Comparison of Colloidal Stability in Montmorillonite and Kaolinite

モンモリロナイトとカオリナイトの分散し易さの比較

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1. INTRODUCTION

In arid and semi-arid regions, soil dispersion which leads to crusting and erosion appears to be one of the most serious problem. The permeability of crusted soil depends mainly upon the clay types, salinity and sodicity of irrigation water. In this study, dispersion and coagulation behavior of montmorillonite and kaolinite was evaluated at various salt concentrations and pH.

2. MATERIALS AND METHODS

2.1 Stock Material Preparation

Montmorillonite clay was obtained from "Kunipia-F" and kaolinte from "Iriki kaolin". The fraction of these clays less than 2 µm was used to prepare homoionic clay of Na^+ and Ca^{2+} using 0.5 M followed by 1.0 M solution of NaCl and $CaCl_2$ for one hour. Then free excess salt was removed by dialysis until the electrical conductivity of equilibrated outer solution was less than 1.0 mS m^{-1}. The pH of each sample after the dialysis was about 6.0. The stock clays were stored at room temperature in a dark place.

2.2 Dispersion and Coagulation Measurement

A clay concentration of 0.2 kg m^{-3} for montmorillonite and 0.1 kg m^{-3} for kaolinite was used for measurement. The solutions of NaCl and $CaCl_2$ with known concentration were added in the respective clay in 50 cm^3 glass tubes. The pH was adjusted to 3-11 using HCl or NaOH. The glass tubes were inverted and shaken by hand for more than 30 seconds. After 24 hours, they were visually inspected by naked eyes using a light beam. A supernatant phase was considered as an indication of coagulation. The critical coagulation concentration (CCC) were taken in between dispersion and coagulation at each pH and expressed as mol_c m^{-3} including base added to change the pH.

Electrical conductivity (EC) was used as an index of salinity of the solution. An empirical relationship between EC (dS m^{-1} at 25 ℃) and ionic strength (I) is given by following equations;

$$\mathrm{EC} = \frac{I}{0.0127} \qquad I = \frac{1}{2}\sum m_i z_i^{\,2}$$

where m_i is the concentration of ith ion (mol m^{-3}) and Z_i is the valence of ith ion.

The sodium adsorption ratio (SAR) defined below was used as an index of sodicity.

$$\mathrm{SAR} = \frac{[\mathrm{Na}^+]}{[\mathrm{Ca}^{2+} + \mathrm{Mg}^{2+}]^{\frac{1}{2}}}$$

where brackets indicates the total concentration of ions (mol m^{-3}) in the solution.

3. RESULTS AND DISCUSSION

3.1 Dispersion and Coagulation under Monovalent Salts

The dispersion and coagulation of montmorillonite and kaolinite under various pH and NaCl concentration is shown in **Figure 1.**

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At pH 6, the CCC of NaCl was 3 $mol_c\ m^{-3}$ for montmorillonite and for kaolinite it varied from 1 to 10 $mol_c\ m^{-3}$. This shows that montmorillonite disperse below pH 6 while kaolinite coagulate. At pH 9, the CCC of NaCl for montmorillonite was 33 $mol_c\ m^{-3}$ while it was 150 $mol_c\ m^{-3}$ for kaolinite. Results indicate that the CCC for montmorillonite was 3.3 times lower than kaolinite at pH 6, and 4.5 times at pH 9. Increased pH cause the development of greater negative charge on kaolinite, and therefore dispersion, which leads to a higher CCC for kaolinite than montmorillonite.

