EXPECTED BENEFITS OF A FULL-SCALE BIOREACTOR LANDFILL

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ABSTRACT: An integrated leachate and landfill gas management system has been incorporated into the design of a municipal solid waste disposal cell. This will enable the facility to be operated as a full-scale bioreactor landfill that will act as a waste treatment unit as well as a waste containment unit. The expected benefits of operating a landfill as a bioreactor are reduced leachate treatment costs, enhanced landfill gas generation, and reduced long-term pollution potential. The potential problems of increased odor generation and interference with landfill operations have been addressed in the design.

1. INTRODUCTION

The Delaware Solid Waste Authority (DSWA) owns and operates the Southern Solid Waste Management Center (SSWMC), which serves as the primary solid waste disposal facility for Sussex County, Delaware. DSWA has been involved in landfill bioreactor studies and has several years of experience with leachate recirculation at SSWMC and its other facilities. Building on this experience, GeoSyntec Consultants (GeoSyntec) and DSWA have designed a new cell at SSWMC to be a full-scale bioreactor landfill. The design emphasizes an integrated approach to leachate and landfill gas management. The purposes of this paper are to describe: (i) the bioreactor landfill concept; (ii) the expected benefits of operating a landfill as a bioreactor; and (iii) the integrated leachate and landfill gas management approach developed by GeoSyntec and DSWA.

2. THE BIOREACTOR LANDFILL CONCEPT

The bioreactor landfill concept is to use a landfill as a waste treatment unit by enhancing the naturally occurring biodegradation processes within the landfill. In a bioreactor landfill, it is expected that complete degradation of the biodegradable material in the landfill can be achieved prior to the end of the post-closure care period, a condition that has not been observed to occur in a conventional landfill. As described in Section 3.4, enhanced biodegradation reduces the pollution potential of the landfill. Therefore, a bioreactor landfill can achieve a level of environmental protection that is even higher than that provided by a conventional lined landfill. Enhanced biodegradation can be achieved by recirculating landfill leachate back into the waste mass, which is the approach presented in this paper. Clearly, leachate recirculation is only appropriate for modern lined landfills; unlined landfills do not have a means for collecting leachate or separating it from the environment.

The recirculation of leachate accelerates the biodegradation of the waste mass in the following ways.

- The recirculated leachate is a source of nutrients (i.e., nitrogen and phosphorus) and organic carbon, which are required for bacterial growth [Moat, 1979].

- Leachate recirculation accelerates the attainment of anaerobic conditions by physically displacing oxygen. Anaerobic conditions are required for methanogenesis, which is generally the terminal reaction in the waste decomposition process [Young, 1995].

- Leachate recirculation lowers the oxidation-reduction potential of the waste mass, which promotes the growth of methanogens.

- Leachate recirculation provides an engineering mechanism through which the pH of the liquid in the waste mass may be adjusted to promote growth of methanogens. The optimum pH range for growth of methanogens is 6.8 to 7.9 [Thorneloe et al., 1993, p. 366]. The pH of acidic landfill leachate can be increased by adding lime or hydroxide prior to recirculation.

DSWA has been performing leachate recirculation for more than a decade. DSWA first began recirculating leachate at its Central Solid Waste Management Center (CSWMC) in 1982, and has been recirculating leachate at SSWMC since 1985. To evaluate the effectiveness of leachate recirculation for accelerating waste decomposition at its landfills, DSWA routinely collects the following data: (i) leachate quality data from two landfills where leachate is recirculated (i.e., CSWMC and SSWMC) and one where leachate is not recirculated (i.e., the Northern Solid Waste Management Center (NSWMC)); and (ii) landfill gas generation data from two 1-acre (0.4-ha) landfill cells that were constructed at CSWMC for research purposes (referred to hereafter as the test cells).

As described in the next section, operating a landfill as a bioreactor has the potential to reduce the cost of operating a landfill in addition to providing increased environmental protection. In addition, selected data from DSWA facilities are summarized and used to support the validity of these expectations.

