Polymer Enhanced Geosynthetic Clay Liners for Bauxite Storage

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Abstract

Polymer modified geosynthetic clay liners (PMGs) are a fairly recent innovation and are seeing use in situations where traditional geosynthetic clay liners (GCLs) do not provide sufficiently low hydraulic conductivity. PMGs have found use in waste impoundments for mining and ore processing operations such as red mud storage facilities, reducing the risks associated with such structures. The chemistry of red mud leachates generated by various mining operations, such as the Bayer process, is well documented. These leachates can have high ionic strengths and elevated pH values compared with other common GCL applications, such as MSW landfills. Our research has shown that new PMGs are compatible with a range of high pH chemistries, such as bauxite liquors, cement kiln dust (CKD) and trona mining. Various types of bentonites sourced from various locations were evaluated with a particular polymer type. The influence of liner design parameters, such as mass per unit area, on the hydraulic conductivity was evaluated. ASTM D6766, *Standard Test Method for Evaluation of Hydraulic Properties of Geosynthetic Clay Liners Permeated with Potentially Incompatible Aqueous Solutions,*[1] can be used to confirm the hydraulic compatibility of GCLs with mining leachates. Research on appropriate termination criteria as well as performance limits will also be presented.

Keywords: Red mud storage, geosynthetic clay liner, polymer modified bentonite, chemical compatibility, hydraulic conductivity.

1. Introduction

Geosynthetic clay liners (GCL) and polymer modified geosynthetic clay liners (PMGs) are gaining favor for use in industrial waste disposal and ore processing applications. [2-4] The GCLs or PMGs can be a component of a composite liner system that will allow for increased performance (relative to compacted clay), as well as a more environmentally responsible and economical design. The performance advantages afforded by GCL will minimize the risk of leakage into the environment. Additionally, GCLs and PMGs can provide manufactured quality assurance and ease of installation.

Traditional sodium bentonite based GCLs function best in conditions that promote the swelling and sealing power of the hydrated montmorillonite platelets of the clay. However, applications that involve high ionic strength and or high pH conditions can preclude the use of traditional sodium bentonite GCLs due to reduced swelling potential of the bentonite. Trona mining, bauxite mining and CKD storage are applications which have both high dissolved salt concentrations and are also highly alkaline. Trona (also referred to as sodium sesquicarbonate), is mined to produce soda ash that is used in commercial applications/products such as baking soda, glass production, and flue gas desulfurization agents to name a few. In Trona mining, mining process waste water is piped to surface impoundments or ponds. In a similar manner, red mud waste generated by the chemical leaching process of bauxite for aluminum production is storage in tailings dams. Red mud must be stored indefinitely due to the hazardous nature of the waste. Recent high profile red mud storage dam failures have led to improved storage designs utilizing composite liners. Cement kiln dust (CKD) is another highly alkaline type of waste. CKD is a waste product that is removed from cement kiln exhaust gas by air pollution control devices. Some of the CKD that is not recycled in the cement manufacturing process is typically disposed in landfills, waste piles, or surface impoundments. When this dust mixes with water it can be corrosive and promote the mobility of heavy metals in the soils surrounding a storage facility. Other risks associated with the leaching of CKD is the presence of heavy metals such as arsenic, cadmium, chromium, thallium and lead as wells the presence of dioxin in the dust.

New clay liner technologies have recently been developed to extend the use of a manufactured liner into these aggressive applications. Silica modified bentonites as well as polymer modified bentonite technologies have been successfully used in these applications. A particularly interesting aspect of the engineering and design of the liner has been the type of bentonite which is suitable for use. Studies by Benson[5] et al and Gates[6] et al have found that bentonites with a naturally high concentration of silica can yield lower hydraulic conductivities compared to traditional bentonites that meet traditional performance criteria such as GRI-GCL3. [7] These studies demonstrated the accessory minerals associated with the particular bentonite source can result in different hydraulic performance. For this study, bentonites sourced from the US, China, India and Turkey were mixed with a proprietary polymer treat package and compared for the chemical compatibility with various bauxite, trona and CKD leachates. Also, we sought to understand the influence of mass per unit area on the performance of systems which ranged from 3.7 to 5.3 kilograms per square meter.

2. Experimental

Inductively Coupled Plasma (ICP)
ICP testing was performed on a Thermo Scientific iCAP 7000 Series ICP spectrometer unit equipped with a radial argon torch. The Teva 1.6.5 software was used to collect the data. Prior to testing, the original leachate for the bauxite leachates were diluted 1:100 with deionized water. The trona leachates were diluted 1:1000 with deionized water. The ICP was calibrated with standard electrolyte solution: 5, 50, 100 and 200 ppm prior to analysis. The leachate samples were analyzed for calcium, aluminum, manganese, magnesium, iron, zinc, potassium sulfur, phosphorus, copper and silicon.