3.2 Dispersion and Coagulation under Divalent Salts

At pH 6, the CCC of $CaCl_2$ for montmorillonite was 0.45 $mol_c\ m^{-3}$ while it was 2.5 $mol_c\ m^{-3}$ for kaolinite. At pH 9, the CCC was 1.7 $mol_c\ m^{-3}$ for montmorillonite while it was 3.5 $mol_c\ m^{-3}$ for kaolinite (**Figure 2**). At pH 9, the CCC of $CaCl_2$ for montmorillonite was 20 times lower than NaCl for effective coagulation, while for kaolinite it was 43 times lower. According to Schulze-Hardy rule, the CCC ratio of Na^+:Ca^{2+} should be 1:64 for colloid with high Stern potential (ψ_δ >200 mV). Our results show that kaolinite is not far from the rule, indicating a higher Stern potential than montmorillonite.

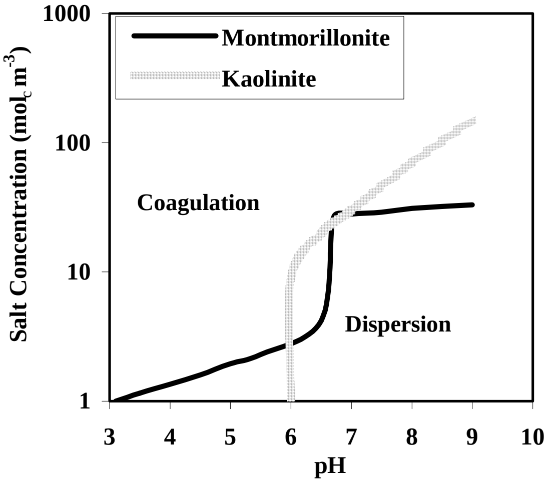

Figure 1. CCC of NaCl for montmorillonite and kaolinite under various pH

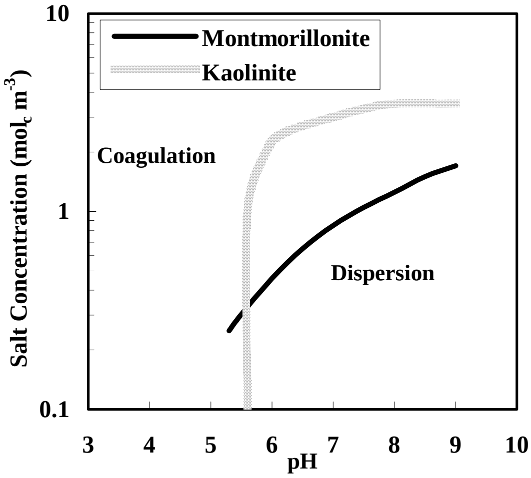

Figure 2. CCC of $CaCl_2$ for montmorillonite and kaolinite under various pH

3.3 Effect of Salinity and Sodicity

The dispersion and coagulation of montmorillonite and kaolinite under various sodium adsorption ratio (SAR) and EC is shown in **Figure 3**. At high pH, mostly the case of a sodic soil, the soil system required relatively higher EC (salinity) for coagulation under the SAR. Soil dispersion occurred even at low SAR (sodicity) when salinity was lower than the CCC, leading to deteriorated soil structure. The basic relationship between salinity and sodicity outlined here may serve as a baseline for understanding low quality groundwater use and drainage water reuse in arid and semi-arid regions.

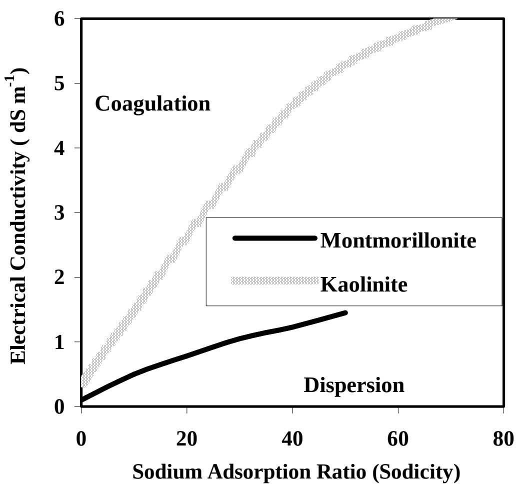

Figure 3. CCC under salinity and sodicity