Bioreactor Landfill Design

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• Modern landfill design entails many elements
  – Foundations
  – Liner systems
  – Leachate collection systems
  – Stormwater control systems
  – Slope stability considerations
  – Leachate management systems
  – Gas extraction systems
  – Capping and closure
Bioreactor Landfill Design

• The use of bioreactor technology at landfills can impact all of these phases of design.

• In addition, a design must be provided for the addition of liquids (and perhaps air) into the landfill.
Elements of Leachate Recirculation System Design

• What to recirculate
• How much to recirculate
  – In total
  – Over a given period of time
• Method to recirculate
• Configuration and spacing of recirculation devices
• Develop operating constraints of system
Recirculation Amounts

• How much to recirculate:
  – Typical approach is to add enough liquid to bring the landfilled waste to field capacity.
  – Field capacity is the moisture content that the waste can “hold” under the influence of gravity.
Recirculation Amounts

• How much to recirculate:
  – Initial moisture content: 15-25% (wet wt)
  – Field capacity: 35-45% (wet wt)

• An increase from 20% to 35% in moisture content requires:
  55 gallons per ton
Recirculation Rates

• Large amounts of water are thus required to get the landfill to field capacity
• What rate do you add the leachate? (i.e. how fast can you add the leachate)
• Depends on several issues:
  – Meeting regulatory requirements
  – The ability of the landfill and the devices to accept the liquids
  – Limitations on pressure buildup
  – Available liquids supply
  – Operational timeline
  – Minimizing seeps
Impact of Regulations on Determining Recirculation Rates

• Primary regulatory controlling factor: the requirement to meet less than one foot of head on the liner.

• For as-built landfills, the leachate collection system can be designed to handle the leachate recirculation rate you need (closer spacings, use of geonets)

• For retrofit landfills, the rate of leachate recirculation may be limited by the existing design.
Impact of Regulations on Determining Recirculation Rates

• Assessing impact of leachate recirculation on head on the liner.
• Predict head assuming that the leachate recirculation rate is equal to the impingement rate into the LCS.
• Perform the HELP model.
Impact of Regulations on Determining Recirculation Rates

• Using the HELP model to predict head on the liner:
  – HELP has a feature to recirculate a percentage of the leachate collected in one layer back to another layer
  – HELP also allows the addition of a constant “sub-surface” inflow into particular layers
  – HELP is limited when it comes to complicated recirculation scenarios
Impact of Regulations on Determining Recirculation Rates

• Other complicating factors:
• How do you account for all of the existing moisture storage capacity in the landfill?
• How do you account for the possible clogging in the leachate collection system?
Ability of Waste and Devices to Accept Leachate

• It is important to remember that compacted waste is not very permeable, and the recirculation rate might be limited by the waste and the device.

• Examples:
  – Infiltration ponds at ACSWL: 3,000 – 5,000 gallons per acre-day
  – Injection lines at ACSWL: 0.005 gpm per ft of injection line per ft of pressure head
Other Factors Affecting Leachate Recirculation Rate

– Limitations on pressure buildup (slope stability concerns?)
– Available liquids supply
– Operational timeline
– Minimizing seeps
Sizing and Spacing of Devices

• The sizing and spacing of devices is somewhat limited by the lack of data regarding moisture distribution in operating bioreactor landfills.

• Methods are available to be estimate the distribution of liquids in landfills.
  – Analytical solutions
  – Numerical modeling
Development of Operating Constraints

• Operating constraints that should be considered include:
  • Pressures and leachate depths
  • Amount of time any one device is operated
  • Rotation among devices
Liquids Addition Methods

• How do you get the liquids in?

• Leachate recirculation systems
  – Surface Systems vs Subsurface Systems
  – Retrofit vs As-built
Liquids Addition Method

- The method used will depend on several items:
  - Current condition of landfill (new? completed?)
  - Sources of liquids
  - Goals of the owner/operator
  - Available equipment
  - Cost
  - Interference with landfill operations
  - Regulatory concerns
As-Built vs Retrofit

As-Built
- Surface application methods as waste is filled up. Focus on working face.
- **Horizontal trenches** buried in the landfill as waste is deposited.
- Surface systems when complete.

