Effect of the liquid's quality on the hydration ratio of a composite aggregate particle system to be use as a liner material at landfill sites

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1. Introduction

Bentonite clay base liners had been used as hydraulic barriers at landfill sites, for remediation projects for contaminated sites and for secondary containment systems (Rowe 1998). AquaBlok composite aggregate particle system (CAPS) is an engineered formulation of dry clay minerals (often bentonite), polymers, and an aggregate core showed in fig. 1 (AquaBlok technical report #1). Textural and swelling properties of bentonite are of paramount importance since they will determine properties of the engineered barrier, such as hydraulic conductivity, gas permeability, absorption capacity, etc. (Neaman, Pelleiter and Villieras 2002). The swelling abilities of bentonite clays (main component of the Aquablok) are highly related to the chemistry of pore liquid. At a landfill site, the barriers are subject to permeation by more than one liquid. The cations, the concentration, and/or the dielectric constant of the permeating fluid(s) will have a strong influence on the swelling and therefore the hydraulic conductivity factor of clay liner. The sequence of liquids by witch the clay barrier is hydrated it is very important for maintaining a low hydraulic conductivity factor. Pure, reagent grade, and organic chemicals, added to the presence of liquids such as glycol and methanol, may increase dramatically the hydraulic conductivity of a clay liner previously saturated with water (Green 1981) and (Brown et al. 1984). The aim of this study was conducted in order to measure the swelling ratio of the CAPS's formulation in different types of liquids, such as liquids with different pH levels, municipal tap water, raw leachate, artificial leachate and liquids with high concentrations of Ca^{++} and Cl^-.

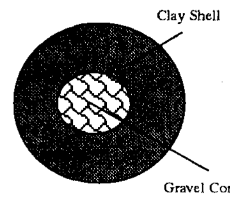

Fig. 1. Configuration of a typical AquaBlok Particle

2. Materials and Method

The Aquablok formulation used, had a content of 40% of bentonite and polymers per particle weight. The reagent liquids were selected to be representative of what an Aquablok barrier may be subject to in a landfill site area. Liquids prepared with distil water and HNO_3 or KCl to obtain acidity or alkaline values of pH= 2, 5, 7, 9 and 12; Raw leachate; Artificial leachate; Liquids with high concentrations of 5000mg L^{-1} of Ca^{++} or 8% of Cl^-, prepared with distil water and $Ca(NO_3)_2 \cdot 4H_2O$ or NaCl respectively; and tap water. Ten samples were measured.

As the gravel core does not possess swelling properties and will only work as a skeleton for providing support to the top layer's vertical stress, they were removed. The clay mineral component samples were dried to a constant weight at 105 ± 5°C. 40 ± 0.2 g of dried and finely ground clay mineral were added to 2000-mL of reagent liquid in a clean graduated cylinder (L/S=50). The samples were allowed to free swell in the reagents for a period of 300 hours were changes in volume, pH, EC and ORP, were recorded after the first hour and then after every 20 hour period.

3. Results and Discussion

The Gouy-Chapman theory (1910-1913) is considered the most successful theory that describes the diffused double layer (DDL). The swelling abilities of clays such as those included in the smectite group are highly related to the colloidal activity; the dielectric constant, electrolyte concentration of the solution, and the solute's cation valence will determine the swelling ratio of the clay, but other factor such as suspended solids and microorganism, the initial moisture content of the clay, layer charge, origin of the sample may influence as well.

As it was expected the characteristics of the liquid induced to different swelling ratios. fig. 2 shows the change of volume in cm^3 of the samples within a period of 300 hrs; the sample hydrated in the solution with pH 5 had the greatest swelling ratio while those hydrated with high concentration of Ca^{++} , Cl^- and raw leachate had the lowest. The values of the EC in ms/cm within the 300 hrs period are show in fig. 3; samples hydrated with high concentration of Ca^{++} and Cl^- and raw leachate had the highest EC values while the other liquids had a fairly low level.

Changes on the pH values are express on fig. 4. Slight changes of pH was observed in the solution with very high pH (above 10) and solutions with low pH (below 5), while all the samples with pH levels within the 5 and 9 range, a rapid increase on the pH values was noted. The changes on the ORP values are express on fig. 5. Very small changes on the ORP value was noted, therefore, so using the ORP data for prediction on the swelling behavior of the samples, seems to have little importance.

