CHAPTER 6

LEACHATE RECIRCULATION SYSTEM DESIGN

One of the major challenges facing leachate recirculation implementation is system design. The results produced in this project can be instrumental to the design process. General design steps for new and retro-fit installations as well as a discussion of construction, operation, and monitoring concerns are presented below.

6.1 New Installations

The incorporation of a leachate recirculation system (LRS) into the design of a new facility provides the best opportunity to take full advantage of leachate recirculation. It does however, require advanced planning of the construction and operating phases.

One of the most heavily regulated and scrutinized portions of a landfill design is the LCS. There are a variety of equations, as discussed in Section 2.2, and computer models (HELP being the most commonly used) which can be used to design a LCS. Regardless of the technique used, the design of a LCS is based on selecting a leachate arrival rate and then varying the drainage slope and length until the design head is not exceeded. RCRA Subtitle D regulations specify a maximum design head of 30 cm. In an equation based design, the leachate arrival rate is calculated from a design precipitation event, i.e. 25 yr., 24 hr, and a runoff coefficient. Some designers use open-cell conditions, no runoff, as a safety factor for their designs. The design of a LCS for a leachate recirculating landfill will require that the leachate arrival rate be adjusted to account for the additional leachate loading due to recirculation operations. One possible approach to designing a LCS for a recirculating landfill would be to design a conventional LCS based on a design storm and open cell conditions, no runoff, as a safety factor. This design could then be analyzed using a computer model such as HELP for performance, head variation, based on the actual anticipated climactic conditions, runoff, and leachate recirculation loadings.

The next design step would be to determine when leachate recirculation operations will take place. Some sites may wish to recirculate leachate only to inactive or closed portions of the landfill while other sites may desire to begin recirculating leachate as soon as possible. Those sites wishing to postpone leachate reapplication must be sure to provide sufficient leachate storage or have arrangements in place for the removal and treatment of excess leachate. Those sites which wish to begin leachate reapplication as soon as possible must decide what technique they will employ and be aware that leachate storage and provisions for off-site treatment will still be required. Non-invasive pre-wetting techniques which may be employed prior to the construction of a LRS include fabricated sprinkler arrays and spray application via tanker trucks or fire hoses. Sites may wish to incorporate vertical wells or horizontal trenches into the landfill as it is constructed. Some landfills have placed a horizontal trench on top of each lift of waste prior to the placement of intermediate cover while others have constructed vertical wells one man-hole section at a time. After a man-hole section is placed, waste is filled around it. These systems are ultimately interconnected to form the final leachate recirculation system. The placement of permanent leachate recirculation devices during filling operations does lead to a few concerns. The devices may be damaged by compaction equipment or may complicate daily landfill operations. For instance, in the case of the vertical well, the waste material around the well cannot be compacted due to stability concerns. The lateral pressure exerted by compaction operations may tip the well.

System design can now be addressed. Leachate application rates can be estimated using a hydrologic model such as HELP to predict leachate production. Waste permeability can be estimated from literature values, anticipated waste composition and density, and compaction impacts. It may be desirable to underestimate the permeability and thus the required spacing. This theory is based on the fact that it would be difficult to install new devices if the waste is not being wetted uniformly, whereas, individual device injection rates could be reduced or terminated if the impact areas are overlapping significantly. Device spacing can then be estimated from the information provided in Chapter 4. The lateral movement results for the homogeneous waste mass can be used as guidelines but, it is likely that the waste mass will have a higher lateral than vertical permeability which will increase leachate spreading. Also, heterogeneities within the waste mass make it difficult to predict the exact route leachate will move along. When applying the lateral movement information presented in Chapter 4, it is important to note that the device spacing would be twice the anticipated lateral movement.

Landfills which incorporate the LRS during filling operations will find that device placement will be driven to some degree by daily operations and convenience. Care should be taken to ensure that devices are placed not just for the sake of convenience but also such that the waste mass will be most uniformly wetted. Ensuring conscientious device placement will require that a schematic of the total system be produced and explained to operators. A time line for device placement could also be developed based on anticipated waste arrival rates. When devices are placed, information on device location, dimensions, and orientation should be collected, archived, and recorded on the system schematic previously produced. This procedure will ensure that the installed leachate recirculation does not vary significantly from the designed system. Valves should be clearly labeled as to which device they adjust. Accurate labeling is particularly important for the horizontal trenches where the pipes will ultimately be buried and several pipes may be protruding from the waste mass at the same point.

