Florida Bioreactor Landfill Demonstration Project

Executive Summary

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Presented to the:
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Bureau of Solid and Hazardous Waste

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1. Introduction

Management of municipal solid waste (MSW) is an important issue around the world. Landfilling is the most common MSW management option in the United States. MSW management in Florida reflects that of the nation. The amount of Florida MSW generated was approximately 34 million tons in 2006 and about 65 percent was managed by landfilling. Landfilled waste produces landfill gas and leachate, a liquid that drains from a landfill. Inappropriate management of leachate and landfill gas can pose a threat to human health and the environment. For these reasons, landfill owners manage leachate, landfill gas, and monitor groundwater for years after landfill closure.

The traditional landfill is commonly referred to as a "dry tomb" landfill because it is primarily designed to store MSW and to minimize water contact with the waste. As a result, waste decomposition or stabilization occurs very slowly. In contrast to dry tomb landfills, bioreactor landfills aim to enhance and accelerate biodegradation of landfilled waste by providing better conditions for microorganisms. A bioreactor landfill enhances microbiological processes to transform and stabilize the readily and moderately decomposable organic waste constituents in a shorter period of time (typically 5 to 10 years) in comparison to a conventional landfill (typically 30 to 50 years, or more). One of the primary features of a bioreactor landfill is the recirculation of landfill leachate or other liquids. Another feature of a bioreactor landfill that has been studied for the acceleration of waste decomposition and landfill stabilization is the addition of air. The injection of air, and thus oxygen, promotes the aerobic stabilization of the landfilled waste. This is the same process that decomposes waste in a traditional compost system.

Operating a landfill as a bioreactor may offer several potential benefits over a conventional landfill. The primary advantage is accelerated waste stabilization, making bioreactor operation a more sustainable waste management option. Also, using leachate recirculation for moisture addition may offer considerable costs savings on leachate treatment. At sites where leachate treatment is not expensive, this advantage may be less. At sites with limited leachate management options, the savings could be substantial. It has been reported that there is a 15 to 30 percent gain in landfill space when landfilled waste becomes stabilized. If the landfill operators utilize this air space gain, then increased revenue can be substantial. In bioreactor landfills, gas generation rates during the early years are much higher than in conventional landfills, therefore landfill gas can be recovered over a shorter period of time and therefore more economically.

While the solid waste management profession has recognized the strong potential benefits offered by bioreactor landfill operation compared to conventional dry tomb landfilling, wide-scale bioreactor implementation has been limited by a lack of standardized design and operational procedures and guidelines. The Florida Bioreactor Demonstration Project approached this problem by working with several landfill operators in Florida to implement the technology so that researchers from the State University System could gather critical data at full-scale operating levels and provide needed guidance for future implementation.

Landfilling Municipal solid waste (MSW) in an active cell at New River Regional Landfill

2. Primary Goal and Objectives

As bioreactor landfills are becoming more common for disposal of municipal solid waste, there is greater demand for research on design parameters, technologies for monitoring and controlling the bioreactor, and quantifying the costs and benefits. The primary goal of the Florida Bioreactor Demonstration Project project is:

The design, construction, operation, and monitoring of a full-scale landfill bioreactor in Florida in a manner that permits a complete and fair evaluation of this technology as a method of solid waste management, with appropriate consideration of science, engineering, environmental, and economic issues.

The Florida Department of Environmental Protection (FDEP) awarded a grant to the Florida Center for Solid and Hazardous Waste Management (now the Hinkley Center) to conduct the demonstration of full-scale landfill bioreactor technology in Florida. The demonstration project was managed by the Hinkley for Solid and Hazardous Waste Management in accordance with a Work Plan as required by the FDEP grant award, and involved participation of the University of Florida and the University of Central Florida.

Research conducted for this project was performed at a number of landfill sites in cooperation with their respective owners and operators. The sites included: the New River Regional Landfill (NRRL) in Union County, owned and operated by the New River Solid Waste Association; the Tomoka Farms Road Landfill (TFRL), operated by Volusia County; the Polk County North Central Landfill (PCNCL), operated by Polk County; Alachua County Southwest Landfill (ACSWL), operated by Alachua County; and Highlands County Landfill (HCL), operated by Highlands County. The FDEP selected the NRRL, as the site to conduct the full-scale landfill bioreactor demonstration project and compare both aerobic and anaerobic waste decomposition processes.

