

多様なイオン種の存在下での天然アロフェンのコロイド安定性

The colloidal stability of natural allophane in the presence of diverse ion species

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Abstract

To investigate the aggregation and charging behaviors of natural clay allophane in the presence of diverse ion species, the stability ratio (W) and electrophoretic mobility (EPM) of allophane were examined. The results of W with EPM show ion specific effect, which is not explicitly considered by the DLVO theory. However, the experimental relationship between critical coagulation ionic strength (CCIS) and surface charge density is in good agreement with the predicted one based on DLVO theory.

Key words: DLVO theory; Surface charge; Critical coagulation ionic strength

1. Introduction

Allophane is one of the typical clay minerals among the young volcanic ash soils, which are widely distributed in Japan. To understand the colloidal stability of natural clay allophane in different water chemistry is in the sense of significant to the soil usage and environment protection. Therefore, this research focuses on the colloidal stability of natural clay allophane.

To better understand the colloidal stability of allophane, its aggregation-dispersion process should be investigated. Adding electrolyte to the allophane suspension can induce aggregation of particles. The range of electrolyte concentration can be divided into slow and fast aggregation regions by a critical salt concentration in the aggregation rate transition. This critical salt concentration is called critical coagulation concentration (CCC), which can reflect the effect of a salt on the stability of a colloidal suspension.

Assuming a high surface potential and the presence of symmetric $z:z$ electrolyte, Derjaguin-Landau and Verwey-Overbeek (DLVO) theory could quantitatively explain the dependency of CCC

$\propto 1/z^6$, which is known as the empirical Schulze-Hardy rule. However, the soluble electrolytes commonly used in experiments are usually of the $z:1$ or $1:z$ type. In another aspect, the surface charge density observed in electrophoresis experiments is quite low. In addition, the DLVO theory ignores the ion specificity when explaining the particle aggregation process.

In this regard, the DLVO theory with Debye-Hückel (DH) approximation for low electric potential can be considered, and it is better to use the critical coagulation ionic strength (CCIS) instead of CCC. Therefore, we investigate the applicability of the DLVO theory to the aggregation behaviors of allophane particles in the presence of diverse ion species by considering the relationship between the CCIS and the surface charge density (σ).

2. Materials and Methods

Different species of ions, such as multivalent counter-ions and oxyanions, exhibit different effects on aggregation and charging behaviors of allophane due to different ion valence and ion specificity. Therefore, allophane suspension and electrolytes

solutions containing different ion species were prepared to investigate the effect of diverse ions species on the stability of allophane suspension.

To examine the aggregation and charging behaviors of allophane, dynamic and electrophoretic light scattering experiments were performed to measure the hydrodynamic diameter and electrophoretic mobility of allophane particles as a function of electrolyte concentration and ion type. Through the obtained experimental results, the stability ratio, CCC, CCIS and surface charge density were further examined.

3. Results and Discussion

For all the electrolyte types, the results of stability ratio and electrophoretic mobility as a function of the electrolyte concentration were well correlated and could be qualitatively explained by the DLVO theory.

Then, we calculated and summarized the experimental CCC of all electrolytes. The results show that DLVO theory may fail to explain the Schulze-Hardy rule under the experimental conditions, or the experimental CCCs do not follow the empirical Schulze-Hardy rule due to the ion specificity.

In such a situation, we considered to apply the DLVO theory within DH approximation and investigated the relationship between CCIS and surface charge density. The experimental data are in good agreement with the DLVO prediction within the DH approximation which indicates that the DLVO forces are the main driving forces in the aggregation process of natural clay allophane in the presence of diverse ion species (Fig. 1).

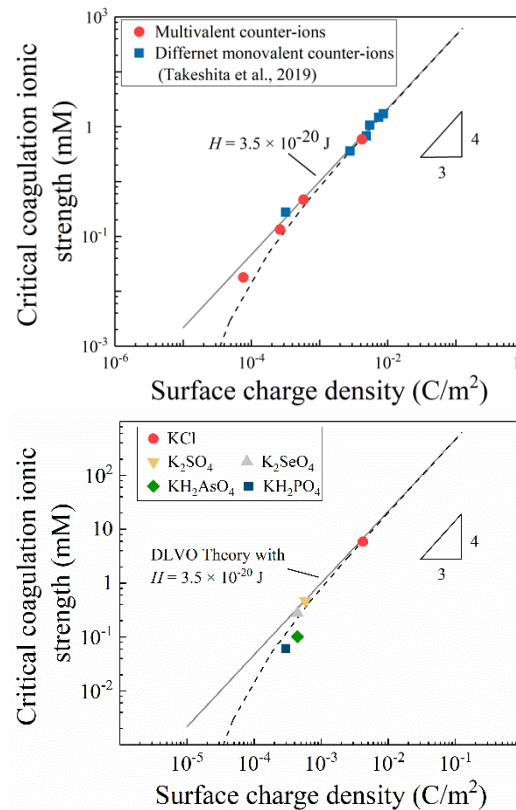


Fig.1 The critical coagulation ionic strength against surface charge density of allophane particles in the presence of KCl and potassium salts with different multivalent counter-ions (top) and oxyanions (bottom) at pH 5. The symbols are experimental data. The lines are the DLVO prediction. H is the Hamaker constant. The broken lines are drawn by considering the effect of thick double layer.

4. Conclusion

We conclude that the DLVO theory with surface charge density could explain the colloid stability in terms of CCIS of natural clay allophane in the presence of diverse ion species.

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