Operations which install leachate recirculation devices in closed or inactive sections of the landfill will have to consider primarily the required device spacing based on estimated application rates and waste permeability. The results presented in Chapter Four will again be useful to this process. The spacing between devices should be approximately twice the lateral movement distance. Special attention should be paid to distancing the devices from the vertical and lateral boundaries of the landfills to prevent seep problems. Since the devices may be installed just prior to closure, it may not be possible to sufficiently distance the trenches from the upper surface of the landfill. In this case, flow barriers (prefabricated infiltrators or a layer of a low permeability soil) should be installed above the trench to inhibit the vertical movement of leachate.

As an example, horizontal trench and vertical well recirculation system requirements will be calculated for a 3-ha (7.5-ac) landfill which plans to recirculate leachate at a rate of 20 m^3/ha/day, a total of 60 m^3/day. The landfill has an areal footprint of 300 m by 100 m and the waste is estimated to have a permeability of 10^{-4} cm/s..

If horizontal trenches are used, they will be run parallel to the 100 m side of the landfill and have a perforated section of 60 m, providing a 20 m buffer on each end to limit the chance of side seeps. Leachate will be pumped to one trench each day for a duration of 8 hours, for a leachate application rate of 125 l/m/day. The lateral movement would be approximately 3.75 m, from Figure 4.1.7, and the upward movement would be 2.25 m. Therefore the trenches should be spaced 7.5 m apart, a total of 40 trenches, and distanced at least 2.25 m from the landfill grade.

If 1.2-m (4-ft) diameter vertical wells are used, leachate will be applied to four wells per day for a duration of 8 hours. The average daily application rate per well is then 15 m^3, resulting in a lateral movement of 2.75 m, from Figure 4.2.8. Each well would then impact an area of 35.5 m^2. A 10-m buffer distance around the landfill perimeter will be used to prevent side-seeps. The area receiving leachate recirculation is then 280 m by 80 m (22,400 m^2) and requires 630 wells. Increasing the loading to 20 m^3/day/well would decrease the number of wells required to 479.

These design examples would produce a conservative device spacing. The anisotropic waste conditions discussed previously will likely result in lateral movements greater than the homogeneous waste mass modeling indicated. The exact effect of heterogeneities within the waste mass is difficult to predict. Modeling of heterogeneous waste masses indicated that leachate will move around low permeability materials but did not suggest a significant increase in the lateral movement.

6.2 Retro-fitting Existing Facilities

The installation of a LRS into an existing landfill whether it is open, closed, or undergoing closure may be desirable from several perspectives. Open landfills may choose to recirculate leachate for a variety of reasons including:

- reduce leachate generation,
- reduce leachate disposal costs,
- promote waste stabilization to decrease future liability,
- prolong landfill site life by increasing waste decay and settlement, or
- enhance gas generation.

Closed landfills which are impacting groundwater quality may choose leachate recirculation as an in-situ method to decrease contaminant source mass. Landfills undergoing closure may find leachate recirculation to be desirable for the following reasons:

- decrease leachate disposal costs due to in-situ storage and treatment of leachate,
- decrease future liability through enhanced waste degradation, or
- enhance gas production if methane recovery or energy production are being considered.

Regardless of the reason for implementing a LRS, existing facilities will face several challenges. In the United States, one of the most fundamental landfill design criterion is the RCRA-Subtitle D specification that the LCS be designed such that the head on the liner never exceeds 30 cm. The actual maximum design head used ranges between 3 and 30 cm depending on the type of LCS and state regulations. A LCS design based on a head other than 30 cm must provide groundwater protection equivalent to that which would be provided by the 30 cm head design. This equivalency is based on leakage rates (see Figure 6.2.1). As mentioned above, new landfills which plan to use leachate recirculation are often required to go over and above the general LCS guidelines to ensure that the extra leachate impinging on the liner as a result of leachate recirculation will not result in an increased threat to groundwater. Ensuring regulators that leachate recirculation will not result in a threat to local groundwater will most likely drive the design process.

