OBSERVED BENEFITS AND PROBLEMS ASSOCIATED WITH LEACHATE RECIRCULATION

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SUMMARY: Many landfills around the United States are now allowed to recirculate leachate in a controlled manner. This paper reports on observations of benefits and problems that the author has observed where leachate recirculation has occurred. Benefits include accelerated waste degradation resulting in settlement and higher gas production, high effective waste densities, and treatment and disposal of landfill leachate. Problems have included flooding of gas collection wells, side slope seeps, increased odor problems, and plugging of the leachate collection layer. In addition, potential slope stability issues could be caused by waste saturation. Several practical design and operational recommendations are suggested to help manage these issues.

1. INTRODUCTION

Landfills in the United States have been allowed to recirculate leachate 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 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 (1200 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. The remainder of this paper focuses on observations made on one specific landfill cell for a facility of this type. For reference, the following leachate recirculation statistics are made available for this site.

- Leachate recirculation on the particular cell being reported occurred over a period of five years, from the summer of 1998 through the end of 2002. The leachate was irrigated primarily during the dry summer season, and sometimes in the fall and winter during periods of no rain.

- All of the data and observations for this sitewere within one landfill cell, approximately 12 ha in area. Annual leachate generation rates from this cell during this period ranged from 45,000 to 93,000 m^3. Figure 1 presents general leachate generation data compared to rainfall for the cell being discussed.
- Average thickness of waste started at 20 m when leachate recirculation began, and ended up at approximately 50 m thick when leachate recirculation ended.
- The method used to apply the leachate was by spraying the top surface of the waste that had been freshly landfilled that day using "big-gun" irrigation equipment. The size of the working face on which leachate was irrigated each day was an average of approximately 0.6 ha. The leachate irrigation was performed in the late afternoon and evening after landfilling operations had ceased for the day.
- Rates of leachate recirculation ranged from 0.17-0.33 m^3 per tonne of waste during the actual period of recirculation, which was only during the periods of little or no rainfall. If the total annual amounts of recirculated leachate, which ranged from 12,000 to 55,000 m^3, were divided by the total annual tonnage of waste, which ranged from 360,000 to 450,000 tonnes, then the average annual leachate application rate would range from approximately 0.03-0.12 m^3 per tonne of waste.

2. OBSERVED BENEFITS OF LEACHATE RECIRCULATION

There are often two primary objectives that can be accomplished by recirculating leachate in a landfill. One objective is to dispose of and treat leachate. A second objective is to significantly increase the extent and rate of waste decomposition over what would otherwise occur within the landfill. The following benefits were attributed to the leachate recirculation program:

- Dramatic settlement was observed. This is considered a benefit because it resulted in increased waste capacity from year to year. Over 3m of settlement was commonly noted from year to year.
- Very high "effective" waste densities were obtained. The effective densities were calculated by dividing the annual airspace consumed by the annual gate tonnage. The airspace consumed was measured using successive aerial photogrammetry, and thus it included the effects of daily and intermediate soil cover, as well as settlement. When leachate recirculation first started in 1998 the effective density was measured at 9.6 kN/m^3. After leachate recirculation had occurred for 5 years the effective density was measured at 11.3 kN/m^3. It is not possible to say how much of the density increase was due to leachate recirculation versus the settlement caused by increased landfill overburden-induced settlement.
- Very accelerated waste degradation occurred as observed by the color and decomposition of the waste drill cuttings when constructing gas wells. Also, the volume of landfill gas appears to have increased after recirculation began, although it is difficult to say objectively how much of this is attributed to leachate recirculation. As discussed below, there were also problems noted with ability to efficiently collect landfill gas.
- Leachate disposal was accomplished. While it is difficult to know what percentage of the leachate was actually retained and finally disposed in the waste mass versus simply recirculating to the bottom, the ability to dispose of 25-70% of the leachate volume by recirculation provided the operator with flexibility in its management. From Figure 1, it appears that heavy recirculation that lasted up unto the end of 2002, at which time the landfill cell was closed and covered with an interim tarp, may have contributed to significant leachate flows for the next year. Thus, some carryover of leachate generation volumes appears to be a result of year-after-

year recirculation. The trend of leachate generation in the second year after the cell was closed clearly indicates that leachate generation is steadily dropping off.

