Don't Let It Slide

Oct 1, 2005 12:00 PM, Timothy D. Stark, Professor of Civil and Environmental Engineering, University of Illinois at Urbana

BIOREACTOR AND LEACHATE recirculation technology is gaining popularity in North America and Europe. Some of the benefits, such as accelerated waste biodegradation/stabilization, accelerated methane gas yield and recovery of landfill air space, make these technologies an attractive alternative to conventional landfills. However, their design can lead to many physical problems, especially slope failures. To keep slopes stable, careful testing, analysis and monitoring must be conducted to prevent unstable conditions from developing.

Slope stability is perhaps the paramount engineering issue for bioreactors and leachate recirculation landfills. A worst-case scenario for these facilities is that a slope becomes unstable through the presence of liquid or the use of injection pressure to introduce the liquid. In general, adding liquid to a landfill can destabilize it. However, there are at least 12 new bioreactor landfills in the United States and Canada that are operating successfully, the are proof that state-of-the practice techniques work.

And although the technology exists to do so, converting existing “dry-tomb” landfills to leachate recirculation or a bioreactor can be troublesome. Many of the design, construction and operation techniques used to advance the dry-tomb concept, such as using low-permeability daily covers, are detrimental to the subsequent addition of liquid. Whether the bioreactor is new or a converted facility, similar stability analyses are used to evaluate both situations.

In a new or converted bioreactor, the analyses must address the effect of additional liquid on the waste and the driving forces, the accelerated degradation of the waste in terms of the unit weight and shear strength, and the effect of adding liquid to the liner system. Stability analyses are also used to estimate the amount of liquid buildup or injection pressure that can be tolerated without lowering the safety of landfill slopes.

The five main effects of additional liquid considered in stability analyses are: a buildup of greater than 1 foot of hydraulic head on the liner system; perched liquids in the waste; perched liquids migrating along a low permeability layer and outbreaking on the slope face, which can result in a veneer or deep stability problem; a change in waste properties such as lower shear strength and higher unit weight; and an accelerated methane gas generation rate, which can further reduce the effective normal stress acting on a potential failure surface. Software used to analyze dry-tomb landfills also can be used to analyze bioreactor stability. The software analyzes the same stages for bioreactors as for the dry-tomb landfills: construction, interim/filling and final build-out. In each of these cases, searches for the critical cross-section and failure surface should be performed, including deep and shallow failure surfaces.

Although the analyses between dry-tomb and bioreactor landfills are similar, there are differences with a bioreactor, such as a greater leachate level at the liner system, perched liquid levels, and increased unit weight and lower shear strength for the degraded waste. The increased unit weight and reduced shear strength are clearly applicable for the final build-out stage analyses. Prorated values of increased unit weight and decreased shear strength can be used for the interim condition if it occurs early in the life of the bioreactor.

For the construction and initial filling analyses, engineering properties for non-degraded waste can be used, e.g., a cohesion of 500 pounds/square foot (psf), a friction angle of 35 degrees and a unit weight of 75 pounds per cubic foot (pcf) to 85 pcf. Ongoing research at North Carolina State University (NCSU), Raleigh, N.C., shows that the shear strength of waste decreases with degradation. Based on research and field observations conducted by the authors, a cohesion of 0 psf, a friction angle of 20 degrees and a unit weight of 100 pcf to 110 pcf is recommended for degraded waste. These parameters are representative of a cohesive soil, which better simulates degraded waste than fresh waste.

Using the non-degraded and degraded engineering properties identified above, a landfill designer develops an estimate of the liquid level acting on the liner system and the location and magnitude of perched liquids in the waste to conduct stability analyses to evaluate safety issues. The authors usually recommend a conservative leachate buildup of five feet on the liner system and a conservative perched liquid depth of 10 feet at various locations in the waste to evaluate safety. During operation of the bioreactor or leachate recirculation system, it is recommended that the landfill's liquid level be monitored to ensure the levels are not exceeding what the facility was designed to accommodate.

Stability analyses are used to evaluate the effect of injection pressures on safety and the impact of perched liquid levels throughout the waste. To reduce perched liquids' potential, bioreactor designs promoting uniform distribution and maximum liquid absorption are preferred.