Veolia’s Bioreactor Landfill Experience

Todd Watermolen
Vice President Engineering & Compliance
Veolia ES Solid Waste, Inc.

Veolia’s World-wide Network of Operating Landfills

- Proactiva – Joint Venture -Veolia Environnement and FCC
Questions? Thank You.

Turning waste into a resource
The objective of the Anaerobic Landfill Bioreactor is to accelerate the anaerobic decomposition of waste by providing optimal conditions for microorganisms. The most important variable is achieving an adequate moisture content.
SWANA Bioreactor Landfill Definition

Any permitted Subtitle D landfill or landfill cell where liquid or air is injected in a controlled fashion into the waste mass in order to accelerate or enhance biostabilization of the waste.
TYPICAL BIOREACTOR LANDFILL
CROSS-SECTION WITH LIQUIDS EXTRACTION
AND ACTIVE GAS EXTRACTION
Typical Bioreactor Landfill with dual purpose liquid distribution and gas collection lines
Excavated Waste Moisture Measurements from Well Drilling
Veolia Greentree Landfill

Site Characteristics

- Fully contained, engineered facility.
- Began operations December 1986.
- Total permitted volume = 24,179,800 cubic meters with 16,644,300 M³ of waste in place.
- Waste characteristics >95% MSW.
Veolia Greentree Landfill

Site Characteristics

- Total permitted waste footprint 936 hectares.
- Current Landfill Gas Management 9,000 M³ per hour.
- Current leachate generation 315,800 liters per day with on site leachate treatment.

NORTH AMERICA
SOLID WASTE

<table>
<thead>
<tr>
<th>Location</th>
<th>% MSW</th>
<th>Average Metric Tons Per Day</th>
<th>Years Operational</th>
<th>Cap In Place</th>
<th>Volume of Waste in Place (Cubic Meters)</th>
<th>Total Permitted Volume (Cubic Meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site One Zone A w/o Recirculation</td>
<td>73</td>
<td>1052</td>
<td>1986-1995</td>
<td>26 acres with clay soil cap completed in 1993 and 20 acres with geomembrane cap completed in 1996</td>
<td>2,713,405</td>
<td>2,826,559</td>
</tr>
<tr>
<td>Site One Zone B w/o Recirculation</td>
<td>70</td>
<td>1152</td>
<td>1990 to 2004</td>
<td>geomembrane cap on outside slopes completed 2001 and 23.2 Acres with geomembrane cap completed in Dec. 2004</td>
<td>2,924,369</td>
<td>2,924,369</td>
</tr>
<tr>
<td>Site One Zone C with Recirculation</td>
<td>75</td>
<td>1152</td>
<td>1990 to 2004</td>
<td>8.3 acres with geomembrane cap completed in Dec. 2004</td>
<td>1,168,293</td>
<td>1,168,293</td>
</tr>
<tr>
<td>Site Two Cell 1</td>
<td>83</td>
<td>2994</td>
<td>2000 to 2004</td>
<td>Final Cover over area 12.0 Acres with geomembrane cap completed in 2004</td>
<td>1,011,143</td>
<td>1,011,143</td>
</tr>
<tr>
<td>Site Two Cell 2</td>
<td>86</td>
<td>3175</td>
<td>2001 to 2004</td>
<td>Final Cover over area 7.6 Acres with geomembrane cap completed in 2004</td>
<td>786,584</td>
<td>786,584</td>
</tr>
<tr>
<td>Site Two Cell 3</td>
<td>89</td>
<td>3357</td>
<td>2001 to August 2005</td>
<td>Final Cover over area 7.3 Acres with geomembrane cap completed in 2005</td>
<td>725,118</td>
<td>725,118</td>
</tr>
<tr>
<td>Site Two Cell 4</td>
<td>89</td>
<td>3901</td>
<td>2001 to September 2005</td>
<td>Final Cover over area 9.3 Acres with geomembrane cap completed in 2005</td>
<td>1,011,307</td>
<td>1,039,920</td>
</tr>
<tr>
<td>Site Two Cell 5</td>
<td>92</td>
<td>3992</td>
<td>2/18/2006 to present</td>
<td>Intermediate cover and advancing</td>
<td>1,066,798</td>
<td>1,538,708</td>
</tr>
<tr>
<td>Location</td>
<td>No. of Gas Wells</td>
<td>No. of Samples Collected</td>
<td>Average Moisture Content</td>
<td>Average Waste Density</td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------</td>
<td>-----------------</td>
<td>--------------------------</td>
<td>--------------------------</td>
<td>-----------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site One Zone A w/o Recirculation</td>
<td>39</td>
<td>0</td>
<td>28.0</td>
<td>951</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site One Zone B w/o Recirculation</td>
<td>23</td>
<td>13</td>
<td>37.3</td>
<td>1612</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site One Zone C with Recirculation</td>
<td>34</td>
<td>31</td>
<td>29</td>
<td>1755</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site Two Cell 1</td>
<td>15</td>
<td>26</td>
<td>36.6</td>
<td>1818</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site Two Cell 2</td>
<td>11</td>
<td>8</td>
<td>28.6</td>
<td>1554</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site Two Cell 3</td>
<td>13</td>
<td>23</td>
<td>41.0</td>
<td>1605</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site Two Cell 4</td>
<td>12</td>
<td>3</td>
<td>43.2</td>
<td>1794</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site Two Cell 5</td>
<td>17</td>
<td>12</td>
<td>39.6</td>
<td>1480</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site Two Cell 6/7A</td>
<td>14</td>
<td>21</td>
<td>40.6</td>
<td>1690*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site Two Cell 7B/8A</td>
<td>1</td>
<td>3</td>
<td>59.5</td>
<td>1690*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site Two Cell 8B/9A</td>
<td>0</td>
<td>0</td>
<td>ND</td>
<td>1690*</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Density in Cells 6/7A and 7B/8A were calculated using total tons disposed in both cells combined because tons were not separated accurately during disposal of waste.
Veolia ES Greentree Landfill
Leachate Generation and Precipitation

