INTEGRATED LEACHATE AND LANDFILL GAS MANAGEMENT

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SUMMARY: An integrated leachate and landfill gas management system has been designed for a proposed municipal solid waste disposal cell in which leachate recirculation will be performed. The integrated leachate recirculation and landfill gas management system will function during landfill operations and after closure. The expected benefits of the system are: reduced leachate treatment costs, accelerated decomposition of waste, and effective odor control.

1. INTRODUCTION

The Delaware Solid Waste Authority (DSWA) owns and operates the Southern Solid Waste Management Center (SSWMC), which serves as the primary sanitary landfill disposal facility for Sussex County, Delaware, USA. DSWA has several years of experience with leachate recirculation at SSWMC and at its Central Solid Waste Management Center (CSWMC) in Kent County, Delaware. Building on this experience, the authors developed an integrated approach to leachate and landfill gas management for a proposed 9.7-ha (24-acre) disposal cell (designated as Cell 3) at the SSWMC. The integrated approach was developed to address the problems that DSWA has experienced with leachate recirculation. Therefore, the purposes of this paper are: (i) to present a summary of the leachate recirculation experiences of DSWA; and (ii) to describe the integrated leachate and landfill gas management system that has been designed for the SSWMC Cell 3 development project.

2. LEACHATE RECIRCULATION EXPERIENCE

2.1 Introduction

DSWA first began to recirculate leachate at its CSWMC site in 1982, and has recirculated leachate at SSWMC since 1985. The purposes of leachate recirculation, as described by Pohland (1986), are: (i) to reduce leachate treatment costs; and (ii) to accelerate the decomposition of the waste, thereby reducing the long-term pollution potential of the landfill. In this section, the leachate recirculation methods that have been used by DSWA are described, and an evaluation of the extent to which the goals of leachate recirculation are being accomplished at DSWA landfill sites is presented.

2.2 Leachate Recirculation Methods

2.2.1 Overview

DSWA has used the following four methods for leachate recirculation (Watson, 1993): (i) recharge wells; (ii) spray irrigation; (iii) exposed surface application; and (iv) leach fields. Each of these methods is briefly described with their advantages and disadvantages in Table 1. The methods are described in more detail in Sections 2.2.2 through 2.2.4.

Table 1. Summary of Leachate Recirculation Methods Previously used at DSWA Sites

Method	Time of Usage	Advantages	Disadvantages
Recharge Wells	During operations and after closure	•requires little effort to operate •can be done in almost all weather conditions •successful during winter months	•leachate reaches the leachate collection system sooner because it is injected deep into the landfill •if not sealed, recharge wells become concentrated landfill gas emission points, especially during leachate injection when landfill gas is displaced from the landfill
Spray Irrigation	During operations	•significant amount of evaporation •leachate is distributed evenly on top of the landfill resulting in more leachate being stored in the waste and less returning to the leachate collection system	•can only be used during optimum weather conditions (dry, temperatures above freezing, and little wind) •causes the most odors •requires the most time and effort to operate
Exposed Surface Application	During operations	•requires little effort to operate •distributes leachate over large areas on top of the landfill	•cannot be used if cover soil is frozen •cannot be used in wet weather conditions •may prevent landfilling on top of a ponded area for a long period of time •causes odors
Leach Fields	After closure	•requires little effort to operate •can be automated •distributes leachate over large areas on top of the landfill	•not considered suitable for use during landfill operations

2.2.2 Recharge Wells

The most commonly used leachate recirculation method at DSWA sites has been leachate recharge wells. A typical recharge well is shown in Figure 1. Perforated precast concrete manhole sections (1.2 m (4 ft) high and 1.2 m (4 ft) in diameter) costing approximately $275 each are used to construct the recharge wells. The manhole sections are filled with 75-mm to 100-mm (3-in. to 4-in.) diameter crushed stone. The total installed cost is approximately $346 per meter of well ($105 per foot). Each well can also be used for landfill gas extraction, but not while leachate is being injected. To recirculate leachate using recharge wells, leachate is pumped from storage tanks, sumps, or tanker trucks into the recharge wells; the leachate then percolates into the waste. At CSWMC, pumps operating against a head of 24 to 31 m (78 to 102 ft) deliver 10 to 23 m^3/hr (45 to 100 gpm) of leachate to recharge wells during injection events. The recharge wells are typically installed after the first lift of waste is placed and are extended upward as additional layers of waste are placed in the landfill. Recharge wells require little effort to operate and can be used both during landfill operations and after closure. In addition, leachate can be recirculated into the wells in almost all weather conditions, including conditions encountered during winter months. The disadvantages of using recharge wells for recirculation of leachate are: (i) leachate tends to reach the leachate collection system sooner than for other recirculating methods because leachate is injected deep into the landfill; and (ii) if not sealed, the wells become concentrated landfill gas emission points, especially during leachate injection, which displaces gas from the landfill.

