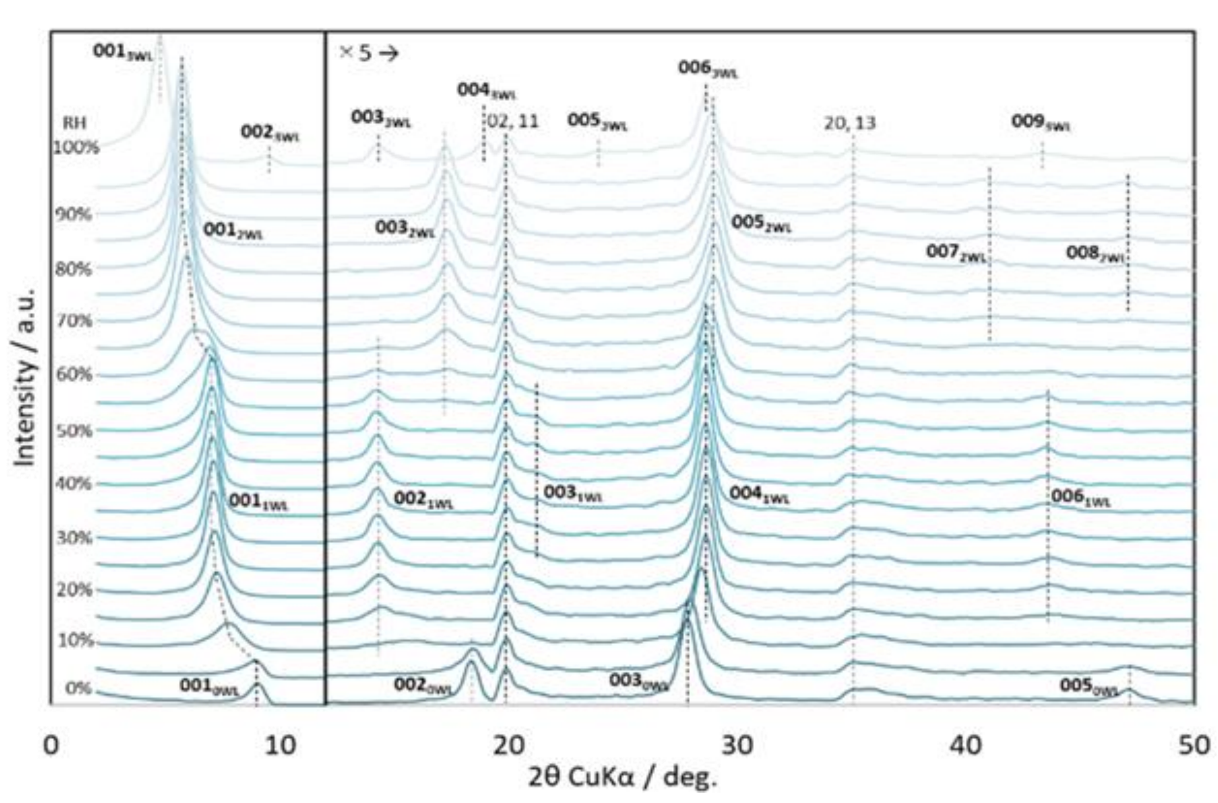

Figure 1. XRD profiles of Na-Smectite on desorption process.

Figure 1 shows an example of an X-ray diffraction profile.

The peak at the top of the profile is due to Bragg reflection, and the following relationship exists between crystal spacing d and diffraction angle 2θ.

$$n\lambda = 2d\sin\theta$$

n : positive integer , λ : wavelength of the X-ray

Figure 2 shows the humidity dependence of spacing d_{001}.