- The quality of the leachate appears to have been mildly treated in some respects by the recirculation program. Figures 2-5 might indicate the following trends:
  - Certain volatile organic compounds (VOC's), temperature, conductivity, total dissolved solids (TDS), and chemical oxygen demand (COD) appear to have reached a peak during the middle of the 5-year recirculation period (approximately during the year 2000). After the peak, the concentrations of constituents appear to decline, indicating that some level of leachate treatment is occurring.
  - There is an unexplained increase in concentration of some VOC's, certain dissolved metals, TDS, and chloride from the last sampling event, which is nearly two years after the cell was interim-closed. This could be an anomalous sampling event, or it could be related to latent liquids that are freely draining without dilution from the saturated waste. Only future sampling and analysis results will indicate which is true.

3. OBSERVED PROBLEMS WITH LEACHATE RECIRCULATION

There are definite problems created by liquid addition to the waste. The following items were noted to be significant issues that had to be addressed as a result of leachate recirculation:

- Increased odor was noted. Although odor control is always an issue for landfills with nearby residences, problems in controlling odor could possibly be attributed due to increased gas production at the same time that the collection efficiency was lowered due to trouble keeping up with the accelerated gas generation.
- Side slope seeps became a problem where a significant amount of leachate is exfiltrating from the waste on the slopes, requiring special interim-cover and final-cover seep interception drains.
- Clogging and precipitation of inorganic materials in the leachate collection drain rock and sumps was noted. Although this phenomenon is not uncommon with landfills (e.g. Rowe et. al, 2004) leachate recirculation will tend to exacerbate the problem because clogging has been noted to be greater the more saturated and the more used the leachate collection layer becomes.
- Extensive flooding of gas wells occurred as a result of leachate irrigation. This required the operator to set up a large air compressor needed to run air-diaphragm pumps that would de-water the gas wells. Flooded gas well greatly reduce the gas collection efficiency with can lead to odor problems.
- Significant amounts of leachate get into gas collection suction lines, especially from horizontal wells, due to the well-field suction. This caused surging of gas pressures, and uneven gas delivery to the cogeneration engines.

In addition to these observed problems, there are also conjectured long-term problems. The largest potential long-term concern is that of slope instability caused by liquid head buildup 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. The increased volume of liquid in the leak detection system, noted in the last year even while the primary leachate collection volume is decreasing, could possibly suggest greater head over the primary liner within the landfill that might be caused by clogging and degradation of the leachate collection system. Certainly leachate recirculation could only exacerbate this type of problem.

4. PRACTICAL DESIGN GUIDANCE FOR "BIOREACTOR" FACILITIES

4.1 Leachate collection system (LCS) design and operation

Field examples of clogging of LCS are not uncommon. Rowe et. al (2004) describe the factors that can influence clogging. To maximize the life of the LCS and minimize problems that would be associated with head buildup (e.g. slope instability, higher leakage, higher temperatures, accelerated aging of geosynthetics), practical design and operational measures include the following:

- 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 show that the filter acts as a fixed-film reactor that treats the leachate and substantially extends the life of the underlying drainage layer.
- 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. Clog 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.

4.2 Landfill gas collection system design and operation

Since one of the goals of adding liquid to landfills is to accelerate decomposition, it follows that extra measures will be needed to collect landfill gas. Since the addition of liquids tends to flood gas collection wells, which hampers their performance, the issue is all the more critical to address in an intentional manner. Practical measures that can be implemented to improve the gas collection efficiency are as follows:

- Design and install gas collection piping on the floor of the landfill as part of its initial construction. Make sure that the perimeter of the leachate collection system is sealed with low-permeability soil to minimize air intrusion. The benefit of having the initial gas collection pipes on the landfill base is that it will be on a solid foundation that will not settle, and should be well-drained by virtue of the LCS.
- Provide a robust slope on "horizontal" wells of at least 5% and preferably 10%, and provide large gravel sumps to drain leachate and condensate that accumulate in the well.

- Design and install large, robust liquid knockout sumps and J-traps in gas header pipes. Horizontal wells will tend to attract large amounts of leachate in addition to condensate that may end up in the gas collection headers. Liquids in the gas collection headers cause regular surging of suction pressures which can affect blower and engine performance on cogeneration facilities.
- Install pneumatic diaphragm pumps in the gas collection wells to dewater the wells. This requires the use of a large compressor in a location central to the gas wells, and constant operation and maintenance.
- Insert a gas collection layer and piping immediately below the final cover system. The concern for final landfill cover designs incorporating geomembranes is that the gas can cause an uplift pressure. From a slope-stability point of view, gas pressure is an excess pore pressure that serves to reduce the effective normal stress. This pressure results in a decrease in the effective stress beneath the final cover geomembrane that can ultimately lead to a slope stability failure or surface “whales”. Also, new regulations in the United States require monitoring of landfill gas surface emissions. This requires enhanced near-surface control techniques to contain gas. Details regarding a design approach for this are provided by Thiel (1998). A schematic of part of the design solution is illustrated in Figure 6.