3. EXPECTED BENEFITS OF A BIOREACTOR LANDFILL

3.1 <u>Overview</u>

The expected benefits of operating a landfill as a bioreactor are: (i) reduced leachate treatment costs; (ii) enhanced landfill gas (LFG) generation; and (iii) reduced long-term pollution potential through accelerated waste stabilization. In the following subsections, each of these benefits is described.

3.2 Reduced Leachate Treatment Costs

An expected benefit of operating a landfill as a bioreactor is reduced leachate treatment costs. This is accomplished by the long-term and the temporary retention of recirculated leachate within the waste mass, both of which are economically beneficial, as described below. Note that both long-term and temporary leachate retention is accomplished by increasing the moisture content of the pore spaces in the waste and daily cover, not by increasing the leachate head on the landfill liner system.

A portion of the leachate that is recirculated will be retained in the landfill and may never need to be treated because the recirculated leachate increases the average long-term moisture content of the landfill. The potential of tremendous increase in long-term retention of liquid in a typical landfill is illustrated by the following example. A representative value for field capacity of municipal solid waste reported by Schroeder et al. [1994] is 0.292 vol/vol (i.e., 0.292 ft^3 of liquid per ft^3 of waste). A reasonable assumption for moisture content of waste in a landfill in a non-arid location is 80 percent of field capacity (i.e., 0.234 vol/vol). The difference between these values represents the theoretical additional volume of liquid that could be retained in the waste: 0.058 ft^3 of liquid per ft^3 of refuse, which equals 12 gallons per cubic yard or 12 million gallons (45 million liters) for a 1 million cubic yard (765,000 m^3) landfill. The degree to which the potential for additional long-term retention can be realized for a particular landfill is largely dependent on the uniformity with which recirculated leachate can be distributed within the waste mass. The bioreactor landfill design described in Section 4 is expected to provide a fairly uniform distribution of recirculated leachate.

The portion of leachate that is not retained long-term is temporarily retained as it drains through the waste mass. Using the landfill to provide temporary additional leachate storage may result in lower capital costs for leachate management. For example, during periods of high leachate flow rates, leachate recirculation can be used to equalize the rate at which leachate is treated, eliminating the need for additional infrastructure (i.e., storage or treatment facilities) to handle peak flows.

The cost for a leachate recirculation system is relatively low when compared to the cost of other leachate treatment options. The capital cost for developing a leachate recirculation system (i.e., a pumping station and leachate distribution network) has ranged from approximately $10,000 to $200,000 for the various DSWA systems. For comparison, preliminary cost estimates for leachate treatment plants being considered by DSWA for treatment of comparable quantities of leachate ranged from $1,000,000 to $6,000,000. Excess leachate from DSWA facilities is currently delivered by tanker trucks to an industrial waste-water treatment plant. The cost of transportation (for an average round-trip distance of 125 miles (200 km)) and treatment in 1995 was $110/1,000 gal ($29/m^3). Leachate recirculation reduces the need for this external treatment. During 1994, DSWA saved or deferred approximately $150,000 by recirculating 1.36 million gallons (5,000 m^3) of leachate at the CSWMC facility.

3.3 Enhanced Landfill Gas Generation

A second benefit of operating a landfill as a bioreactor is to accelerate the rate of landfill gas production within a landfill, increasing the economic viability of landfill gas utilization projects. Results of pilot-scale tests have shown that leachate recirculation accelerates the decomposition process and increases the production of landfill gas [Pohland 1975, 1980; Pohland et al. 1979]. The clearest evidence that leachate recirculation has accelerated the decomposition of waste in DSWA landfills is shown by the landfill gas generation data from the two tests cells, one in which leachate recirculation is performed and one in which it is not. The landfill gas generation rate of the cell with recirculation is approximately ten times greater than that of the cell without recirculation. At all DSWA landfills where recirculation has been used, increased landfill gas generation, accompanied by increased odors, has been observed. The manner in which the design of the expansion at SSWMC addresses the problem of increased odors is described in Section 4.

