Evaluation of Sorptive Amendments for Use in Earthen Liners at Waste Disposal Facilities

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Introduction

Clay and geomembrane composite liner systems are commonly used to protect groundwater supplies from contamination by municipal and industrial waste land disposal facilities. The primary design characteristic for these earthen liners is maintenance of a low hydraulic conductivity to minimize contaminant advection. Under this condition, the primary pollutant transport mechanism is diffusion, which may contribute significantly to the mass flux of organic contaminants out of the liner (Gullick et al., 1996). The magnitude of the diffusive flux is controlled by two factors: weak contaminant sorption and the short diffusion length. The addition of a geomembrane layer to the design of earthen liners can further serve to minimize pollutant advection, but diffusion through this layer still occurs (Rowe et al., 1995) and the geomembrane may fail due to rupture along a seam or if punctured.

Another method of enhancing pollutant sorption and thus minimizing pollutant flux out of liners is to amend conventional liners with materials capable of strongly sorbing organic pollutants. Several suggested amendments include organophillic bentonite, activated carbon, shale and fly ash (Gullick et al., 1996; Smith and Jaffé, 1994; Bierck and Chang, 1994; Mott and Weber 1992). For example, in a study conducted by Smith and Jaffé (1994), simulations of benzene transport through a conventional sand-bentonite liner were compared to simulations through a sand-bentonite liner modified with an organophillic bentonite. Results of the simulations show that benzene in the modified liner was released over a much longer time period, resulting in maximum concentrations beneath the liner that were orders of magnitude lower compared to a conventional liner.

Objectives

Our primary objective is to demonstrate that amendments with high sorption capacity for organic pollutants can be added to earthen liners to significantly improve liner performance and provide an acceptable cost-benefit ratio. To meet this objective, we are working to quantify the effects of organophilic bentonites, shale, and activated carbon as amendments to a soil-bentonite earthen liner on the overall performance of the earthen liner and then to develop and test an optimization algorithm for the design of a multi-layer liner with sorptive amendments. To date, we have quantified the sorption of three solutes to the proposed liner materials, and we have measured the permeabilities of soil-bentonite earthen liners containing different amounts of organophilic bentonites, shale, or activated carbon for two liquids (water and a synthetic leachate). The primary purpose of this data collection effort will be to provide a comprehensive set of parameters for solute transport and optimization simulations. However, these experiments will also investigate several fundamental issues, including how sorption and permeability are affected by different leachate concentrations.

Conclusions

We are currently investigating the sorption and mechanical properties of four potential materials that could be incorporated into earthen waste disposal liners: shale, activated carbon, and two organophillic bentonites, benzyltriethyl-ammonium bentonite (BTEA-bentonite) and hexadecyltrimethyl-ammonium bentonite (HDTMA-bentonite). The sorption capacity of these sorbents for three nonionic solutes (benzene, trichloroethene, and 1,2-dichlorobenzene) was determined using a batch isotherm method and compared to Ottawa sand and Na-bentonite. It was determined that all solutes sorbed more strongly to the proposed amendments than to the sand or Na-bentonite. Sorption of the solutes to HDTMA-bentonite is approximately linear and noncompetitive, whereas sorption of the solutes to the remaining three solutes is nonlinear and competitive. The order of the sorbents' strength of sorption for each single solute system is (from greatest to weakest sorption) is activated carbon, BTEA-bentonite, HDTMA-bentonite, and shale. Solute sorption to the Ottawa sand and the Na-bentonite is negligible. Although the weakest sorption was observed for shale, it is the least expensive sorptive amendment being considered in this work.

Permeability tests were performed on compacted specimens comprised of Ottawa sand, Na-bentonite, and each of the sorptive amendments at a mass fraction of either 3 or 9% with either 0.002 N $CaSO_4$ or a synthetic leachate as the permeant liquid. Initial results indicate that the permeability of these specimens to both permeant liquids is within the design requirement of $1x10^{-7}$ cm/s.

Mechanical properties such as shear strength and consolidation tests and laboratory classification tests will be performed on the soil mixtures, as well as pure samples of the Ottawa sand, the HDTMA-bentonite, the sodium bentonite, and the activated carbon. Classification tests will include grain size analysis (ASTM D 422), specific gravity (ASTM D854), and Atterberg limits (ASTM D4318) for the fine-grained soils. Results from these experiments will be presented.

References

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