4.3 Sideslope drains for gas and leachate seeps on interim and final covers

Leachate seeps on sideslopes occur in landfills even without the recirculation of leachate, and where recirculation occurs the problem is potentially amplified. Uncontrolled lateral seepage can manifest itself by distressed vegetation, unsightly wet zones on the landfill sideslopes, local slope instabilities, the release of leachate, and an increase in odor. Although it may be possible to explicitly design a drainage layer just for these seeps, the author has found that adequate seep collection capacity is provided, even in situations where seeps are a chronic problem, if a drainage layer is designed to facilitate gas collection as described above in Section 4.2. Both the surface gas emission and sideslope seep issues can be controlled with a common design solution, as illustrated in Figure 6.

4.4 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 high-pressure leachate injection.

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.

5. 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.

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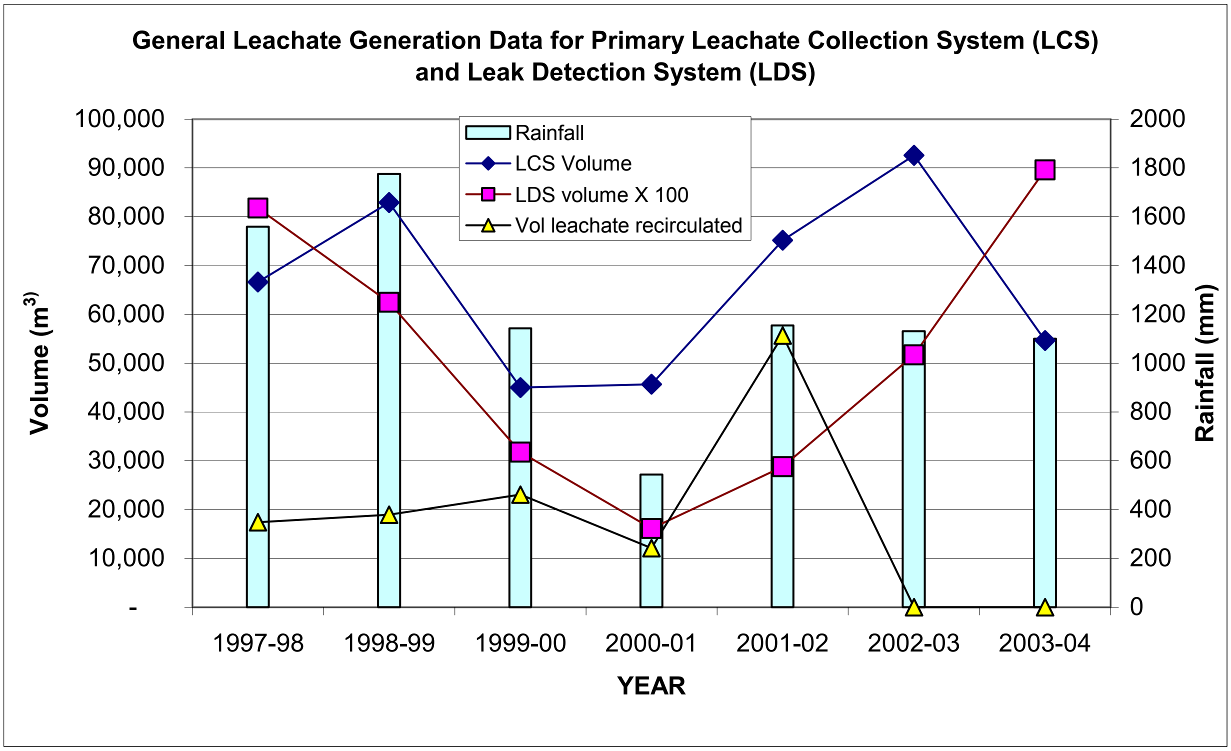

Figure 1. Leachate volume and rain data vs time for case history.