2.2.3 Spray Irrigation

Recirculation of leachate by spray irrigation is accomplished using a large agricultural-type traveling spray device. The primary advantage of this method is the significant reduction of leachate volume achieved because of evaporation; DSWA has estimated (through measurements of recirculated volumes) that as much as 30 percent of sprayed leachate may evaporate under favorable evaporation conditions. In addition, the leachate is distributed evenly over the top of the landfill, which provides a uniform wetting of the waste and maximizes the time required for the leachate to reach the leachate collection system. The disadvantages of spray irrigation are: (i) spraying causes the most odors of any recirculation method used; (ii) spraying can only be performed during dry, warm, windless weather conditions; and (iii) the spraying method requires the most time and effort to operate.

2.2.4 Exposed Surface Application

Exposed surface application is performed by either: (i) pumping leachate through perforated pipe that is laid on the landfill surface; or (ii) creating a pond of leachate within a bermed area on top of the landfill. Exposed surface application requires little effort to operate and enables distribution of leachate over a large area of the top of the landfill. The disadvantages of exposed surface application are: (i) it cannot be used on frozen cover soil or during rainy weather; (ii) it may prevent landfilling on top of a ponded area for a long period of time; and (iii) it causes odors.

2.2.5 Leach Fields

Leach fields are a means to achieve surface application of leachate without directly exposing the leachate to the atmosphere. A layout of a typical leach field used by DSWA is shown in Figure 2. As shown on the figure, the leach fields typically consist of rows of perforated high-density polyethylene (HDPE) arches, called infiltrator units, in a layer of high-permeability stone buried beneath the landfill cover system. The infiltrator units provide a larger leachate storage capacity compared to using crushed stone alone. DSWA estimates the construction cost of leach fields to be $\$75/m^2$ ($\$7/ft^2$). They are the preferred method for long-term leachate recirculation at closed landfills because: (i) the injection of leachate can be automated; (ii) leachate is distributed over large areas on top of the landfilled waste; and (iii) the system does not occupy any area on the closed landfill surface. In addition, because the system is buried, it does not cause odor problems. However, these structures have only been used as permanent installations at the top of closed landfills and not at intermediate elevations within landfills because the infiltrator units will not withstand high normal stress and because of the expense and interference with landfill operations associated with constructing them.

2.2.6 Summary

The problems associated with leachate recirculation described above can be summarized as: (i) increased odor production; (ii) interference with landfill operations; and (iii) difficulty achieving uniform wetting of waste. The manner in which the proposed integrated leachate and landfill gas management system addresses these problems is described in Section 3.

2.3 Leachate Recirculation Evaluation

2.3.1 Overview

To evaluate the effectiveness of leachate recirculation for treating leachate and 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 0.4-ha (1-acre) landfill cells that were constructed at CSWMC for research purposes (referred to as the test cells). In this section, selected data are summarized and used to evaluate the extent to which the goals of leachate recirculation are being achieved at DSWA facilities.

2.3.2 Leachate Treatment

One of the primary goals of leachate recirculation is to provide an economical means for managing leachate by reducing treatment costs. In this section, evidence is presented that leachate recirculation is an effective method of treatment and that it is less costly than other leachate treatment options. Recirculation achieves in-situ treatment of the leachate by providing moisture and nutrients for the anaerobes that act to decompose the 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, showing that contaminant concentrations have decreased over time in leachate from landfills where recirculation is performed.

Leachate quality data from a landfill where recirculation is practiced (i.e., Disposal Area B at CSWMC) are shown in Table 2 (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 occurred, similar to stabilization patterns observed in pilot scale studies. The same pattern has not been observed at the NSWMC facility where leachate is not recirculated.

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 includes costs for pumping stations and leachate distribution networks; these costs have 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 200 km (125 miles)) and treatment in 1995 is \$3/m^3 (\$11/1,000 gal). Leachate recirculation reduces the need for this external treatment. During 1994, DSWA saved approximately \$150,000 by recirculating 5,000 m^3 of leachate at the CSWMC facility.

Table 2: 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

2.3.3 Acceleration of Waste Decomposition

A second goal of leachate recirculation is to reduce the long-term pollution potential of a landfill by accelerating and enhancing the decomposition of the waste. The goal is to use the landfill as a bioreactor to stabilize the waste, rather than just as a container to store the waste. 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 current 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 leachate recirculation system is discussed in Section 3.4). 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). 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 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) while it does not clearly indicate whether or not the cell without recirculation did. In addition, 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.