3.4 Reduced Long-Term Pollution Potential

A third benefit of operating a landfill as a bioreactor is to reduce the long-term pollution potential of the landfill. This is accomplished by accelerating and enhancing the decomposition of the waste, thereby improving the quality of the leachate and breaking down potential pollutants within the waste mass. Even some hazardous substances that may be present in the waste mass in small quantities can be degraded. Compounds that are susceptible to anaerobic biodegradation include chlorinated aliphatics (e.g., trichloroethylene and perchloroethylene) [Fathepure and Boyd, 1988; Freedman and Gossett, 1989], chlorinated monoaromatics (e.g., pentachlorophenol) [Sims et al., 1990], and polychlorinated biphenyls (PCBs) [Bedard, 1990; Berkaw et al., 1996].

The decomposition (or stabilization) of solid waste has been described by Pohland [1986] as occurring in five phases, each characterized by distinctive biological processes and resulting products of reaction. It is possible to identify the decomposition phase of a landfill by monitoring leachate and landfill gas composition and landfill gas production rate. The application of leachate and gas monitoring for optimizing the performance of a bioreactor landfill is discussed in Section 4.4. The clearest evidence that leachate recirculation has accelerated the decomposition of waste in DSWA landfills is shown by data from the two test cells, one in which leachate recirculation is performed and one in which it is not. Monitoring data indicate that the cell with leachate recirculation reached the fifth phase of decomposition prior to capping (i.e., in about two years) [Pohland, 1995]. The data is inconclusive regarding the decomposition phase of the cell without recirculation at the time of capping. In addition, results of pilot-scale tests have shown that leachate recirculation accelerates the decomposition process and increases the production of landfill gas [Pohland 1975, 1980; Pohland et al. 1979].

Recirculation achieves in-situ treatment of the leachate by providing moisture and nutrients for the anaerobes that decompose waste and, in turn, reduce the organic content of the leachate. Many pilot scale studies have shown the ability of leachate recirculation to substantially decrease the concentration of contaminants in leachate over a period of less than two years [Pohland 1975, 1980; Pohland et al., 1979; Tittlebaum, 1982]. Data from DSWA landfills confirm this finding, as described below.

Leachate quality data from a landfill where recirculation is performed (i.e., Disposal Area B at CSWMC) are shown in Table 1 (from Watson [1993]); this leachate quality is typical of the quality of leachate from landfills where DSWA recirculates leachate. It can be seen that, during active filling of the landfill from 1983 to 1988, the organic content of the leachate (i.e., TOC, COD, and BOD-5) was very high. After closure in late 1988, a rapid decrease in organic content and an increase in pH occurred, similar to stabilization patterns observed in pilot scale studies [Pohland, 1995]. The same pattern has not been observed at the NSWMC facility where leachate is not recirculated.

Table 1: Quality of Leachate from Disposal Area B of CSWMC

Parameter Date	pH (standard units)	COD (mg/liter)	BOD-5 (mg/liter)	TOC (mg/liter)
Sep-83	5.39	20,000	1,773	6,170
Mar-84	7.00	120	76	25
Jan-85	5.70	29,893	17,300	
Jan-86	5.74	30,000	20,250	10,000
Jan-87	5.75	34,556	25,750	10,000
Jan-88	6.15	28,300	20,500	1,900
Jan-89	6.75	15,550	12,591	4,950
Jan-90	6.80	5,620	1,144	1,178
Jan-91	7.16	1,775	352	238
Jan-92	7.16	1,800	540	540
Dec-92	7.39	1,000	50	290
Minimum	5.39	120	50	25
Maximum	7.39	34,556	25,750	10,000
Average	6.45	15,329	9,121	3,529

Notes: COD = chemical oxygen demand
BOD-5 = biological oxygen demand (5-day)
TOC = total organic carbon

3.5 <u>Comments on Optimization of Benefits</u>

The benefits of operating a landfill as a bioreactor are a function of operational and environmental factors. With the right combination of operational and climatic factors, it would be possible to recirculate 100 percent of a landfill's leachate into the waste mass for long-term retention. This combination of factors would consist of: (i) a relatively rapid filling rate, which reduces the length of time the waste is exposed to precipitation; (ii) a low to moderate annual precipitation rate; and (iii) recirculation methods that achieve a fairly uniform distribution of recirculated leachate within the waste mass.