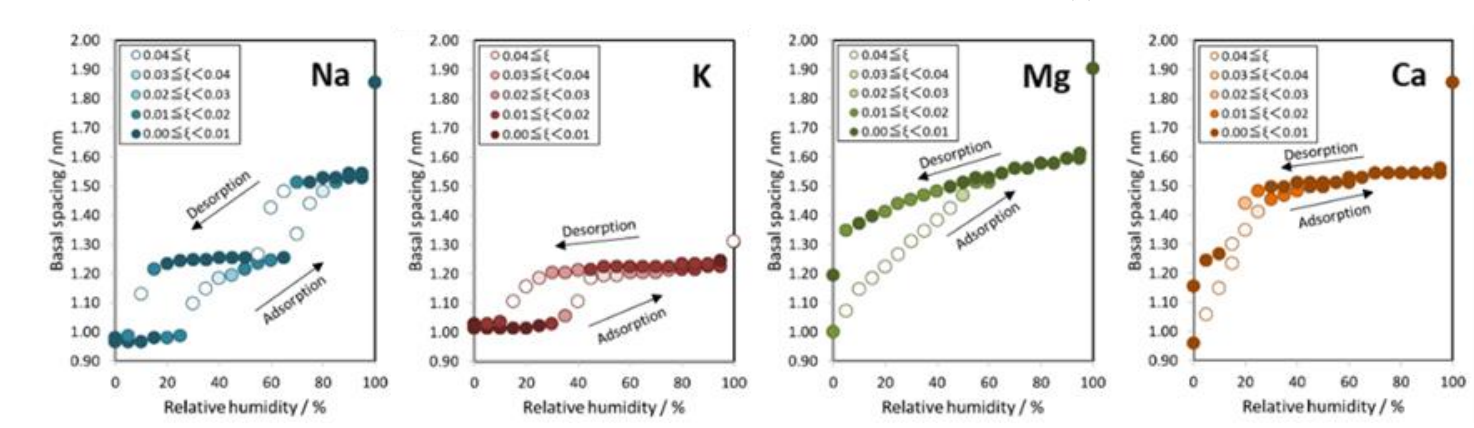

Figure 2. Changes in basal spacing d_{001} of Na-, K-, Mg- and Ca-Smectite. The color of the circles indicates degree of interstratification.

Water molecules in Smectite

Figure 3 shows an example of a near-infrared absorption spectrum. The absorption observed in this region is the combination tone (ν+δ) of the stretching vibration ν and angular vibration δ of OH groups.

Figure 5 shows the humidity dependence of water content. Water content reflects changes in spacing.

Figure 6 shows the relationship between spacing and water content. Monovalent and divalent ions exhibit very different patterns.

the hydrogen Smectite spectrum exhibited characteristics that were extremely similar to those of magnesium Smectite (Figure 8). This leads us to conclude that, in magnesium Smectite, hydrolysis produces H_3O^+.

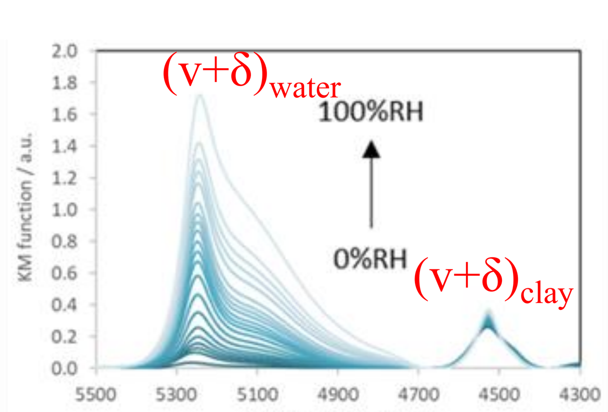

Figure 3. NIR spectrums of Na-Smectite on adsorption process.

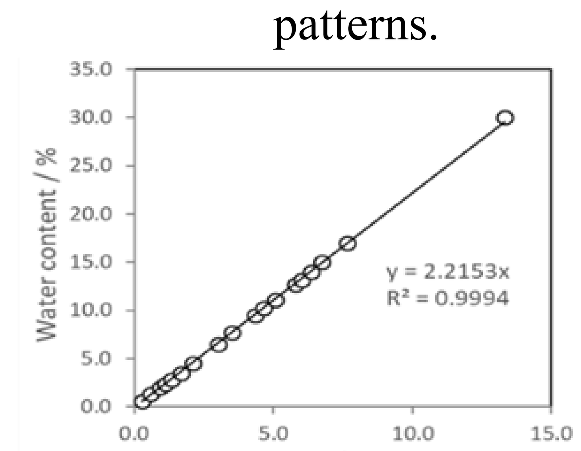

Figure 4. Relation between water content and normalized area of $(\nu+\delta)_{water}$ A_w' (Na-Smectite) .