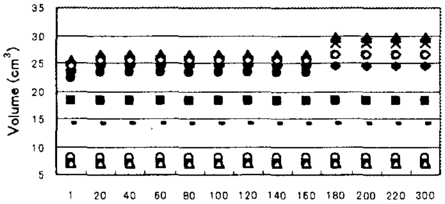

Fig. 2. Change of the volume within a 300 hrs. period of time

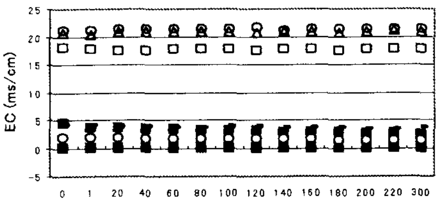

Fig. 3. Change of the EC within a 300 hrs. period of time

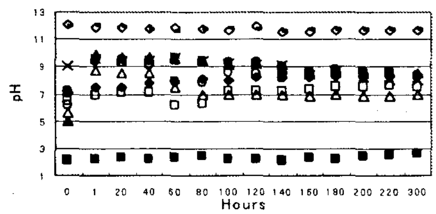

Fig. 4. Changes of pH values within a 300 hrs. period of time

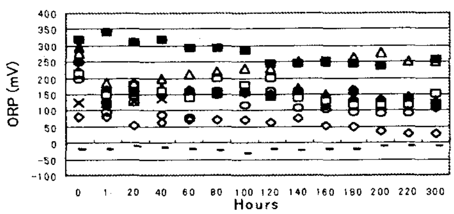

Fig. 5. Changes of the ORP within a 300 hrs. period of time

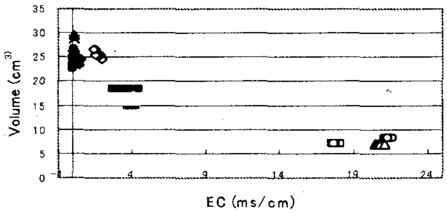

Fig. 6. Relationship of the EC on the swelling ratio of the samples

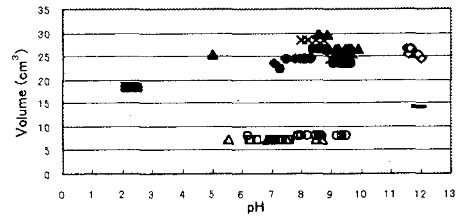

Fig. 7. Relationship of the pH with the swelling ratio of the samples

(◆) Tap Water; (■) pH2; (▲) pH5; (●) pH7; (×) pH9; (◇) pH12; (□) Raw Leachate; (△) 5000mgL^{-1} of Ca^{++}; (O) 8% of Cl^-; (-) Artificial Leachate.

Those samples hydrated in solutions with high electrolyte concentration such as the raw and artificial leachates, the solutions with high concentrations of ions (5000mg L^{-1} of Ca^{++} or 8% of Cl^-) swell lest compared to the other samples with low electrolyte concentrations; the solution of pH5 presented the lowest EC value and the highest swelling ratio (fig. 6).

The pH of a solution not only characterizes chemical reactions important in terms of hydraulic conductivity, but also can affect significantly the soil fabric (fig. 7). pH levels between 5 and 9 are characterized as mild acid-neutral solutions, and it it's well knowing that the pH of bentonite ranges between 8 and 9, therefore, a possible reason for the rapid increase of the pH in the sample hydrated in the solution with pH 5 (as shown in fig. 4) is that the alkalinity of the pore water was neutralized by the acid, allowing the bentonite to swell more. Shackelford (1994) reported that there are three mechanisms that may contribute to an increase in the hydraulic conductivity of a clay soil after being permeated with a liquids with a low pH level (e.g. pH2); a) flocculation of the clay; b) dissolution of the clay minerals in the clay; and c) dissolution of other mineral in the clay soil. The dissolution of carbonates initially leas to buffering, re-precipitation, pore clogging, and decrease in the hydraulic conductivity. Depletion of the buffering capacity leads to a decrease in pH, dissolution of constituents and possible increase in the hydraulic conductivity.

4. Conclusion

This study was aimed to understand the swelling behavior of a CAPS formulation on liquids that may interact with the clay barrier at a landfill site. The results of free swell tests can be used to predict the effect that the hydrating liquid will have on the hydraulic conductivity of a clay barrier. Liquids with low EC concentration will allow the bentonite to swell more, taking into consideration other factors such as suspended solids, microorganism, origin of the clay etc. It is intended to believe that a great expansion ratio when compacted to a high density level, can assure a lower hydraulic conductivity fact of the barrier, but this needs to be corroborated by standardized hydraulic conductivity tests.

References
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