# LEACHATE RECIRCULATION AND POTENTAIL CONCERNS ON LANDFILL STABIITY

Richard Thiel and Monte Christie
Vector Engineering, 143E Spring Hill Dr, Grass Valley, CA 95945 USA

## ABSTRACT

Many landfills around the United States are now allowed to recirculate leachate in a controlled manner. Various benefits and problems with leachate recirculation have been observed and reported in the literature. One of the potential issues with leachate recirculation is that slope stability could be reduced by over saturation of the waste. This paper presents a sensitivity analysis on the potential for slope stability failures due to elevated leachate levels within the waste mass. Several practical design and operational recommendations are suggested to help manage these issues.

## INTRODUCTION

Landfills in the United States have been allowed to recirculate leachate at RCRA-compliant sites meeting specified criteria and at approved experimental sites for the past decade. Recently, greater flexibility for state-level approval of leachate recirculation and other liquids additions to municipal solid waste (MSW) landfills has been granted.

At large-volume sites (more than 3,000 tonnes per day) located in a dry climate (less than 500 mm per year of rainfall) the addition of leachate plus high liquid-bearing waste (e.g. dredged river sediments) has been observed by the authors to have negligible physical consequences. It has been observed that all of the leachate produced has been able to be applied to the waste mass with no observed problems of excessive settlement or any perceived increase in leachate generation. Indeed, it is doubtful that any of the leachate that is reintroduced returns to the leachate collection system. All of the leachate generated by these landfills is able to be disposed in this manner.

In contrast, the recirculation of leachate at a medium-sized MSW landfill (1,200 tonnes per day) located in a moderate rainfall area (1,100 mm per year) has been observed to result in significant physical consequences, both beneficial and problematic. Thiel (2005) reported on observed benefits and problems associated with recirculating leachate at such a site. Observed benefits included accelerated settlement, high effective waste densities, accelerated waste degradation and gas generation, leachate disposal, and some level of leachate treatment. Observed problems included increased odor, formation of side-slope seeps, accelerated clogging of the leachate collection gravel, and flooding of gas wells and gas collection main lines. Thiel (2005) suggested various design and operational remedies to improve the potential problems caused by leachate recirculation.

An additional potential problem mentioned in the Thiel (2005) paper was the potential long-term concern of slope instability caused by liquid head build-up within the waste mass and clogging of the leachate collection layer. There is no leachate-head monitoring within the leachate collection system at the landfill that was described, and there were several indications that such buildup could be occuring. Indicators of leachate head buildup within the landfill included side-slope seeps, encounters of elevated liquid levels when drilling vertical gas wells, and increased volume of liquid in the leak detection system. Of course, the head build-up observed at the landfill could be due to localized ponded water within the waste mass and not connected with the leachate collection layer. However, without any monitoring established within the leachate collection layer, it is difficult to rule out head build-up within the leachate collection layer. The remainder of this paper provides a sensitivity analysis regarding the effect of increased head in the landfill on slope stability.

## SLOPE STABILITY ANALYSES

Next to gravity, pore pressures are the single most prevalent factor contributing to slope stability failures. They are also among the most overlooked elements in slope stability analyses. Schmucker and Hendron (1998) illuminate this problem when they state that “Very little is known at this time regarding the generation and distribution of pore pressures in MSW landfills.”

Pore pressures are not commonly included in landfill analyses. Many of the dramatic landfill failures reported in the industry can be attributed to pore pressures that built up either in the foundation, due to waste loading, or in the waste itself, due to leachate buildup or leachate injection. Schmucker and Hendron (1998) attributed the failure of the Rumpke site, in part, to leachate buildup caused by an ice dam at the toe. Although that conclusion is opposed by Stark et al. (2000), the analysis presented by Schmucker and Hendron (1998), and even the elevated leachate levels used by Stark et al. (2000), should be cause enough for any designer to take heed regarding potential elevated leachate levels and their implications for slope stability. The Dona Juana landfill failure (Hendron et al., 1999) was attributed to large volumes of leachate injected into the waste, and low-permeability daily cover soils causing head build-up within the waste mass.

When performing slope stability analyses, designers should consider the potential for unanticipated pore pressures, especially for landfills where leachate recirculation is practiced. Unanticipated conditions may occur in landfills due to clogging of the leachate collection systems or aggressive leachate recirculation in the waste mass. Additional discussion of this issue is provided by Koerner and Soong (2000). Thiel (2001) describes how pore pressures could lead to a localized exceedence of peak strength in the bottom liner, leading ultimately to a progressive failure, and thus recommends that the stability be checked for a potential leachate buildup, especially near the toe of the landfill.