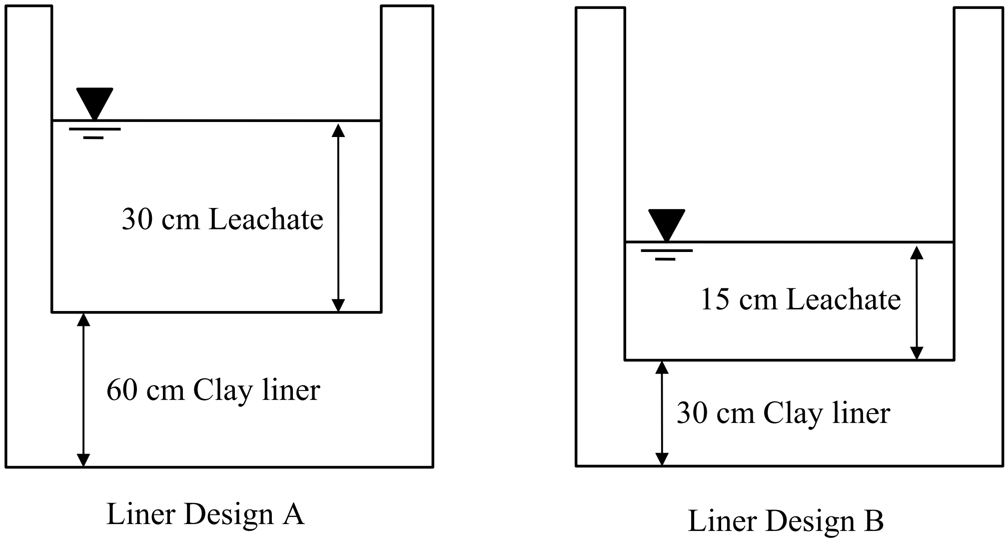

Figure 6.2.1. Hydraulically equivalent liner designs, note that the discharge through each liner is the same.

Since the LCS is the ultimate barrier between leachate and the environment, an accurate assessment of its current condition would be a logical first step. This assessment should include the following:

- original design,
- collection pipe inspections,
- an estimate of the current permeability of drainage materials, and
- maintenance requirements.

The ultimate result of this process would be to determine a maximum acceptable leachate loading rate to the individual bays of the LCS. The term LCS bay used here refers to the area contributing leachate to a single collection pipe. This leachate loading rate can then be converted to acceptable leachate recirculation rates, again per LCS bay. An areal plan of the landfill should then be made which includes elevations, LCS bay locations, and acceptable loading rates for individual areas.

The actual amount of leachate which is to be recirculated should then be calculated. This rate would be based on the amount of leachate stored on site plus any future sources of leachate.

The selection of a leachate recirculation system and its layout would be the next step. Device spacing will be based upon the anticipated leachate reapplication rate, frequency, and waste permeability. Leachate application rate and frequency will be based on the leachate mass balance discussed above. The permeability of the waste mass will be difficult to determine precisely. Laboratory scale permeameter tests, due to their scale, do not provide representative waste permeabilities while field tests for permeability are difficult to perform and again are function of the local waste characteristics. Estimating the permeability as low, medium, or high based on waste materials, operations, and compaction may provide sufficient information to approach the design process. Analysis of historical information on the relationship between precipitation events and leachate generation may also provide some insight into permeability. System performance can be fine tuned by adjusting application rates as discussed below. The figures provided in Chapter 4 for lateral and vertical movement can be used for guidance in this area as shown in the design example in the previous section. The spacing between devices should be approximately twice the lateral movement distance. Special attention should be paid to distancing the devices from the vertical and lateral boundaries of the landfills to prevent seep problems. In retrofit installations, it may not be possible to significantly distance the trenches from the upper surface of the landfill. In this case, flow barriers (prefabricated infiltrators or a layer of a low permeability soil) should be installed above the trench.