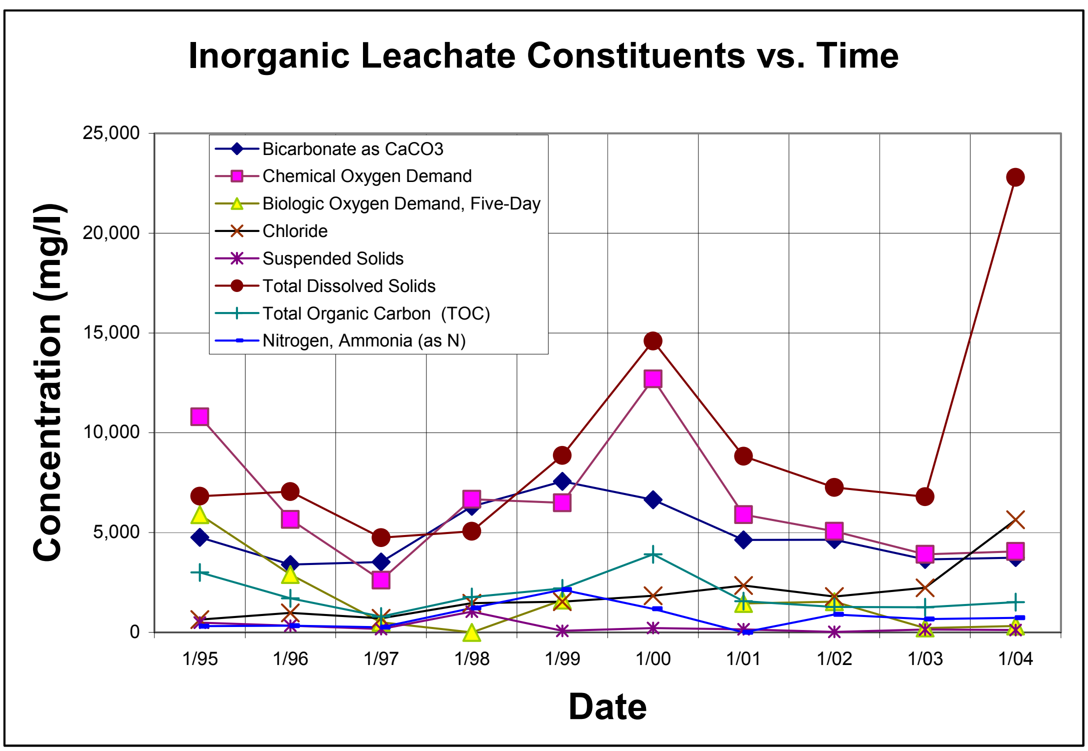

Figure 2. Leachate chemistry vs time for inorganic constituents.