3. Innovative Concepts and Techniques

In the Florida Bioreactor Demonstration Project, a number of innovative concepts and techniques were introduced to design, operate, and monitor the bioreactor landfill. The research teams were successfully compliant to FDEP and Permit regulations during construction and operation of the bioreactor. Some innovative concepts of the NRRL bioreactor are: 1) clustered vertical wells, 2) integrated landfill gas collection system, 3) segregated leachate collection manholes, 4) instrumentation with innovative technology installed for monitoring the bioreactor processes. The installation of pressure transducers, total earth pressure cells, moisture sensors, thermocouple wires, and piezometers

Specific Objectives of the project

1. Design and operate a bioreactor using innovative techniques and concepts.
2. Design and operate a bioreactor in at least one site in such a manner as to enable the control and measure all major inputs and outputs.
3. Evaluate the use of aerobic bioreactor landfill technology and compare the aerobic approach to the use of anaerobic bioreactor technology in at least one site.
4. Instrument the landfills to permit in-situ monitoring of bioreactor activity and to measure previously unmeasured information (e.g. leachate head on the liner effectiveness).
5. Monitor the landfills in a manner that allows the measurement and impact of bioreactor activities and to allow control of the waste treatment process (e.g. leachate and gas composition and generation, waste characteristics, and settlement).
6. Collect data through instrumentation, field monitoring, and laboratory analysis that will enable the project team to assess the success of the project, the feasibility of this technology for other sites, and the future design and operation of landfill bioreactors in Florida.
7. Develop standardized design and operation procedures.
8. Further define and quantify the true costs and benefits of landfill bioreactors.
9. Provide a resource and training ground for students in the State University System, landfill operators, and engineers.

Vertical wells were drilled at the New River bioreactor. Small diameter pipes (PVC; 2 inches in diameter) were placed into holes constructed with an open-flight rotary auger (4.5 inches in diameter).

The New River bioreactor was constructed with an exposed geomembrane cap. This proved to be a good method to contain side slope seeps. It also became an integral part of the gas collection system.

are in-situ, and collected the bioreactor's responses by waste placement, moisture addition, and aeration. The construction of the NRRL bioreactor landfill began in 2001. One hundred thirty-four vertical wells, grouped into 45 clusters were installed. Each cluster consists of three wells with depths of 20, 40, and 60 feet, respectively. Part of the bioreactor was configured to add air to the waste on a controlled basis. Moisture addition into the bioreactor was initiated in 2003 and air injection experiment started in 2004. Cell 1 and Cell 2 at NRRL had been operated as bioreactors until February 2008. In addition, studies of bioreactor landfill technologies using lysimeters in UF laboratories and at landfill sites were conducted. These lab scale bioreactor studies provided on understanding of the impact of variable bioreactor activities.

Knowing flow rate-pressure relationship is necessary to design a bioreactor. This photo shows monitoring injection rate and injection pressure.

Different techniques to measure the performance of the bioreactor and the progress toward the waste stabilization were used in the project. Monitoring plan of the NRRL bioreactor was provided on the permit, including major inputs and outputs of the bioreactor. The major inputs of the bioreactor at NRRL include the amount of moisture added and air injected. The major outputs in the operation of the bioreactor landfills are quality and quantity of gas and leachate generated, moisture content, temperature of the waste, and vertical settlement of the landfill. The research teams studied the impact of bioreactor activities on leachate quality and waste stabilization using the outputs.

Major input parameters for the operation of a bioreactor

- Moisture addition (About 6.28 million gallons of liquid added in the anaerobic area of the NRRL bioreactor).
- Air addition (About 51 million cubic feet of air was injected in the aerobic area of the NRRL bioreactor).

Major output parameters for the operation of a bioreactor

- Leachate production and quality.
- Landfill gas production and quality.
- Data from in-situ sensors (moisture levels, temperature, head on liner, pore water pressure, and total earth pressure).
- Settlement of the bioreactor.

4. Summary of Major Accomplishments

Performance of Instruments

The research conducted has shown some limitations of various sensors and has produced recommendations for the modification of instruments to make them more adaptable for use in bioreactor landfills.