Finally, to realize the maximum benefits from bioreactor landfill operations, the bioreactor concept should be integrated into the design, operation, and monitoring of the landfill. Performing leachate recirculation as an independent and low priority activity is likely to cause problems (e.g., increased odors and interference with landfill operations). To provide the benefits of bioreactor operation, while reducing attendant problems, GeoSyntec designed an integrated leachate and landfill gas management system, as well as a plan for operations and monitoring. This system is described in the next section.

4. BIOREACTOR LANDFILL DESIGN AND OPERATION

4.1 Overview

The expansion at SSWMC (i.e., Cell 3) is scheduled to be opened in November 1996. Cell 3 has been designed to function as a full-scale bioreactor landfill through the use of an integrated leachate and landfill gas management system. The primary functions of the integrated leachate and landfill gas management system are to re-inject leachate into the landfill and extract landfill gas from the landfill during both the operational and post-closure periods. The following are presented in the remainder of this section: (i) the criteria for the design of the system; (ii) a description of the system design; and (iii) the proposed manner in which the system will be operated.

4.2 Design Criteria

The integrated leachate and landfill gas management system was designed to provide the benefits of leachate recirculation described in Section 3, while addressing the problems presented by leachate recirculation. Therefore, the following criteria were applied to the design of the system.

- The system must be operable throughout the life of the landfill, both during operations and throughout the post-closure period.
- The design and operation of the system must comply with the requirements of applicable air quality and solid waste regulations.
- The system must minimize the emission of odors.
- To begin leachate recirculation and odor control as soon as possible, the first phase of the system must be operable no later than two years from the first placement of waste in Cell 3.
- To minimize interference with landfill operations, the system must be constructed in phases in coordination with the landfill filling sequence.
- The system should provide a fairly uniform distribution of recirculated leachate throughout the landfill mass.

- To the extent possible, the leachate recirculation and landfill gas extraction piping should be co-located to reduce construction costs.
- The potential for biological clogging of the system must be minimized.
- Leachate must be prevented from hampering the functioning of the landfill gas extraction system.
- Leachate must not be exposed to the atmosphere or seep out of the surface of the landfill.
- The entire system must be served by a single leachate pump station and a single landfill gas flare station.

4.3 Description of the System Design

4.3.1 System Layout

The proposed system, which is illustrated in Figure 1, is called the Horizontal Integrated Recirculation and Extraction System (HIRES). A horizontal configuration is used because more efficient odor control and a more even distribution of recirculated leachate can be achieved by a horizontal system than by a vertical system. The key elements of this system are pairs of horizontal trenches distributed throughout the waste mass. As shown in Figure 2, each pair of trenches consists of a leachate injection trench and a landfill gas extraction trench that are horizontally separated by a distance of 5 ft (1.5 m). Each trench contains a perforated high-density polyethylene (HDPE) pipe, and is filled with crushed stone. The horizontal spacing between pairs of trenches is 80 ft (24 m) and the vertical spacing between layers of trenches is 20 ft (6 m). Within the proposed 100-ft (30-m) height of Cell 3, the HIRES trench pairs will be installed in four different layers (i.e., at heights of approximately 20, 40, 60, and 80 ft (6, 12, 18, and 24 m) above the liner system). The trenches in each layer will be offset horizontally from the trenches in the layers above and below. The selected layout provides a very high efficiency for landfill gas collection (i.e., 100 percent of the waste in the landfill is within the estimated gas extraction zone of influence) and a high waste wetting efficiency (i.e., approximately 70 percent of the waste is within the estimated wetting zone of influence).