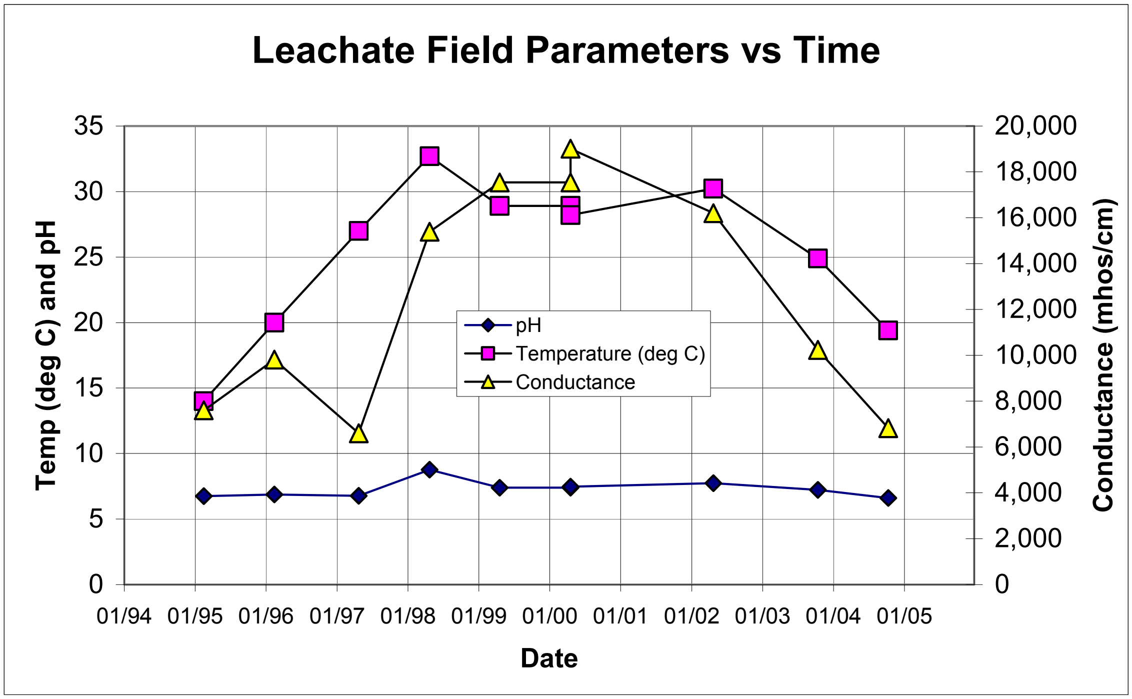

Figure 3. Leachate chemistry vs time for field parameters.

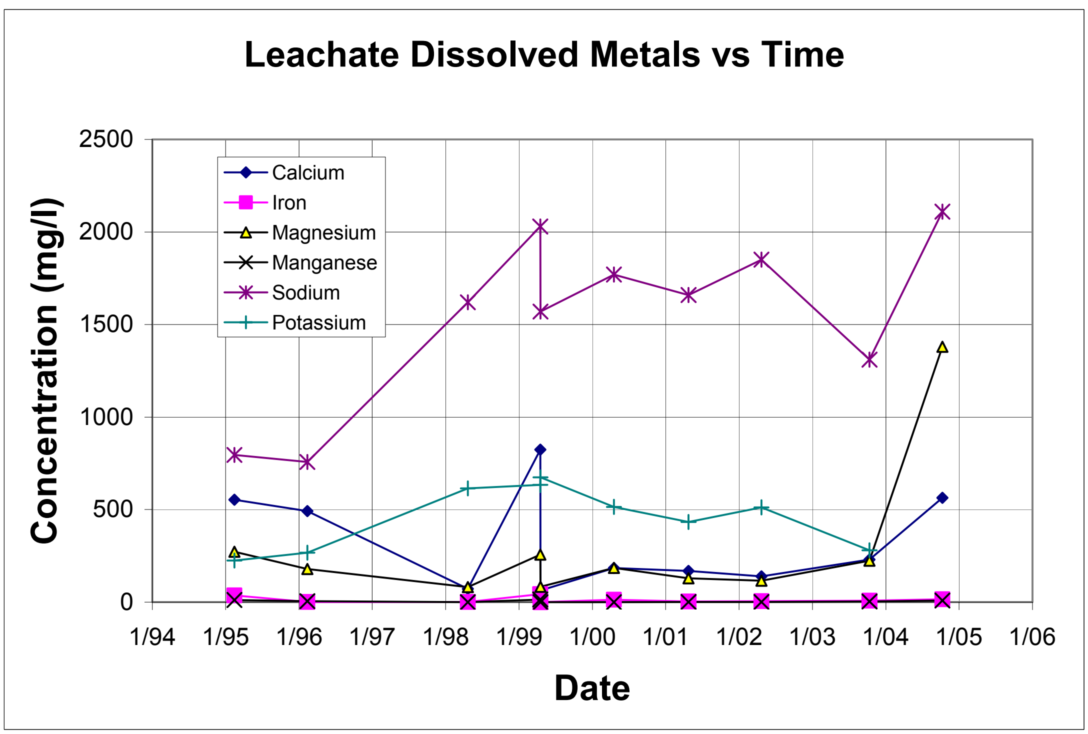

Figure 4. Leachate chemistry vs time for dissolved metals.