Retrofit
- Surface systems on completed waste fill.
- **Vertical wells.**
- Shallow subsurface horizontal trenches.
Leachate Recirculation Methods

- Leachate (or other liquids) can be added to the waste in a variety of methods.
- **Surface application**
  - Systems prior to capping
  - Systems after caps have been in place
- **Subsurface application**
  - Horizontal trenches or galleries
  - Vertical wells
  - Combination systems
Methods of Surface Application of Leachate

Direct Wetting of the Working Face

• Leachate can be sprayed or pumped onto the waste as it is tipped and compacted.
• Provides good means of moisture distribution.
• Potential concerns:
  – Working conditions
  – Exposure to workers
  – Runoff
Methods of Surface Application of Leachate

**Spray or Drip Irrigation**

- Leachate can be dripped or sprayed onto the waste or an area of daily or intermediate cover.
- Depending on weather conditions, spray irrigation provides a means of achieving large evaporation rates. This may be counterproductive depending on the needs of the landfill.
- Potential concerns:
  - Exposure to workers (spray)
  - Runoff
  - Recirculation limited to dry weather
Methods of Surface Application of Leachate

**Infiltration Ponds**

- An area can be excavated or bermed off and leachate can be ponded.
- Provides an easy method for attaining good moisture distribution (in area under ponds).
- Potential concerns:
  - When evaporation and infiltration are less than rainfall and runoff, water accumulates.
  - Floating waste.
  - Interference with operations.
Methods of Surface Application of Leachate

• Leach Fields
Methods of Surface Application of Leachate

• Trenches
Methods of Subsurface Application of Leachate

- Subsurface methods are often preferred because:
  - The allow moisture distribution within the waste.
  - Leachate can be added under pressure to achieve better distribution.
  - They can be operated under wet weather conditions.
Subsurface Methods

- Vertical Injection Wells
- Horizontal Trenches
- Buried Infiltration Galleries
Focus on Two Subsurface Methods

• Horizontal Trenches
  – Shallow systems
  – Deep systems

• Vertical Injection Wells
  – Large diameter systems
  – Small diameter systems
Shallow Horizontal Trenches

1. Existing Landfill at Grade

Existing Landfill at Grade

**MSW**

Liner and Leachate Collection System

50+ ft
2. Excavate Trench and Install Bedding and Pipe

Shallow Horizontal Trenches

MSW

Liner and Leachate Collection System

3 - 15 ft
Shallow Horizontal Trenches

3. Backfill

Liner and Leachate Collection System

MSW
4. Additional Trenches

Shallow Horizontal Trenches

MSW

Liner and Leachate Collection System

50 – 200 ft
Shallow Horizontal Trenches

5. Recirculate

MSW

Liner and Leachate Collection System
Shallow Horizontal Trenches

5. Recirculate

MSW

Liner and Leachate Collection System
1. Install Horizontal Trenches on Lower Lifts
Deep Horizontal Trenches

2. Continue Installing

Liner and Leachate Collection System
Deep Horizontal Trenches

3. Continue Installing

Liner and Leachate Collection System
Deep Horizontal Trenches

4. Recirculate Leachate

Liner and Leachate Collection System
Deep Horizontal Trenches

4. Recirculate Leachate
Materials of Construction

• Preferred piping material is HDPE
• Typical pipe size is 3 to 4 inches (perhaps larger if gas collection is desired)
• Typical trench width is 3 to 5 ft
• Typical hole diameter (3/8 – ¾ inch)
• Bedding materials:
  – Chipped tires
  – Stone
  – Other? (crushed brick, crushed glass)
  – None?
Construction Issues

• Where do you construct the pipe?
• Issues from excavation of waste
  – Odors
  – Exposed garbage
  – Disruption of operations
• Who performs the construction?
• Where do you stop perforations?
• How can you minimize future seepage?
• How do you connect pipe up in the future?
• When a landfill is retrofitted with horizontal trenches, multiple trenches are constructed at one depth across the landfill