The close proximity of each gas extraction trench to a leachate injection trench enhances the odor control capability of the HIRES. The injection trenches are concentrated odor sources because: (i) during the process of leachate injection, landfill gas is displaced and is forced either out of the landfill or to a gas extraction structure; and (ii) it is expected that landfill gas will be generated most rapidly around the injection trenches due to the elevated moisture content and organic strength caused by leachate recirculation. To achieve effective odor control, gas extraction should be performed at the same time that leachate is injected. Therefore, separate pipes are used rather than a single pipe through which extraction and injection are alternately performed.

The configuration was also designed to minimize the likelihood of: (i) leachate entering the gas extraction components of the system; or (ii) leachate seeping onto the landfill surface.

The horizontal spacing and the slight vertical offset between the trenches of each pair were selected to provide a low likelihood that recirculated leachate would flood the landfill gas extraction pipes. In the event that leachate enters the landfill gas transmission pipe network, it will be removed by high-capacity condensate management structures. To minimize the potential for leachate seeps to develop, the trenches will end 40 ft (12 m) away from the landfill sideslope. This 40-ft (12-m) buffer will also reduce the amount of air intrusion into the gas extraction system.

To minimize interference with landfill operations and to begin leachate recirculation as soon as possible, the HIRES will be constructed in eight phases. A detailed sequence for the filling of Cell 3 and the construction of the HIRES has been designed to allow HIRES construction and landfill operations to proceed simultaneously at different locations in Cell 3 without interfering with each other. In the next section, the components of the HIRES are further described.

4.3.2 System Components

The HIRES is composed of the following: (i) leachate recirculation pumps located in a pump house adjacent to Cell 3; (ii) leachate recirculation and landfill gas transmission piping; (iii) trench pairs for leachate injection and landfill gas extraction; (iv) four leach fields on top of Cell 3 for leachate recirculation; and (v) a landfill gas flare station adjacent to the pump house. Each of these components is described below.

The Cell 3 pump house will contain two leachate recirculation pumps. The pumps will draw leachate from the Cell 3 leachate storage tanks and pump it through a forcemain to a pipe distribution network to the leachate injection trenches. The pumps will be variable-speed positive-displacement pumps capable of pumping 100 gpm (23 m^3/hr) against a head of 120 ft (37 m). At this pumping rate, approximately (50,000 gal) (190 m^3) of leachate can be pumped to the top of Cell 3 in an 8-hour work day. The automatic pump control system will activate the leachate recirculation pumps at selected times and regulate the rate and duration of pumping.

The leachate recirculation and landfill gas transmission piping will be installed between the pump house/flare station and the injection/extraction trench pairs. Both the leachate and LFG pipes will be made of HDPE. The piping includes control valves for: (i) directing leachate to specific trench groups or leach fields; and (ii) throttling or shutting off the vacuum applied to specific trench groups, as needed. The HIRES design can be modified to provide the capability of controlling individual trench pairs rather than groups if a greater level of control is desired.

The leachate injection and landfill gas extraction trenches will contain thick-walled, perforated HDPE pipe and aggregate. The pipe wall thickness was selected to resist crushing throughout the life of landfill. HDPE will be used because of its resistance to corrosion and degradation. Aggregate (i.e., 2 to 3 in. (50 to 75 mm) in diameter) will be used to minimize the likelihood of biological growth blocking the flow of leachate. Because the clogging potential of granular materials increases with the rate of leachate flow through them [Koerner et al., 1994] and because the flow rate of leachate through the injection trenches is expected to be much greater than that through leachate collection material in the liner system, coarser material is required to prevent clogging for the leachate injection trenches than for the leachate collection layer.

At the time of landfill closure, leach fields will be constructed on top of Cell 3. A cross section of a leach field is shown in Figure 3. Each leach field will be 110 ft by 75 ft (34 m by 23 m) in size and will contain 23 rows of infiltrator units in a bed of crushed stone. The four leach fields will cover approximately one-third of the top area of the landfill.

