CONTAMINANT TRANSPORT MECHANISMS IN COMPOSITE LINER SYSTEMS

There are two mechanisms by which contaminants are transported through a barrier layer. The first mechanism is *advective* flow, where contaminants are carried in the liquid flowing through the barrier layer due to the presence of a *hydraulic* gradient. The second mechanism is *diffusive* flow, in which contaminants are transported due to the presence of a *concentration* gradient. It is currently believed that diffusion is the dominant transport mechanism when advective flow is very small (i.e, when the permeability of the barrier layer is low). The gradient, be it hydraulic or concentration-based, is a function of liner thickness. The thinner the liner, the higher the gradient. Obviously, then, a GCL, because it is so much thinner than a compacted clay liner (CCL), will theoretically yield a higher diffusion rate. For this reason, there have been questions regarding the use of a thin barrier layer for waste containment applications.

But this issue is somewhat misleading. We need to expand our view of the diffusion concept and consider the entire liner system. First of all, the presence of a geomembrane means that leakage is likely to occur only around localized small holes. The area over which diffusion would occur is therefore minuscule. Is it a critical issue that diffusive flow through a GCL is occurring faster than through a CCL in a 6-inch area around a geomembrane hole? It seems quite logical to argue that diffusion is not a relevant concern in modern liner systems, where the geomembrane controls overall performance and the clay layer serves only as a secondary barrier to advective flow. If we were still in the era where clays were the only barrier layers in the liner system, the diffusion argument would be more relevant, because it would occur over the entire area of the liner. But this is not the case.

This fact alone justifies the argument that diffusion is not a critical design or equivalency consideration. Nevertheless, let's continue with to explore the issue of diffusion in the context of today's modern liner systems. In a *double composite liner system,* the drainage layer between the two liners prevents the buildup of any leachate, and there can be no lasting concentration gradient on the secondary liner. Thus, leakage through the liner system as a whole occurs only by advective flow. Diffusion in a double composite liner system is a non-issue.

In a *single composite liner system,* diffusive flow theoretically will occur to a greater extent with a GCL than with a CCL. But the flux of contaminants into the *groundwater* ultimately is determined by the characteristics of the soil *below* the liner, *not* the liner itself. Why? Because diffusion relies on the presence of a concentration gradient. As diffusion occurs through the GCL, the contaminant concentrations eventually equalize on either side of the liner, and the concentration gradient therefore is eliminated. Contaminant transport at this point is determined by the soil between the bottom of the GCL and the groundwater table. This is the same soil that would be underneath the CCL-based system and is likely to be comparatively high in permeability such that advective flow is the dominant transport mechanism. Contaminants will theoretically break through to the bottom of the liner system more rapidly with a GCL than with a CCL, but after this point, *diffusion no longer occurs because the concentration gradient is eliminated.* In the long term, then, the flux of contaminants will be identical.

The only difference is that the GCL-based system will theoretically reach this point faster than the CCL-based system. Again, diffusion therefore is essentially a non-issue.

There are two other important points to consider. First, there is a startling lack of data to demonstrate that diffusion really is the "dominant" transport mechanism in clay liners. To my knowledge, the only research done in this area is by Shackleford, who used *one* type of clay soil and *one* chemical contaminant (chloride). This is very scant experimental evidence with which to establish design guidelines or liner system recommendations.

Second, the diffusion concept rests entirely on the assumption that the CCL is perfectly constructed and has completely uniform permeability across its area, such that there are no zones of preferential advective flow, which could otherwise dominate contaminant transport. Prior research has consistently indicated that this is simply not the case. CCLs are well known for their localized defects in which flow is conducted at a far greater rate than would be predicted by lab-scale permeability testing. It is unlikely that a CCL can be so uniformly constructed, especially in unfavorable weather conditions such as cold and warm temperatures and persistent rainfall. GCLs, however, are highly controlled, factory-manufactured products whose permeability performance will be much more uniform with far fewer localized defects which could control flow characteristics. GCLs are also far less sensitive to ambient weather conditions, which can drastically affect CCL performance.

When all these factors are considered together, there is certainly no reason to suggest that a GCL is anything less than equivalent to a CCL with respect to contaminant transport. This conclusion is also supported by Daniel and Koerner (1993).

References

Koerner, R. M. and D. E. Daniel. (1993). "Technical Equivalency Assessment of GCLs to CCLs." *Proceedings of the 7th GRI Seminar.* December 14-15, 1993, Philadelphia, PA.

800.527.9948 Fax 847.577.5566