2.3.4 Landfill Gas Management Concerns

Leachate recirculation can cause increased odors by: (i) exposing leachate to the atmosphere; and (ii) displacing landfill gas from the landfill. In addition, leachate recirculation structures, particularly recharge wells, provide preferential pathways for the emission of landfill gas if landfill gas management measures are not implemented. Finally, the acceleration of landfill gas generation caused by leachate recirculation must be considered when estimating the quantity of the landfill gas that the system must manage. However, the acceleration of gas generation is advantageous for the development of beneficial uses of the gas and DSWA is currently evaluating the feasibility of this at its facilities. The manner in which the proposed integrated leachate and landfill gas management system addresses these concerns is described in Section 3.

3. SYSTEM DESIGN AND OPERATION

3.1 Overview

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.

3.2 Design Criteria

The integrated leachate and landfill gas management system was designed to provide the benefits of leachate recirculation, described in Section 2.3, while addressing the problems presented by leachate recirculation, described in Sections 2.2 and 2.4. 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 collocated 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.

3.3 Description of the System Design

3.3.1 System Layout

The proposed system 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 3, each pair of trenches consists of a leachate injection trench and a landfill gas extraction trench that are horizontally separated by a distance of 1.5 m (5 ft). Each trench contains a perforated HDPE pipe, and is filled with crushed stone. The horizontal spacing between pairs of trenches is 24 m (80 ft) and the vertical spacing between layers of trenches is 6 m (20 ft). Within the proposed 30-m (100-ft) height of Cell 3, the trench pairs of the HIRES will be installed in four different layers (i.e., at a height of approximately 6 m, 12 m, 18 m, and 24 m (20, 40, 60, and 80 ft) above the liner system). The trenches in each layer will be offset horizontally from the trenches in the layers above and below. This configuration is shown schematically in Figure 4.

The primary criteria used to develop this configuration were: (i) to achieve a fairly uniform distribution of recirculated leachate throughout the waste mass; and (ii) to minimize the emission of odors. The selected trench spacings provide 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 odor control capability of the HIRES is enhanced by the close proximity of each gas extraction trench to a leachate injection trench. 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 must 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 12 m (40 ft) away from the landfill sideslope. This 12-m (40-ft) 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 (but is not included in this paper) 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 trench pairs, as well as the other components of the HIRES, are further described.

3.3.2 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; (v) a landfill gas flare station adjacent to the pump house; and (vi) control systems. Each of these components is described below.

Two leachate recirculation pumps will be located in the Cell 3 pump house. The pumps will draw leachate from the leachate storage tanks that will serve Cell 3 and pump it through a forcemain to a pipe distribution network and then into the leachate injection trenches. The pumps will be variable-speed positive-displacement pumps capable of pumping 23 m^3/hr (100 gpm) against a head of 37 m (120 ft). At this pumping rate, approximately 190 m^3 (50,000 gal.) of leachate, which equals the leachate storage volume of each of the four leach fields, can be pumped to the top of Cell 3 in an 8-hour work day.

The leachate recirculation and landfill gas transmission piping will be installed from the pump house and flare station to the injection/extraction trench pairs. The pipe will be made of HDPE and will contain valves for: (i) controlling to which group of trenches or leach fields the leachate is directed; and (ii) throttling or shutting off the vacuum applied to groups of extraction trenches, as needed. The ability to control individual trenches rather than groups is an option that may be added to the system in the future.

The leachate injection and landfill gas extraction trenches will contain thick-walled, perforated HDPE pipe and coarse crushed stone. The pipe wall thickness is designed to resist crushing throughout the life of landfill. HDPE will be used because of its resistance to corrosion and degradation. Coarse crushed stone (i.e., 50 to 75 mm (2 to 3 in.) 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 near the top of Cell 3. Leach fields, rather than injection trenches, will be used on top of the landfill because a much greater volume of leachate can be recirculated with leach fields than with injection trenches; leachate recirculation volume estimates are presented in Section 3.3.3. Each leach field will be 34 m by 23 m (110 ft by 75 ft) in size and will contain 23 rows of infiltrator units in a bed of crushed stone. A partial cross section of a leach field is shown in Figure 2. The four leach fields will cover approximately one-third of the top area of the landfill.

