INVESTIGATION ON TRANSPORT OF K^+ IN ARIAKE CLAY UNDERLAIN BY SHIRASU SOIL

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1. INTRODUCTION

Nowadays clay liner in waste disposal landfill system has been caused much attention either by the government or researchers all over the world. In Japan there is a tendency to construct landfill sites in the coastal area of Japan (Kamon and Katsumi, 2001). However, by far as the authors know presently in Japan relatively little study on the advective-diffusion test concerning on the potential utilization of marine clay as soil barrier in landfill system has been done. This results in lacking in the awareness of the transport properties of contaminant through marine clays in Japan. Therefore, it is of importance to investigate the transport performance of contaminant in regional marine clays located in Japan. This study aims to perform a laboratory column test, and then understand the dominant process controlling the migration of K^+ in two types of Kyushu regional soils in Japan, Ariake clay underlain by Shirasu soil.

2. SOIL DESCRIPTION

In this study, Ariake clay and Shirasu soil were sampled at Kohoku Town of Saga Prefecture and Ebino City of Miyazaki Prefecture, respectively. According to Japanese Unified Soil Classification System, Shirasu soil is classified as well-graded sand (SW). The physico-chemical properties of the soils are shown in Table 1.

Table 1 Physico-chemical properties of the soils

Soil type	Ariake clay	Shirasu soil
Specific gravity	2.62	2.43
Natural water content, w_n (%)	153	28
Liquid limit, w_L (%)	116	—
pH at 1:3 soil:solution	8.0	7.1
Clay particle fraction (%)	85	12
Silt particle fraction (%)	14	78
Sand particle fraction (%)	1	10
Main clay mineral	Smectite	—
CEC (meq/100 g)	36	0
K^+ concentration in pore fluid (meq/L)	8.03	0.22

3. TEST PROCEDURE

A schematic plot of the test apparatus in shown in Fig. 1. Details of the test apparatus and soils specimen preparation were provided by Du (2001). Briefly, the Ariake clay specimen prepared by 7 kPa consolidation pressure was placed above the prepared Shirasu soil column which was saturated by downward-flow of de-aired distilled water. Then the source reservoir was placed above the Ariake clay and the synthetic contaminant leachate, KCl solution was introduced into the source reservoir (Fig. 1). A stainless steel cap was covered above the source reservoir. After that, the glass stir bar connected to a motor was fitted to the system. The rotary speed of the motor was controlled as 6 rpm. Throughout the test, K^+ concentration in the reservoirs was periodically monitored. During the test, the water level in the source reservoir was regularly monitored and infiltrated volume was replaced with the same volume of distilled water to re-establish the original water level. The amount of distilled water added was used to calculate the average Darcy velocity through the soil. Upon completion of the diffusion test, the solution in the reservoirs was drained and the source reservoir and base reservoir were disassembled. Both Ariake clay specimen and Shirasu soil specimen was sliced into five sublayers using a stainless steel thread and very thin stainless steel plate, respectively. The pore water in each sublayer of the soils was extracted and K^+ concentrations were measured.

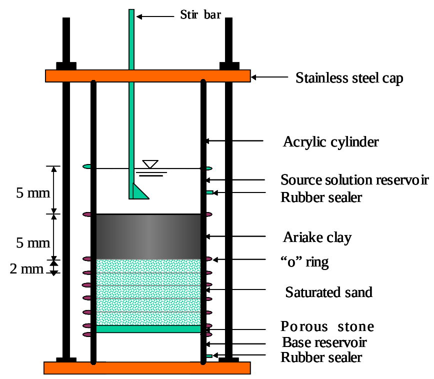

Figure 1 Schematic plot of test apparatus

Key Word adsorption, advection, contaminant, diffusion, dispersion, landfill

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4. TEST RESULTS AND DISCUSSION

The traditional one-dimensional advective-diffusive-dispersive transport governing equation was used in this study to model the K^+ ion migration in the soils. In this study, it is assumed that mechanical dispersion can be neglected and the effect of Darcy velocity on dispersion is discussed in the later part. The upper boundary imposed by the source reservoir is finite mass condition and lower boundary imposed by the base reservoir is fixed outflow condition. Also the continuity of flow and conservation of mass requirements were adopted for simulation. Detailed discuss on the governing equation, bottom conditions and requirements expressed by the mathematic equations were provided by Du (2001). All of these have been completed in a commercial program, POLLUTE V 6.3 as described by Rowe and Booker (1994). The effective diffusion coefficients of Ariake clay and Shirasu soil were back-calculated from the concentration profile in soil specimens by using POLLUTE V6.3. The input parameters are summarized in Table 2. The adsorption parameters of Ariake clay were determined by fitting the batch-type test results using soil: solution at 1: 4 ratio to the Freundlich adsorption model. The effective diffusion coefficient of K^+ for Ariake clay (D_e = 9.0 × 10^{-10} m^2/s) is lower (about 40%) than that of Shirasu soil (D_e = 15.0 × 10^{-10} m^2/s) implying that Ariake clay provides a better diffusion layer. This may be due to the difference in the grain size distribution between these two soils as indicated in Table 1. The predicted concentration profiles in the source and base reservoirs were obtained by using the deduced effective diffusion coefficients of K^+ determined from the concentration profiles in soils and these predicted values were found to well fit to the observed data in the source reservoir and base reservoir (Du, 2001). Since the predicted values well fit to the observed data (see Figure 2), the assumption that mechanical dispersion can be neglected is thought to be correct. From Fig. 2 it can be seen that at v_a = 0 which means the pure diffusion, the predicted values significantly differ from the observed value and predicted value at Darcy velocity v_a = 6.5 × 10^{-9} m/s presented in this study, indicating that it was not diffusion process solely that controls transport of K^+ in soils. Advection process also plays role in controlling the transport of K^+ ions in the soils.

Table 2 Input parameters used in modeling the results

Soil type	Ariake clay	Shirasu soil
Thickness (cm)	5	10
Dry density, ρ_d (g/cm^3)	0.65	1.07
Volumetric water content, θ	0.74	0.51
Adsorption parameters, K_f, n	0.028, 0.720	0, 0
Average Darcy velocity, v_a ×10^{-9} (m/s)	6.5	
Height of solution (cm)	6.9	
Test period (days)	33	
Solution collected, q_c (q_b) ×10^{-10} (per area per time, m/s)	2.5	

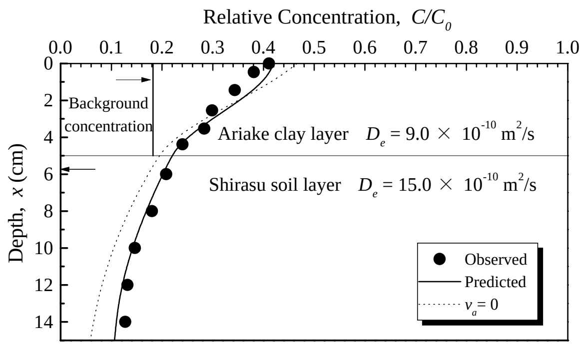

Figure 2 Concentration-depth profile of K^+ in soils

5. CONCLUDING REMARKS

1) The determined effective diffusion coefficient of Ariake clay is lower than that of Shirasu soil, which may be due to the effect of grain size distribution.

2) Mechanical dispersion could be neglected at the Darcy velocity presented is this study. Advection-diffusion is the predominant process controlling the migration of K^+ in the soils.

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