A sensitivity analysis was performed on varying leachate levels within a landfill, as shown in Figure 1. With little or no leachate head levels above the liner, the stability of the landfill cross section shown is not governed by the upper liner interface, but is governed by an interface below the geomembrane. Analyses have demonstrated this slope to have a factor of safety of greater than 1.43, with more improvement over time due to settlement (i.e. slope flattening). If the leachate seeps and elevated leachate observed in the gas wells are due simply to perched leachate zones within the waste, the factor of safety for a slip surface along the liner would be largely unaffected by these perched leachate zones.

If the leachate head has built up above the liner system and is hydraulically connected to the leachate collection layer, the factor of safety decreases with increased leachate head levels. Liquid levels inferred from drilling gas wells and side slope seeps as observed at the referenced landfill indicate that leachate levels could be as high as 15 to 30 meters above the liner. As stated previously, the head build-up observed at the landfill could be due to localized ponded water within the waste mass and not connected with the leachate collection layer, but this is not possible to know without further investigation. Figure 1 illustrates how the factor of safety drops from 1.43 when there is less than 0.3 m of head buildup, to FS=1.1 with about 15 m of leachate head above the liner, to FS<0.9 with 30 m of leachate head above the liner. Note that these analyses assume a value of interface shear strength between the gravel and the smooth geomembrane of 22 degrees. The factor of safety could well be even lower than these numbers if a more conservative, but typical, value of 18 degrees were used. Nonetheless, Figure 1 makes the point: if elevated leachate levels are occurring they could lead to a stability failure.

## PRACTICAL RECOMMENDATIONS FOR OPERATING LEACHATE RECIRCULATION FACILITIES WITH REGARD TO SLOPE STABILITY

One of the best preventative measures for avoid a slippage on the liner system that is caused by excess head pressure is to maintain good drainage within that layer. This speaks to designing and constructing a robust leachate collection system. The following recommendations would apply:

- Use a leachate collection layer with a high void volume. For granular systems this means large gravel size (preferably rounded) that are well sorted. For geonets this would imply very high transmissivity materials with large factors of safety. Well graded sands are the poorest choice for a LCS layer and will quickly clog.

- Use a blanket filter between the waste and the LCS. If a geotextile is used, some studies have shown that a light-weight nonwoven geotextile (e.g. 150 $g/m^2$) is the most appropriate. Studies by Rowe and VanGulck (2001) show that the filter acts as a fixed-film reactor that treats the leachate and substantially extends the life of the underlying drainage layer. They describe how the use of geotextiles as a filter above the drainage gravel have been observed to result in substantially less clogging than that observed in areas with no geotextile. They suggest that geotextiles used in this configuration will experience some clogging, however even if a perched leachate mound developed, this would have no effect on the underlying liner. This would generally be beneficial for slope stability, as well.

- If there is a protective soil layer between the waste and the LCS, the soil should be permeable (e.g. sand) or have permeable zones. Since the protective soil layer is commonly comprised of random site soils that may have a low permeability, one common design technique is to provide permeable "windows" through the protective soil layer using gravel, shredded tires or the like. The permeable "windows" are typically at least 4 m wide and located at the toes of slopes, directly above LCS pipes, or regularly spaced at a distance of approximately 50 m.

- Use large-diameter uniform stone (e.g. 38 mm or larger) around the LCS pipes, and increase the perforation size in the pipes to the maximum size compatible with the surrounding stone.

- Decrease the distance between LCS collection pipes to reduce the mass loading on each pipe. Consider that the LCS gravel or geosynthetic drainage layer might have a transmissivity reduction by a factor of 1,000 and base the pipe spacing on that assumption.

- Lay out the piping to allow regular inspection and cleaning. Clogged material can typically easily be removed during its early formative stages, but can be very difficult to clean once the hard rock-like precipitation takes hold. Video filming of the inside of the pipe walls might be useful to clarify what is going on.

Other considerations for preserving slope stability include the following:

- Design with robust shear interfaces, and check the stability for post-peak (residual) strength conditions. A good interface is rounded gravel on a geomembrane or cushion fabric. Using highly textured geomembranes can help, but the designer needs to verify that the interface with the lowest peak strength will also have an acceptable post-peak strength.