The ultimate design and operating goal of any recirculation program will be to wet as much of the waste mass as possible. This strategy will provide for the most storage opportunities and provide for optimal enhancement of degradation. In order to accomplish this goal, particularly at sites with little leachate, it may be necessary to develop a schedule for the operation of individual recirculation lines. Results previously presented and discussed indicate that maximizing leachate application rates may enhance lateral movement of leachate and drive leachate into areas which would not be wetted at lower rates. Maximizing leachate application can be achieved in two ways. The first is to operate the entire system for short periods of time pumping at a high rate for several hours and then allowing the leachate to drain until a sufficient amount has been collected to recirculate again. The second method would be to develop a pumping schedule for individual recirculation devices aimed at maximizing the leachate application rate and thus the lateral movement of leachate. Rapid leachate arrival would dictate more frequent application at higher rates. In the field studies discussed in Chapter 5, the full-scale operations all reported leachate arriving at the LCS almost instantaneously. Quick leachate arrival times indicate channeled flow thus, the larger the percentage of directly routed leachate, the less the waste mass is being wetted. The information provided by the Mill Seat study indicated that increasing the application rate did not increase the arrival rate which suggests increased leachate storage. The application rate will, however, be limited not only by the capacity of the pumps but also by the development of leachate breakouts. If leachate breakouts are observed, the application rate should be decreased. Since some areas of the landfill may be more prone to breakouts than other areas, the system should be designed with some ability to control the flow to individual devices.

6.3 Construction and Operation Concerns

The LRS design methods detailed above treat the recirculation devices as discrete systems. However, LRS design will also be affected by other criteria such as the daily cover materials used, location of gas collection devices, gas generation, and landfill operating factors such as the rate of waste placement, configuration of working area, and filling routine.

The impact of daily cover materials on leachate routing was well illustrated in Chapter 4. The use of low permeability soils as cover material will impede leachate flow and will increase the risk of leachate breakouts. Therefore, low permeability cover materials should be avoided. If they must be used, the cover layers should be breached prior to the placement of more waste. Sites which include leachate recirculation should consider eliminating the use of soil as a daily cover material altogether. A wide variety of alternative and removable cover materials are being employed at landfills today. Many landfills use these materials to increase the available air space and the life of the landfill. Some of these materials used include:

- degradable spray-on foams,
- degradable cellulose polymers, and
- geo-textiles.

The use of geo-textiles has been shown to create some operational difficulties; they must be placed over the active face at the end of the workday and removed prior to the placement of new waste. These operations are cumbersome and time-consuming. However, the benefits associated with increased airspace and enhanced leachate recirculation may justify the increased operating costs.

Gas collection devices should not be placed within the area impacted by leachate recirculation devices. If leachate reaches the gas collection wells or trenches, pressure builds up and impedes gas removal. For this reason, leachate recirculation and gas collection systems should not be combined. Gas collection devices also provide a preferential leachate flow path which may result in the short-circuiting of leachate and a restricted impact area. Gas collection devices should be monitored for the presence of excess leachate. If leachate is found to be collecting in a gas collection device, the flow rate to the nearest leachate recirculation devices should be reduced until the gas collection device is no longer impacted.

Just as leachate recirculation can impede gas collection, the generation of gas in the landfill can make it difficult to apply leachate. Significant gas pressures may develop in the landfill due to biological activity. This activity may result in a pressure head in the leachate recirculation pipes which must be overcome in order to apply leachate. The easiest method for mitigating this problem is to vent the recirculation system prior to leachate application. The design should address the fact that leachate in the recirculation system may be discharged with the vented gas stream.

Landfill workers, particularly those involved with waste placement and compaction, should be instructed about special operational concerns associated with a leachate recirculating landfills. Most of this instruction will be focused on preventing damage to the recirculation systems, primarily exposed pipes. It may be difficult to cultivate awareness in workers whose job description previously dictated driving over anything in their path. The development of an incentives or disincentives program may be necessary to ensure conscientious waste placement and compaction.

6.4 Monitoring

One of the most important aspects of operating a successful LRS, monitoring, has only recently been addressed.