- Annual Leachate Generation
- Annual Precipitation

Year

1999
2000
2001
2002
2003
2004
2005
2006
2007

Annual Leachate Generation (Liters-Millions)

Annual Precipitation (Centimeters)
Veolia ES Greentree Landfill
Expansion Landfill Area – Average Methane Concentration

Total Cells 1-5 Area:
48.1 Acres
19.5 Hectares
Veolia Pine Ridge Landfill - Bahamas

Site Characteristics

— New landfill facility began operating in 2002.

— 300 tons per day, (19 hectares in area). Waste placed over 7 hectares.

— Primarily MSW with significant C&D due to hurricane events.

— Approximately 2.0 meters of annual precipitation with 90% deposited during one forth of the year.
Veolia Pine Ridge Landfill - Bahamas

Site Characteristics

— Fully contained / engineered facility.
— Active gas extraction system initiated 2004.
— Limited leachate treatment options on the island.
— Managing leachate, surface water and landfill gas for bioreactor landfill.
Woodlawn Bioreactor Landfill, New South Wales, Australia

Site Characteristics

— Fully contained, engineered facility.
— Located 250 km southwest of Sydney.
— Began operations in 2004.
— Mine void, 200 meter depth, 25 million cubic meter volume, 41 hectare surface area.
— Residual municipal solid waste stream with approximately 30% moisture content.

Site Characteristics

— 0.4 meters of annual precipitation, semi arid environment.
— On site leachate treatment.
— Phased active gas extraction system.
— Surface water infiltration – acid mine drainage.
— H₂S gas formation concerns.
Gas Collection
Borg El Arab, Alexandria Egypt Landfill Experience

Site Characteristics

— Fully contained, engineered facility.

— Began operations in 2001, 15 year term (contract)

— Total estimated volume = approx. 15,000,000 cubic meters with 2,800,000 M$^3$ of waste in place (BEA)

— Waste characteristics >95% MSW. Very organic (70% OM) moist waste, 40 – 60% moisture content.

— Total waste footprint, 67 hectares

---

(Borg El Arab, Alexandria Egypt Landfill Experience

Site Characteristics

— Current Landfill Gas Management began in 2003 and currently operates at 500 M$^3$ per hour.

(This site is operated as part of a Global Waste Management contract. There are now two LFs; the El Hamman LF was constructed for use in the summer months as the Borg El Arab site is located near the coastline (vacation area). The figures provided only pertain to BEA.)

— Fully contained, engineered facility.