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

The control systems for the HIRES will consist of an automatic control system for the leachate recirculation pumps and optional wellheads at every gas extraction trench. The pump control system will allow the pump to be activated by a timer and will allow the rate and duration of pumping to be programmed so that a desired volume of leachate can be recirculated at a selected time to a selected location. The optional wellheads would provide the capability to monitor and control the flow of gas from each extraction trench. If the wellheads are not installed, gas flow will be controlled for groups of trenches by valves in the transmission piping network. This moderate level of control and monitoring capability was selected to balance the cost of the system with the monitoring and control needed to optimize its performance, as discussed in Section 3.4.

3.3.3 Expected System Performance

In this section, the expected performance of the HIRES, based on design calculations, is described. The performance of the following two functions of the HIRES is addressed: (i) leachate injection; and (ii) landfill gas extraction.

The expected performance of the leachate injection components of the HIRES can only be approximated because of the large variability in the expected rate of infiltration of leachate into the heterogenous waste mass. In addition to having 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 0.2 to 10 m^3/yr per meter of trench (16 to 880 gal/yr/ft). The total volume of leachate that can be recirculated in one year under hydrostatic conditions is estimated to range from 1,500 to 30,000 m^3/yr (0.4 to 7.8 million gal/yr) for the injection trenches, and from 7,500 to 60,000 m^3/yr (2 to 16 million gal/yr) for the four leach fields. However, the injection trenches are designed to be operated under pressure to increase the rate of recirculation. Prior to closure, it is estimated that Cell 3 will generate approximately 25,000 m^3/yr (6.5 million gal/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.

The landfill gas extraction components of the HIRES are designed to provide efficient gas collection. Calculations regarding landfill gas generation rates, radius of influence of landfill gas extraction trenches, head loss and flow velocity in landfill gas transmission piping, and expected condensate volumes were performed to design these components. 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.

3.4 System Operation

3.4.1 Overview

The success of the HIRES will depend upon the manner in which the system is operated. Although the operation of the gas extraction components of the HIRES will vary little from that of other typical landfill gas management systems, 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.

3.4.2 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 organic 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.

3.4.3 Operational Suggestions

The following operational practices are recommended.

- To increase the ability to monitor the operation of the system, leachate should be recirculated to only one group of trenches or one leach field at a time. To enable this, the system should be equipped with manually-operated control valves.
- When pumping leachate to a group of trenches, pumping should continue until the flow rate decreases significantly, indicating a buildup of pressure in the system. The pressurization of the trenches will increase the volume of waste that is wetted by each trench, 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.

3.4.4 Monitoring

Monitoring is required to determine whether or not effective operation of the leachate recirculation system is being achieved. The parameters most directly related to operational effectiveness are the quality and composition of the landfill gas and the pH (or volatile acids content) of the leachate. A decrease in the quantity of landfill gas extracted or 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. 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.

3.4.5 Gas Extraction

The operation of the gas extraction components should follow well-established procedures for typical landfill gas 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 be adjusted in the field) to the extraction trenches that is compatible with the resistance to air infiltration over the trenches. It is recommended that no vacuum be applied to the trenches until at least one 3-m (10-ft) thick lift of waste has been placed over them. As the overlying fill thickness increases, the vacuum applied to the trenches can be increased as well. If air infiltration is a serious problem, the system can be operated passively until more waste is placed over the trenches. The operation of the flare station (where the gas is combusted) is intended to be continuous and automatic; accordingly, no operation activities are required under usual circumstances.

4. SUMMARY AND CONCLUSIONS

DSWA employs leachate recirculation at its landfills as an in-situ leachate treatment method and to accelerate waste stabilization, thereby reducing costs and the long-term pollution potential of the waste. Evidence for the effectiveness of leachate recirculation for accomplishing these objectives has been presented in this paper. In association with recirculation of leachate, DSWA has experienced the problems of increased odor generation and interference with landfill operations. To provide the benefits of leachate recirculation, while reducing attendant problems, the authors designed an integrated leachate and landfill gas management system that uses leachate injection/landfill gas extraction trench pairs.

The significant features of the system are: (i) the injection/extraction trench pairs; (ii) the coordination of waste filling and HIRES construction sequences; and (iii) the ability to monitor and control the system to optimize its performance. The close proximity of the injection and extraction trenches is expected to effectively control odor problems, while the distribution of trenches throughout the waste mass should provide more uniform wetting of the waste. The phased construction of the system in coordination with a detailed filling sequence plan is expected to minimize interference with landfill operation. Careful attention to the operation of the system 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 for Cell 3 at the SSWMC is expected to provide greater environmental protection and a lower cost for leachate treatment and post-closure care than with other landfill management options without interfering with landfill operations.

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