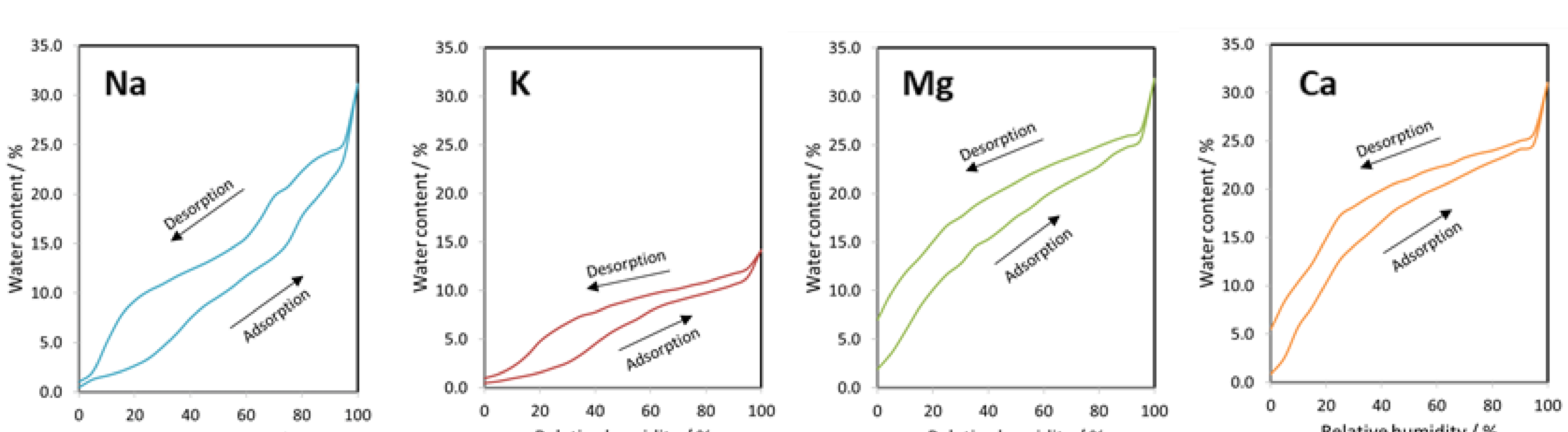

Figure 5. Changes in water content of Na-, K-, Mg- and Ca-Smectite.

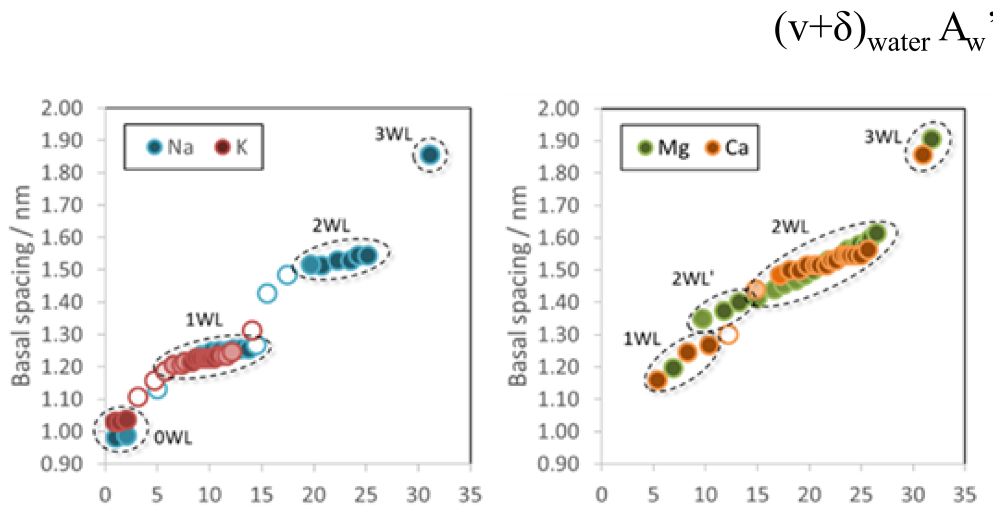

Figure 6. Relation between basal spacing and water content of Na-, K-, Mg- and Ca-Smectite on desorption process.

