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Laboratory investigation of thermally induced desiccation of GCLs in double composite liner systems

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ABSTRACT

The potential for desiccation of GCLs in double composite liner systems under thermal gradients is experimentally investigated. The effects of key initial and boundary conditions such as the GCL mass per unit area, initial GCL and subsoil water content, time lag between waste placement and temperature increase, the applied temperature gradient and the foundation layer thickness are investigated and discussed. The results suggest that surface temperatures of 39–45 °C, corresponding to thermal gradients of 59–67 °C/m, can induce sufficient thermally driven moisture redistribution to cause desiccation of GCLs. For surface temperatures of 29–37 °C and thermal gradients of 20–29 °C/m there was occasional slight cracking observed in about a quarter of the cases examined. Results of laboratory permeability tests on the virgin and exhumed samples are used to assess the self-healing capacity of GCLs.

1. Introduction

Geosynthetic clay liners (GCLs) have numerous applications in geoenvironmental engineering including landfill liners for municipal solid waste (Gassner, 2009; Guyonnet et al., 2009; Dickinson and Brachman, 2010) as well as resource recovery (Gates and Bouazza, 2010; Hornsey et al., 2010; Lange et al., 2010; Rowe et al., 2010a; Shackelford et al., 2010). They can be used as a single liner system or as part of a single or double composite liner system (Rowe et al., 2004).

Although geomembranes (GMBs) are excellent barriers to contaminated liquids when they are intact, fluids can readily leak through holes in a GMB unless there is resistance to that flow. The primary role of the GCL in a composite liner is to minimize the leakage of fluids though any hole in the GMB (Rowe, 1998; Nosko and Touze-Foltz, 2000; Rollin et al., 2002; Needham et al., 2004). For this composite action to be most effective, it is important that the GCL below the GMB not be desiccated, over the entire contaminating lifespan of the landfill (Rowe, 2005).

Biodegradation of organic waste and the hydration of ash in waste material can generate heat which reaches its maximum value in the main body of the waste and decreases toward the landfill base (Collins, 1993). This temperature, and the rate of temperature increase, will depend on the landfill cover, landfill operations, climatic conditions, waste temperature at the time of placement, rate of waste filling, biomass content, leachate level and leachate recirculation (Rowe, 2010).

Several studies have been conducted to define the time-temperature history in the main body of the waste as well as at the base of landfills (Lanini et al., 2001; Yoshida and Rowe, 2003; Rowe, 2005; Yesiller et al., 2005; Koerner et al., 2008; Rowe and Islam, 2009). At the base of MSW landfills with an operating leachate collection system, temperatures of 30-40 °C have been observed. In bioreactor landfills, landfills without a leachate collection system, or where the collection system has failed, higher temperatures of 40–60 °C have been observed. Since the temperatures within an aquifer will remain relatively constant (e.g., at about 10 °C near Toronto in Canada; about 17 °C near Sydney in Australia; about 22 °C near Orlando in Florida), this scenario leads to high temperature gradients which accelerate the aging of the GMB, increase moisture movement, increase the risk of desiccation cracking of the mineral components of the liner, and increase both leakage and diffusion of contaminants (Southen and Rowe, 2005; Rimal and Rowe, 2009; Rowe and Hoor, 2009; Rowe et al., 2010b).

Mechanisms of heat and moisture transport under a GMB due to a temperature gradient are illustrated in Fig. 1. Initially, water within the underlying subsoil is in hydrostatic equilibrium. Under isothermal conditions, once placed, a GCL typically starts to uptake

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