The flare station will consist of a condensate knockout tank, a blower, a flame arrestor, and a flare. The design capacity of the flare is 600 scfm (1,000 standard m^3/hr), which was calculated based on the design capacity of Cell 3 (i.e., 817,000 tons (740,000 Mg) of waste) and the expected filling duration of six years. The accelerated rate of gas generation resulting from leachate recirculation was also accounted for in the design of the HIRES gas management components.

4.3.3 Anticipated System Performance

The expected performance of the HIRES is based on design calculations. The performance of the leachate injection and landfill gas extraction components of HIRES is described below.

Because of the large variability in the expected rate of infiltration of leachate into the heterogeneous waste mass, the expected performance of the leachate injection components of the HIRES can only be approximated. In addition to spatial variability, the infiltration rate is expected to be at a maximum when recirculation is initiated and to decrease over time due to biological growth and saturation of the surrounding waste. Estimates of the time required to drain the injection trenches under hydrostatic conditions range from approximately 2 hours to 2 months for the injection trenches, and from 1 hour to 1 month for the leach fields. For the injection trenches, estimates of the rate at which leachate will be able to be recirculated under hydrostatic conditions range from 16 to 880 gal/yr/ft (0.2 to 10 m^3/yr/m) per year of trench. The total volume of leachate that can be recirculated in one year under hydrostatic conditions is estimated to range from 0.4 to 7.8 million gal/yr (1,500 to 30,000 m^3/yr) for the injection trenches, and from 2 to 16 million gal/yr (7,500 to 60,000 m^3/yr) for the four leach fields. However, the injection trenches are designed to be operated under pressure, which is expected to increase the rate of recirculation. Prior to closure, it is estimated that Cell 3 will generate approximately 6.5 million gal/yr (25,000 m^3/yr) of leachate (not including recirculated leachate). Therefore, as much as half of the leachate that is collected from the leachate collection system will be recirculated; the remainder will be transported to an off-site leachate treatment plant.

To design the landfill gas extraction components, landfill gas generation rates, radius of influence of landfill gas extraction trenches, head loss and flow velocity in landfill gas transmission piping, and estimated condensate volumes were calculated. The condensate management structures are designed to have sufficient capacity to remove a large amount of leachate from the gas transmission pipes in the event that recirculated leachate enters the pipes. Because of the close proximity of leachate recirculation and gas extraction structures and because leachate will not be exposed to the atmosphere, the HIRES is expected to effectively address the additional gas management concerns caused by leachate recirculation.

4.4 System Operation

4.4.1 Overview

Operation of the gas extraction components of the HIRES will vary little from that of other typical landfill gas management systems. However, the operation of the leachate recirculation components will require careful attention. In this section, principles for the operation and monitoring of both the leachate recirculation and landfill gas extraction components are presented.

Effective operation of the leachate recirculation components will require modifying the general operational procedures in response to data gathered from monitoring the HIRES. Therefore, it is important to understand the principles that constitute effective operation of the system, and how to modify operating procedures based on the data collected from the HIRES. The following are presented below: (i) a discussion of the principles of effective leachate recirculation; (ii) suggestions for initial operation of the leachate recirculation system; and (iii) a description of monitoring activities for evaluating the effectiveness of recirculation activities. Finally, the operation of the gas extraction components is addressed.

4.4.2 Leachate Recirculation Principles

The guiding principle for operation of the leachate recirculation system is to optimize the production of methane. When this is achieved, the rate of waste decomposition is maximized and the effectiveness of recirculation for improving the quality of the leachate is maximized. Methane production is optimized when the waste mass is kept uniformly moist (i.e., when the moisture content of the waste is maintained at approximately the waste's field capacity moisture content). However, it is possible that saturating the waste too quickly at the start of the system operation could result in a buildup of volatile fatty acids and a decrease in pH that would inhibit the development of the methane-producing bacteria. The state of development of the methane-producing bacteria is reflected by the leachate characteristics, by the quantity of landfill gas produced, and by the methane content of the gas. When the methane content of the gas reaches approximately 40 to 60 percent, this indicates that a viable methane-producing bacteria population has been established. Once this occurs, leachate recirculation may be performed more frequently.