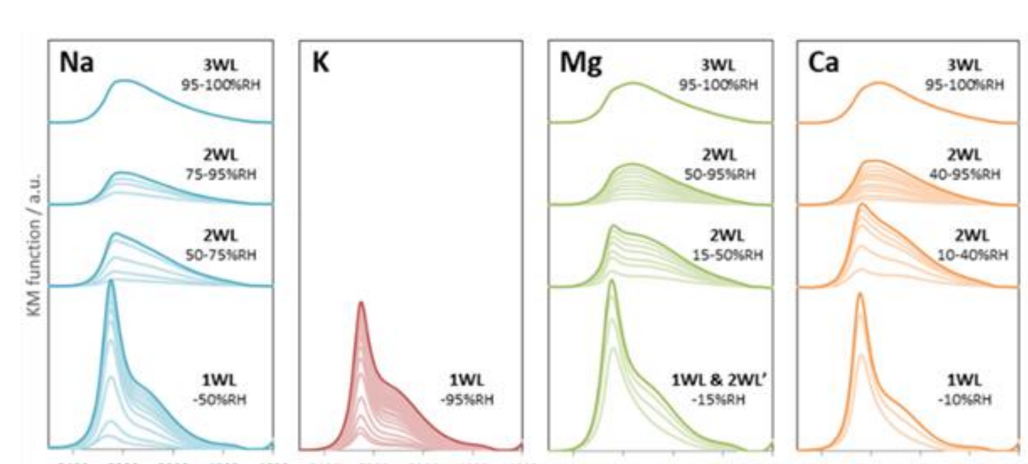

Figure 7. Different spectrums of Na-, K-, Mg- and Ca-Smectite on desorption process.

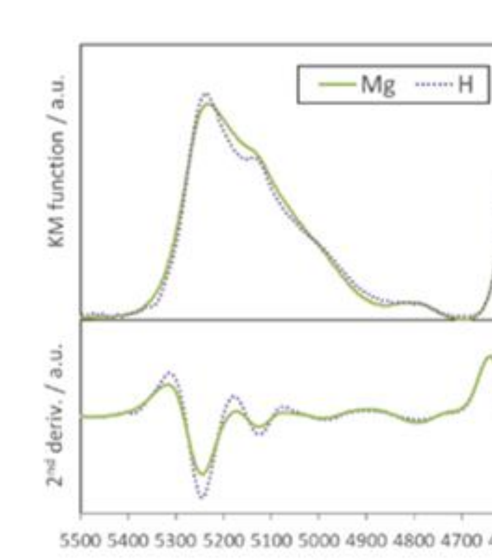

Figure 8. NIR and 2nd deviation spectrums of Mg- and H-Smectite.

Conclusion

High-purity homo-ionic (Na^+, K^+, Mg^{2+}, Ca^{2+}) Smectite was analyzed using X-ray diffraction and near-infrared spectroscopy, producing the below findings regarding crystal structure and the state of water molecules.

(1) Changes in spacing relative to water content are discontinuous for monovalent ions and continuous for divalent ions. There is a possibility that divalent ions with high ion potential change the arrangement of interlayer water molecules.

(2) For 1WL, both OH groups of interlayer water interact with the silicate layer surface facing them, and on the low-humidity side of 2WL, one OH group interacts with the silicate layer surface while the other OH group interacts with different water molecules.

(3) From the high-humidity side of 2WL to 3WL, there is also water that is similar to pure water in terms of vibratory motion.

(4) Water content is about 10±5% for 1WL, 20±5% for 2WL, and 30% for 3WL, regardless of the type of exchangeable cation.

(5) In magnesium Smectite, hydrolysis produces H_3O^+.