Zinc sorption in clay using batch equilibrium and column leaching tests

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Abstract: The amount of zinc sorbed in two kinds of clay, bentonite and illite, were measured using two kinds of tests, batch equilibrium and column leaching tests. Results show that batch equilibrium tests overestimate the attenuation capacity of the soil, compared to the column test. Bentonite shows a higher retention capacity than illite.

Key words: sorption, attenuation, batch equilibrium tests, column leaching tests

Introduction

The sorption process can be investigated through two methods. Batch equilibrium tests simulates a completely dispersed particle soil system while in column tests the contaminant is made to leach through a normally consolidated clay layer, which has a definite matrix and soil structure, and where not all soil particle surfaces are available for interaction with the contaminants.
This study aims to compare results from these two types of tests. Two kinds of clay, bentonite and illite were used as the soil.

Materials and Methods

Batch tests were done by mixing clay with a zinc solution of known initial concentration, then agitated for 24 hours using a magnetic stirrer. The solids were separated from the liquid using a laboratory centrifuge with 5000 rpm for 10 minutes. The supernatant was collected, and analyzed using the Inductive Coupled Plasma – Atomic Emission Spectrometer (ICP-AES) Spectrum 7000. This was done for different initial concentrations ranging from 40 mg/L to 5000 mg/L. Samples that were not immediately analyzed were preserved by adding nitric acid and kept in the refrigerator.
Column tests were conducted by leaching a solution with known concentration over a normally consolidated clay layer. The set up is illustrated in Figure 1. The amount of solids retained in the layers was determined by extraction of the zinc content through acid digestion.

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RESULTS AND DISCUSSION

A total of 17 batch tests were made, eight for bentonite and nine for illite. Bentonite fits the Langmuir model while illite follow the Freundlich sorption isotherm.
Comparing these results with previous studies, the study done by ANTONIADIS AND MCKINLEY (2000) was referred to. In their study, batch tests were also conducted to determine the sorptive capacity of zinc in London clay, which contains quartz, kaolinite, montmorillonite, and muscovite as its principal minerals. Compared with bentonite, London clay shows a lower sorptive capacity. Compared with illite, it has almost the same sorptive capacity in the equilibrium concentrations less than 2000 mg/L. Table 1 summarizes the characteristics of the sorption isotherms.

It can be seen that bentonite has a better retention capacity which can be attributed to its high cation exchange capacity (CEC) and large surface area as has been previously confirmed by other researchers (YONG AND PHADUNGCHEWIT, 1993). This explains why bentonite is the ideal clay liner used in waste containment systems.
There was one leaching test done each for bentonite and illite. The amount of solute retained in the layers after the bentonite leaching tests was determined using acid digestion. Results are shown in Table 2. Three core samples were taken from the clay, with each sample divided into 4 slices each.

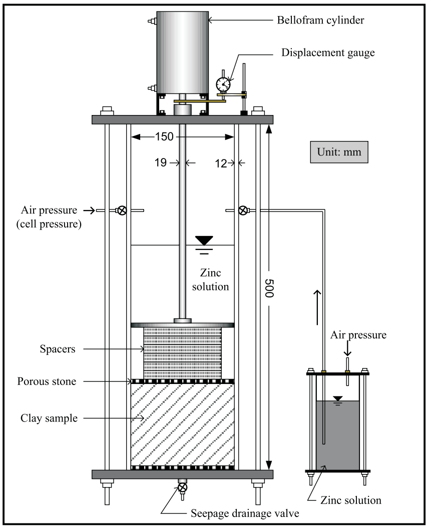

Figure 1. Set up of column test

Table 1. Characteristics of sorption isotherms

	Bentonite	Illite	London Clay
Type of Isotherm	Langmuir	Freundlich	Freundlich
Coefficients	â = 34.96 mg/g á= 0.0014 L/mg	K = 0.1608 N = 0.5899	K = 0.7452 N = 0.3671
R^2 value	0.95	0.88	0.99

The amount of solute retained decreased along the depth of the layer, i.e. the closer the slice is to the top, the more solute were retained. The three cores that were taken were composed of one from the center (Sample A), and two from the sides (Samples B and C). It can be observed that the amount sorbed in the center in the lower two layers is slightly greater than those at the sides. This can be explained by preferential flow at the sidewalls, and that since velocity at the walls are greater, there is less contact time for the zinc to attach itself to the clay. At the upper two layers, there are more solids retained in the sidewalls, since there is precipitation at the top. There is more flow at the sides, therefore, more contaminant passed at the sides, and thus, more precipitates formed in these areas.

Table 2. Amount of solute retained in bentonite layer

	Solute retained (mg/g)			
Distance from Top (mm)	Sample A (Center)	Sample B (Side)	Sample C (Side)	Mean
10	0.1300	0.2130	0.1778	0.1736
20	0.0727	0.0804	0.0667	0.0733
30	0.0766	0.0686	0.0545	0.0665
35	0.0744	0.0577	0.0607	0.0643

The amount of solute retained in the illite layer was also determined through acid digestion. One core sample taken at the center was analyzed. The layer was divided into 7 slices, with the topmost layer measuring 5 mm and the rest 10 mm each. The results are shown in Figure 2. As in the results in bentonite, there is a decreasing trend of solute retained in the layers as it goes farther from the source of contamination.

This is the amount of solute sorbed after leaching 1.6 pore volumes, which is much greater than the total pore volume of 0.19 used in bentonite. It is thus difficult to compare the two materials since different pore volumes were used.

When estimating transport parameters to predict the transport of contaminants, those obtained from column tests are better estimates rather than the batch equilibrium tests since the latter simulate a completely dispersed soil particle system, thus, making all the surfaces of the soil available for interaction with the contaminant, resulting in overestimation of the amount of contaminant that can be sorbed.

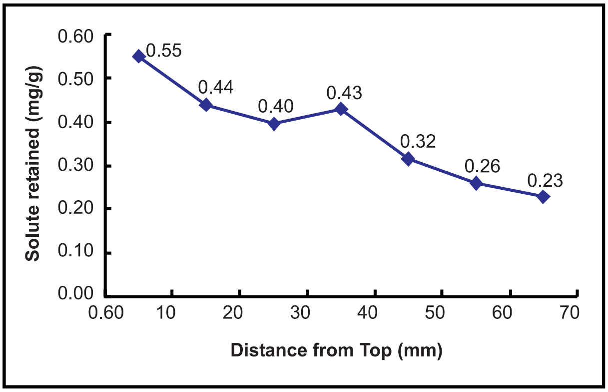

Figure 2. Amount of solute retained in illite layer

CONCLUSIONS

The batch tests can give an estimate for the maximum possible amount of contaminant that can be sorbed by the solids, while column tests can give estimates more representative of the field conditions. If the results of the column leaching procedure are compared with those obtained from the batch tests, it can be seen that the amount of solute sorbed in the batch tests are much more than those obtained from the column tests. Thus, sorption isotherms derived from batch tests should not be applied directly to field conditions.
Compared to illite, bentonite was shown to have a higher retention or attenuating capacity.

Acknowledgements

This work was supported by the Soil Mechanics Laboratory of the Department of Civil Engineering, Tokyo Institute of Technology, the Japanese Ministry of Education (Monbusho) through its full scholarship grant to the main author, and the Japan Society for the Promotion of Science (JSPS), through its research fellowship grant to the second author. The authors also acknowledge Dr. Taro Urase for making the ICP-AES available for the analysis of the samples.

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