4.4.3 Operational Recommendations

The following operational practices are recommended.

- Leachate should be recirculated to only one group of trenches or one leach field at a time in order to increase the ability to monitor the operation of the system.

- When pumping leachate to a group of trench pairs, pumping should continue until the flow rate decreases significantly, indicating a buildup of pressure in the system. The pressurization of the trench pairs will increase the volume of waste that is wetted by each trench pair, and should decrease the amount of localized clogging that may occur.

- Drying periods should be allowed between injection events to allow development of a more uniform wetting of waste throughout the landfill. For design of the HIRES at Cell 3 of SSWMC, drying periods were accounted for in the estimates of annual leachate recirculation volume.

4.4.4 Required Monitoring

Monitoring is required to evaluate whether or not effective operation of the leachate recirculation system is being achieved. The parameters most directly related to operational effectiveness are the quantity and composition of the landfill gas and the pH (or volatile fatty acids content) of the leachate. A methane content of 40 percent or greater would indicate that a viable methane-generating bacteria population has been established and that the leachate recirculation rate could be increased. A decrease in the quantity of landfill gas extracted or a decrease in the methane content of the gas would probably indicate that the waste is either too wet or too dry. A corresponding decrease in leachate pH (i.e., an increase in acidity) would probably indicate that the decreasing methane content is due to the waste being too wet, rather than too dry.

4.4.5 Gas Extraction

The operation of the gas extraction components should follow the well-established procedures for typical landfill gas extraction systems. The objectives of the gas management system are to control landfill gas migration, odors, and air pollutants without drawing an excessive amount of oxygen into the landfill and without interfering with landfilling operations. The concentration of oxygen in the extracted LFG should be limited to a maximum of 5 percent. This can be regulated by applying a level of vacuum to the extraction trenches that is compatible with the resistance to air infiltration over the trenches. This vacuum may be field adjusted as conditions require. It is recommended that the vacuum should not be applied to waste until at least one 10-ft (3-m) thick lift of waste has been placed over the trenches. As the overlying waste thickness increases, the vacuum applied to the trenches may be increased. If air infiltration is observed, the system may be operated in a passive mode until a sufficient thickness of waste is placed over the trench. The operation of the flare station is intended to be continuous and automatic.

5. SUMMARY AND CONCLUSIONS

Operating a landfill as a bioreactor by performing leachate recirculation is expected to reduce leachate treatment costs, enhance landfill gas generation, and reduce the long-term pollution potential. Evidence to support these expectations has been presented based on DSWA's 14 years of experience with leachate recirculation. To provide the benefits of leachate recirculation, while reducing attendant problems (e.g., increased odor generation and interference with landfill operations), GeoSyntec and DSWA designed an integrated leachate and landfill gas management system (i.e., the HIRES) that uses leachate injection/landfill gas extraction trench pairs.

The significant features of HIRES are: (i) injection/extraction trench pairs; (ii) coordinated waste filling and HIRES construction; and (iii) monitoring/controlling the system to optimize its performance. The injection/extraction trench pairs are expected to effectively control odor problems, while distributing leachate uniformly throughout the waste mass. Phased construction of HIRES in coordination with a defined filling sequence is expected to minimize interference with landfill operations. Careful attention to the operation of HIRES and the use of monitoring data to refine operational procedures should increase the effectiveness of the leachate treatment and waste stabilization processes. In conclusion, the integrated leachate and landfill gas management system designed for SSWMC Cell 3 is expected to provide reduced leachate treatment costs, enhanced landfill gas generation, and reduced long-term pollution potential without interfering with landfill operations or causing odor problems.

ACKNOWLEDGEMENTS

The authors are grateful to Dr. John F. Beech, Mr. Eric S. Steinhauser, and Dr. Andrew Autry of GeoSyntec Consultants for their review of the paper.

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