- Reduce the application (i.e. recirculation rate) of leachate to a manageable amount. For example, experience at a mid-sized landfill in a moderate rainfall area has shown that the application rate of 0.3 $m^3$ per tonne of waste (70 gal/ton) is too much and creates operational problems, which could potential lead to slope stability problems. A value closer to 0.12 $m^3$ per tonne of waste (30 gal/ton) might be recommended for that site. The optimal amount is a site-specific issue.

- Conduct field investigations to try to understand if elevated liquid levels in the landfill are perched or continuous down to the liner. This would be most effectively performed by using a cone-penetrometer rig. Also consideration should be given in the design phase to allow head monitoring on the liner system.

## CONCLUSIONS

Leachate recirculation in landfills is a growing practice in the United States and around the world. There are substantial benefits to landfill owners, operators, and society for pursuing this practice. At the same time it is important to recognize the list of technical problems created by aggressive leachate recirculation, and implement intelligent and responsible design and operational measures to address those issues. In particular, analyses have shown that rising leachate levels can impose instability of the landfill. Therefore, the leachate levels must be monitored and accounted for in operation and design of bioreactor landfills.

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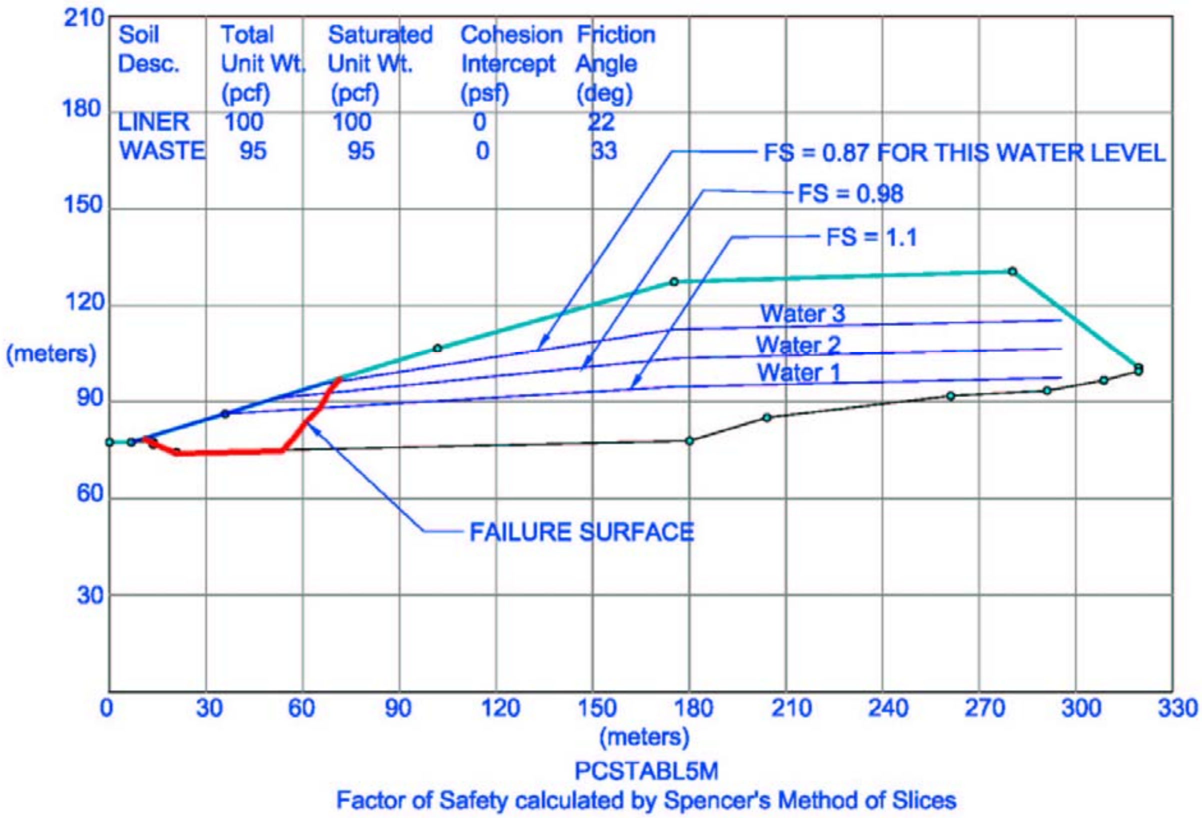


Figure 1. Slope stability analyses showing sensitivity due to rising leachate levels**.**