— Began operations in 2001, 15 year term (contract)

— Total estimated volume = approx. 15,000,000 cubic meters with 2,800,000 M$^3$ of waste in place (BEA)

---
### Site Characteristics

- **Waste characteristics >95% MSW.** Very organic (70% OM) moist waste, 40 – 60% moisture content.
- **Total waste footprint,** 67 hectares
- **Current Landfill Gas Management** began in 2003 and currently operates at 500 M$^3$ per hour.
- *(This site is operated as part of a Global Waste Management contract. There are now two LFs; the El Hamman LF was constructed for use in the summer months as the Borg El Arab site is located near the coastline (vacation area). The figures provided only pertain to BEA.)*

| Borg El Arab, Alexandria Egypt Landfill Experience |
|---------------------------------|-----------------|
| **Site Characteristics**        |                  |
| – Current leachate generation approximately **125 M$^3$** per day evacuated from the site to offsite treatment |
| – <0.2 meters precipitation per year, evaporation 0.18 meters per year. |
| – Phased landfill gas collection system. |
| – Progressive vertical wells |
| – Vertical wells |
Borg El Arab, Alexandria Egypt Landfill Experience

Site Characteristics

– Enclosed flare
– Advanced monitoring and data storage system installed for CDM compliance

Leachate Treatment

– Leachate evaporator
– Evaporation ponds
– Transport to WWTP
Laogang Landfill, China

Site Characteristics

- Laogang MSW Landfill Phase 4 is located at the east end of Laogang Town, Nanhui, Shanghai, located approximately 60 km from Shanghai central. It covers an area of 361 hectares. Length is 4200m, width 800m.

- Commenced design and construction: Dec 2003.


- Ownership: Shanghai Government.
Site Characteristics

—Operating entity: Shanghai Municipal Solid Waste Treatment Company, a joint venture between foreign partners (VES & CITIC Pacific) and local partner Shanghai Chengtou. VES brings the design, construction & operational expertise to the Project.

—Concession agreement to the operating entity: Design, construction and operations for 20 years

—Landfilling capacity: 80 million cbm

Site Characteristics

—Current in-take: 6,300 tpd with majority delivered by barges; less than 10% is delivered by trucks from Nanhui District

—Waste is highly organic and very moist

—Large early gas generation at 3000 cm/hr

—Land and space available well after the 20-year contract

—Landfill gas utilization is accomplished with internal combustion engines (2.5 MW currently)
Laogang Landfill, China

Site Characteristics

― Land and space available well after the 20-year contract.

― The landfill treats waste from 11 districts of Shanghai.

― It is the largest municipal waste sanitary landfill in China.

Laogang Landfill – Liner system

Double-lined disposal areas

Full QA/QC
Laogang Landfill - Tipping Area

Waste characteristics:
- >70% organic waste
- High moisture content

Projects in China – Laogang Landfill

Leachate Treatment
- LTP uses Upflow Anaerobic Sludge Bed (UASB) plus SBR biological processes to treat leachate to class 3 standard, plus reduction in ammonia and nitrogen.
- The effluent is discharged to municipal sewage water treatment plant.
- Design capacity 1,500 tpd; ultimate capacity 3,000 tpd.
- Annual rainfall: 1.5m
Macro Data Results on Bioreactor Landfills

Landfill Gas (LFG) is a good indicator of Bioreactivity.

- Landfill gas generation rates increased by a factor of 3 to 10 times.
- Active LFG system installations are extremely time sensitive due to potential fugitive air emissions.

Macro Data Results of Bioreactor Landfilling

**Waste Characteristics**

- Initial MSW moisture contents are highly variable with ranges from 15% to 40% typical.
- MSW moisture contents increased over time and with depth based on insitu measurements.
- Density increases of 20 to 30% have been recorded where bioreactor activities have been performed over a five year time period.
All Bioreactor Landfill sites are unique

— Must have engineered containment.

— Waste characteristics must have large amounts of organics.

— Hydrologic conditions (rainfall) and moisture management are a key operating factor.

— Economies of scale play an important role in Industrial / Commercial viability of landfill gas utilization (produce 100% to 500% more gas, what can be done to utilize this energy?)

— On site geology and soils (ability to control infiltration).

— Short term and long term landfill gas control is key to good operational controls.