• The trenches are buried as deep as possible so they may be operated under pressure without risk of surface seeps
Installation of deep horizontal trench and piping at retrofit bioreactor landfill
As-Built System
• As-built systems: Liquid addition devices are installed in the waste as the landfill is filled up.
Exploring Crushed Glass as a Drainage Media
Clay plug.
Vertical Injection Wells

• Two major types
  – Large diameter wells
  – Small diameter wells
• Many of the early leachate recirculation attempts used large diameter wells
• Most new designs use small diameter wells
Potential Disadvantage of Vertical Wells

- The greatest hydraulic pressure will be at the bottom of the well.
- This might result in more leachate distribution on the bottom of the landfill.
Vertical Injection Cluster Wells

Use multiple small diameter wells.

Since more wells are needed, installation must not be cost prohibitive.
Installation of Small Diameter Recirculation Wells: Direct Push Technology
Installation of Small Diameter Recirculation Wells: Open Flight Auger
Review of Bioreactor Landfill Design Elements

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• Leachate recirculation system
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Slope stability concerns

Landfill Gas Well

LCRS
Liner
Slope stability concerns

Landfill Gas Well

LCRS

Liner
Slope stability concerns

Landfill Gas Well

LCRS

Liner
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Gas Generation is Enhanced

![Graph showing gas generation over time for bioreactor landfill and traditional landfill. Bioreactor landfill shows an initial increase in gas generation, followed by a decline, while traditional landfill shows a steady increase.]
Traditional Gas Collection Systems at Landfills

• Vertical gas wells are most common method of gas collection
Problems Encountered in Wet Landfills

• Wet landfills, either bioreactors or ones that have received large amounts of rainfall, sometimes have problems with gas collection.
Vertical Wells Flood

• Leachate in a landfill will migrate to the path of least resistance.

• A zone of leachate penetrated by a vertical hole may drain into the holes.

• Gas moving in the direction of the hole may bring leachate with it.
Collection from Recirculation Devices is Difficult

• It is may be very difficult to collect gas from leachate recirculation devices (vertical wells, horizontal trenches).
Important Note

• Gas will flow in the direction of least resistance.

• The path of least resistance is not through saturated waste.
Options for Collecting Gas in Bioreactors

Let’s look at several options for collecting gas from bioreactors

1. Don’t recirculate until after closure
2. Use leachate collection system
3. Let the cap serve as a primary gas collector
4. Smart of use of leachate recirculation devices
Landfill gas generation and flow

- Geomembrane cap
- Vertical gas collection wells
- Horizontal gas collection wells
- Leachate wet well
- Landfill gas pressure
- Leachate collection pipe
- Geomembrane liner
Delay Leachate Recirculation

• One option would be to delay any leachate recirculation until after the landfill has reached final grade.
• Traditional systems (with modifications) can then be used.
• The operating years, however, are often the time when leachate recirculation has been as a leachate management strategy.
Use Leachate Collection System

- The leachate recirculation system can successfully used as a gas collection system.

- The driving force of gas out of the landfill is pressure. If the pressure in the leachate collection system is near atmospheric, gas will migrate in that direction.
Design Considerations

• The landfill should be designed from the beginning with the idea of collecting gas from the leachate collection system
Gas flow
Leachate
clean-out line
To flare
MSW Landfill
Leachate collection pipe
Leachate wet well
Minimum leachate level
Capping Systems for Gas Collection

• Use a cap system with a geomembrane as a gas collector.
  – Composite liner
  – Buried geomembrane
  – Exposed geomembrane
Geomembranes for Gas Collection
Creative Use of Leachate Recirculation Devices

• Use leachate recirculation devices as gas collectors, but don’t count on them as primary collectors.

• Exception: Horizontal trenches on the surface of the landfill.

• Also, use unused recirculation devices as gas collectors to collect gas being produced from other recirculated areas.
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