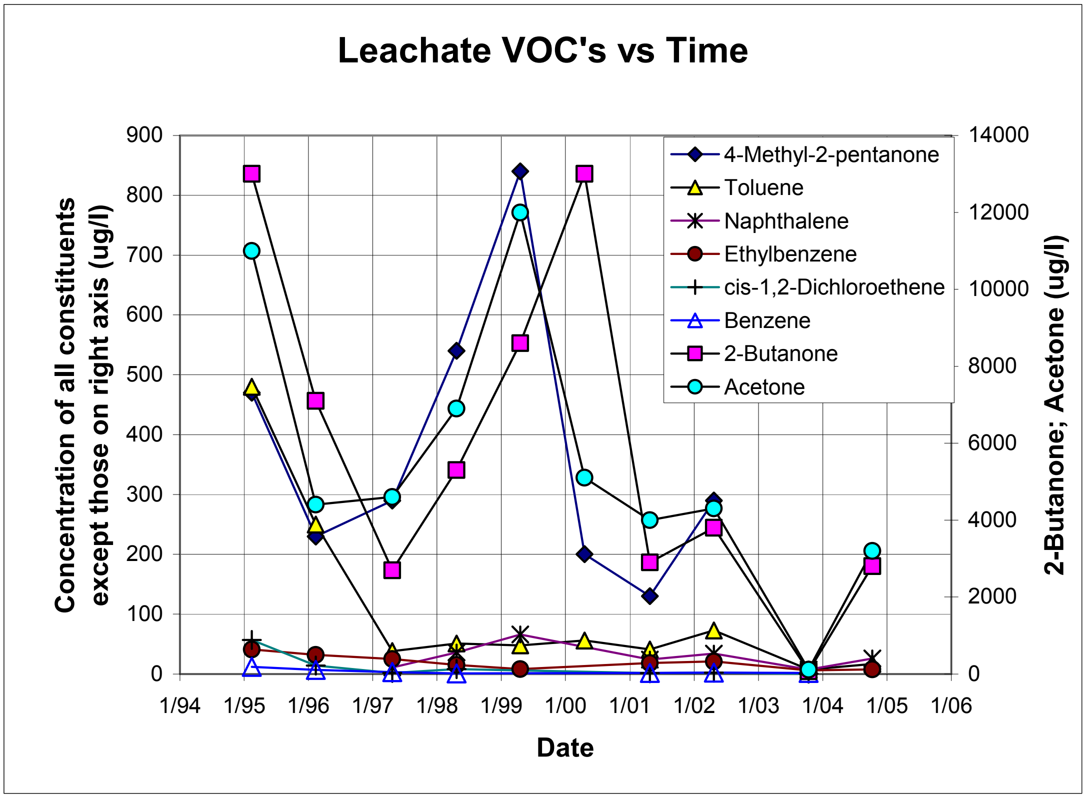

Figure 5. Leachate chemistry vs time for VOCs.

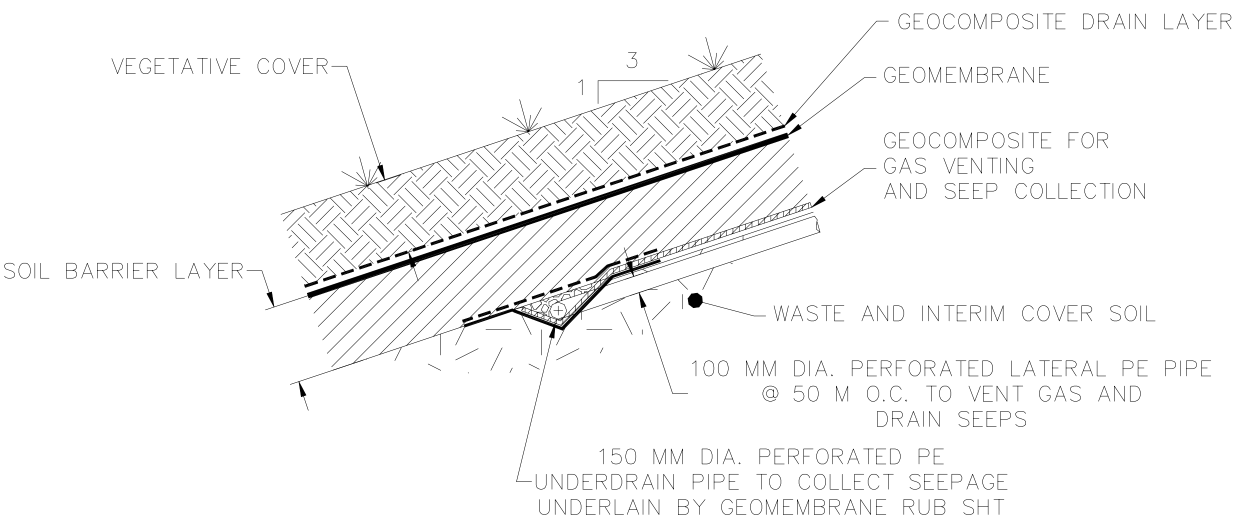

Figure 6. Generic design schematic for combination gas venting and leachate seep collection beneath temporary and final sideslope covers.