It would be unwise to try to operate a wastewater treatment plant, potable water treatment plant, composting facility, air pollution control equipment, or a soil remediation system without a program for monitoring and controlling system performance. Yet, most full-scale leachate recirculation systems do not incorporate a performance monitoring program. Most of those sites that have incorporated monitoring equipment have done so because they are a research site. Full-scale leachate recirculation operations, particularly those focused on enhancing biological activity, must begin to incorporate protocol for monitoring and adjusting system performance.

The landfill boundaries and areas above leachate recirculation devices should be visually inspected during leachate application to ensure that lateral and surface seeps are not developing. If seeps are developing, leachate application rates should be reduced particularly in those devices closest to where the seeps are occurring.

The arrival rate of leachate should be determined. If a large percentage of the leachate is arriving at the LCS almost immediately after application it must be assumed that most of the leachate is flowing through preferential channels and little of the waste mass is being wetted. Excessive preferential flow would dictate increasing application rates in order to drive leachate into the waste mass. When the Mill Seat Landfill increased leachate application rates by an order of magnitude, there was only a slight increase in the amount of leachate generated which indicates increased leachate storage and wetting. The increase in application rate did result in some vertical seeps which were resolved by a slight decrease in the application rate. The production of leachate should also be monitored to ensure that a reasonable amount of leachate is being generated. If leachate is being recirculated, some of it should be reaching the LCS. If it is not, leachate is most likely accumulating somewhere in the landfill. This accumulation can be a serious problem. The degree of severity depends primarily upon where the leachate is accumulating. The three main areas where leachate could be accumulating are the LCS, the gas collection system (GCS), and the waste mass. An accumulation of leachate in the LCS indicates that the removal system has become clogged. This scenario is promoted by socking collection pipes with a geo-textile. Excessive leachate head in the LCS creates a driving force for leakage, propagates side seeps at the base of the landfill, and, if pressures are excessive, may result in a decrease in the geotechnical stability of the landfill. Leachate has also been shown to collect in gas collection wells which results in a failure of the gas collection system. If the GCS is inoperative, gas will exit the landfill through breaches in the cover and cap materials. This impediment of the GCS will cause performance problems for those sites collecting gas for energy recovery as well as a variety of other issues, including:

- Gas migration through the cover layers may kill the vegetation resulting in an increased risk of soil erosion.
- Subsurface gas migration may reach enclosed structures causing a serious risk of explosion.
- Uncontrolled gas releases may result in odor problems as well as non-compliance with Clean Air Act and RCRA emission regulations.

It has been implied by some that the buildup of leachate in the waste mass is not a problem because it does not violate RCRA Subtitle D head-on-the-liner regulations. However, in reality, saturated zones within the landfill can result in an increased risk of leachate breakout and can destabilize the waste mass resulting in slope failures. Areas of excessive saturation within the landfill also suggests that some areas are not being wetted.

If leachate recirculation operations are being conducted with the goal of increased biological activity, the system's performance will be directly related to the amount of waste impacted by recirculation. Rigorous system design will facilitate uniform wetting. However, adjusting the application rate of individual devices will be necessary to fine tune system performance. In order to assess the impact of flow rate adjustment, some type of monitoring system will be required. The installation of moisture sensors would be the most direct method of gathering data on the moisture content of the waste mass. However, the application of traditional moisture sensors to the solid waste environment is somewhat difficult. The sensors are designed for use in soil systems where the sensors are in intimate contact with the soil. Intimate contact is difficult to guarantee in a landfill. Also, the sensors, particularly the wiring, tend to be somewhat fragile which is not conducive to successful installation while the landfill is active. Installation to closed landfill sections requires invasive drilling which may create preferential flow paths and affect system hydraulics. The interpretation of sensor data must be done with regard to the fact that the waste mass is extremely heterogeneous.

A simpler technique for adjusting system performance would be to monitor the injection pressures and flow rates to individual recirculation devices. Individual flow rates and pressures could then be adjusted and balanced to maximize system performance. The potential for leachate breakouts could be minimized by ensuring that the injection pressure was not excessive.

The development of moisture monitoring equipment for the landfill environment and implementation of monitoring protocol will greatly facilitate the installation and operation of future leachate recirculation systems.