Hydraulic Conductivity
Hydraulic conductivity tests on GCL specimens were conducted in a flexible-wall permeameter using a falling headwater / constant tail water method described in ASTM D6766.[1] The GCLs were hydrated with permeant liquid in the permeameter for 48 hr at an effective confining stress of 10 kPa. After prehydration, the effective confining stress was increased to 20 kPa, and the hydraulic gradient was set at approximately 150. Influent for the specimen was introduced using a burette. The permeate was collected in sealed individual vials. Perm testing was conducted for varying lengths of time depending on the hydraulic properties of the sample.

Leachate Characterization
Determination of electrical conductivity (EC) was performed using a Mettler Toledo SevenGo Pro conductivity meter. The EC was expressed as microsiemens per cm (µS/cm). The pH of the leachates and permeates were measured using an Oakton Ion 700 pH meter equipped with an Oakton Acorn model 35811-98 probe. Chloride contents was estimated by QuanTab® Test Strips. The sulfate content estimated by the sulfur content detected by ICP.

Calculations:
Ionic Strength (I):

$$I = \frac{1}{2}\sum_{i=1}^{n} c_i z_i^2$$

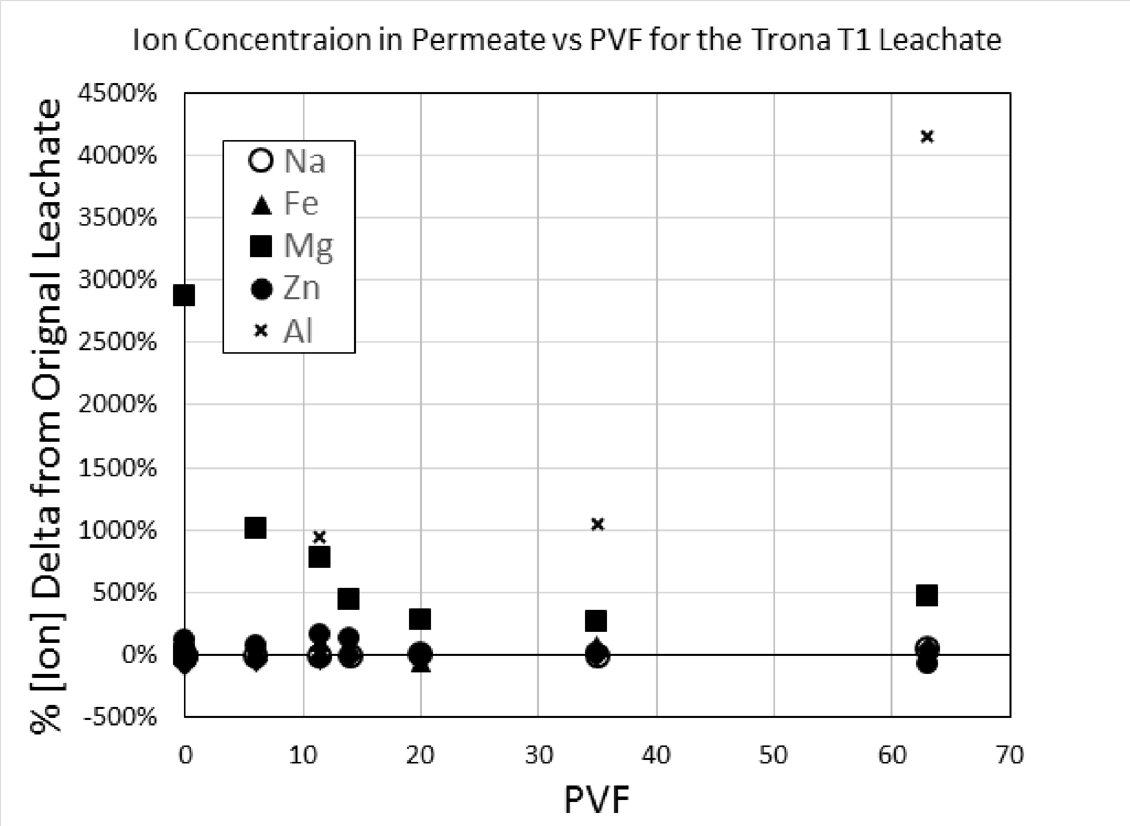

Figure 6. Relative ion concentration changes vs PVF for the Trona T1 Leachate with the PMG-4 U system.

4. Conclusion

The hydraulic conductivity of a new polymer modified GCL (PMG-4) was evaluated for high pH leachates. For the PMG-4 system, the maximum electrical conductivity that allowed for low hydraulic conductivities was ~133 000 µS/cm. The regionally source of bentonite did not have a major influence of the hydraulic conductivity. Higher mass per unit area results in lower hydraulic conductivity values for the synthetic bauxite leachate. Depending on the leachate tested, the hydraulic equilibrium occurred at different points in the experiments. For bauxite leachate testing, hydraulic equilibrium occurred at approximately 2 PVF. For trona leachate testing, hydraulic equilibrium occurred at approximately 53 PVF. In addition, the ion chemistry changes as function of PVF was dependent upon the type of ion for the trona leachate. Our work indicates that the ultimate permeability, hydraulic equilibrium and chemical equilibrium is leachate specific. Testing must be conducted to a sufficient pore volume of flow to be confident the system has reached a steady state.

5. References

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