Quantification of Diffusion Across Composite Liners

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Introduction

Early concern on clay liners focused on their hydraulic characteristics and the ability to limit advective transport. As the understanding of compaction parameters and environmental factors on hydraulic conductivity of clay liners improved, construction of uniformly high quality clay liners with a hydraulic conductivity of 1×10^{-7} cm/s or less has become a common practice. Introduction of geosynthetic clay liners (GCLs) made even lower hydraulic conductivity and high quality a reality. With the requirement of composite liners involving a geomembrane and a compacted clay or GCL along with leachate collection, the advective transport was significantly reduced. It also became apparent that diffusive transport in such systems becomes significant, especially for volatile organic compounds (VOCs) since they diffuse more readily and are toxic at much lower concentration than many inorganic chemicals. The geomembrane is often believed to be the primary barrier to contaminant transport. However, for VOCs, the clay component usually controls the rate of transport since VOCs diffuse through geomembrane at appreciable rates (Park and Nibras 1993). Therefore, transport of VOCs through clay liners and modeling of transport through composite liners merit scrutiny and the effectiveness of modern landfill liner systems to minimize migration of VOCs is of concern. Furthermore, liner systems for MSW landfills should usually be compared based on transport of VOCs (Foose et al. 2002). Failure to include an analysis of diffusion of VOCs through intact liners can lead to incorrect conclusions regarding equivalency.

Results from recent research

A comparison of the three composite liner systems [GCL, Subtitle D, and Wisconsin NR500 (0.6-m and 1.2-m thick compacted clay, respectively). all with 1.5-mm thick HDPE geomembrane] was conducted for a one-hectare section of liner based on a numerical model of the problem (Foose et al. 2002). The frequency of geomembrane defects was assumed to be 2.5 defects/ha and the area of defects 0.66 cm^2, which are consistent with the findings of Giroud and Bonaparte (1989). The depth of leachate was set at 30 cm and the length of the simulation period was 100 years. For the transport of toluene, the pertinent soil and geomembrane transport parameters were obtained from the research conducted at the University of Wisconsin-Madison (Park and Nibras 1993 and Kim et al. 2001). At 100 years, the cumulative mass discharged for the GCL composite liner is 18,365 g/ha compared to 385 g/ha for the Subtitle D liner and 43 g/ha for the Wisconsin NR500 liner (Figure 1). The cumulative mass of toluene discharged was as much as 23 million times higher than the cumulative mass of cadmium discharged even though the concentrations of both solutes in the leachate were assumed to be equal. The reason for this difference in contaminant flux and mass discharged is that transport of toluene occurs across the entire surface of the liner, whereas transport of cadmium primarily occurs through a small area beneath defects in the geomembrane. Analyses showed that the variation in mass flow rates of inorganic solutes for different types of liners is less than an order of magnitude. For VOCs, composite liners having thicker soil barriers had lower mass flux and greater sorptive capacity than the GCL composite liner. An analysis based on leakage rate would lead to the opposite conclusion.

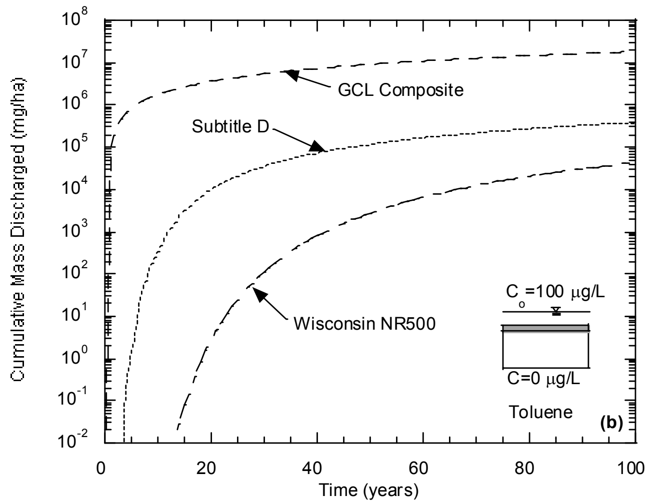

Figure. 1. Mass Discharge of Toluene in Composite Liners- (from Foose et al. 2002)

Research needs

A limitation of these conclusions is that laboratory or field data are unavailable regarding contaminant transport from composite liners. Thus, the accuracy of the models in replicating field conditions is unknown. Additionally, these conclusions are based solely on solute transport. Other factors such as resistance to environmental degradation, potential for catastrophic puncture, quality of construction, and mechanical stability should also be considered.

References

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