Pressure transducers worked properly for a period of time. However, over the course of the experimental

work, they eventually failed to provide reliable data for measuring head on liner. Likely, the failure of the pressure transducers was due to frequent lightning strikes near the data logger station, overburdened pressure due to waste placement above the sensors, marine grease applied to the sensors to prohibit biological growth, and/or improper orientation of the sensors when they were installed.

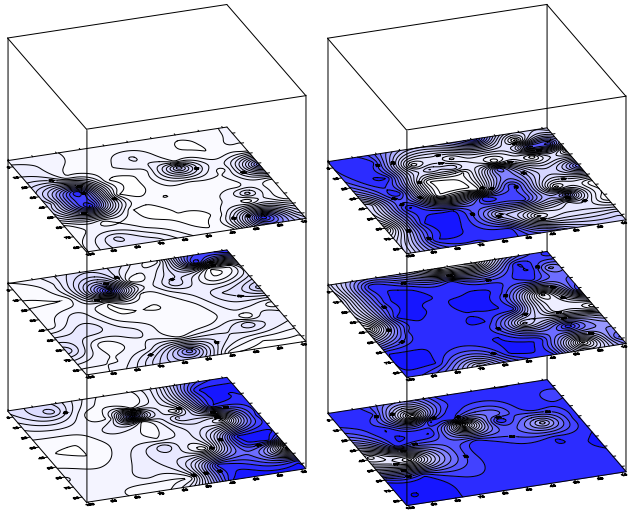
Total earth pressure cells demonstrated incremental pressure increase as a result of lift placement, which was expected. Overburdened pressure measured was found to be on an average, 50% less than the calculated overburdened pressure based on waste height and density. This was attributed to factors such as arching, susceptibility to point loads, and possible pressure cell malfunction. This observation is now being examined further at the Polk County North Central bioreactor.

In-situ instrumentation techniques were employed for the NRRL bioreactor. Data collected from the sensors were analyzed to measure the performance of the bioreactor.

Two different types of moisture sensors were used: an electrical resistance sensor referred to as MTG; and time domain reflectometry (TDR). The simultaneous increase in the moisture content by TDR and MTG sensors installed at the NRRL bioreactor gave an indication that both technologies were capable of measuring the changes of moisture level in the landfill. However, the absolute values of the data indicated that there is some difference between the two measurement technologies while reading the absolute moisture content. Due to the high manufacturing cost of TDR sensors, this technology could be limited in its application to bioreactor landfills where there is a need to measure moisture contents at multiple locations.

During the air injection experiment, temperature of landfilled waste and air flow rate per well were monitored. If the temperature approached a limit, air flow rate was reduced.

The overall temperature of the waste inside the landfill increased in areas where a significant amount of air was added. Temperature in the shallow layer was readily affected by air injection of adjacent injection wells. Rapid temperature rises halted air addition due to the risk of sub-surface fires. Field trials of air addition at NRRL indicated that it was very difficult to control temperature by changing the rate of air addition. The results from NRRL also indicated that it was



Data from in-situ instrumentation were used to visualize the status inside the landfill. The figures above show moisture levels with different depths before (left) and after (right) operating the bioreactor.

difficult to add air in areas that were deep or wet. These observations suggest that aerobic treatment of large landfills are likely to be problematic.

Leachate and Landfill Gas Generation

Leachate quality using simulated bioreactor lysimeters show rapid degradation of biodegradable pollutants in leachate, particularly by operating aerobic bioreactors. Leachate quality was determined by measuring water quality parameters such as pH, chemical oxygen demand (COD), biochemical oxygen demand (BOD), total organic carbon (TOC), ions, and metals. Leachate quality varied with time and by conditions (aerobic and anaerobic). For example, ammonia concentration increased over time in the anaerobic lysimeters but did not increase in the aerobic lysimeters. Similar results were observed by long-term leachate quality monitoring at the Alachua bioreactor and the Polk bioreactor that were operated anaerobically. These results indicates that non-biodegradable and persistent leachate constituents were accumulated over time while biodegradable constituents decreased.

Performance of the bioreactor operation was verified by drilling and sampling landfilled waste. The samples were collected from different areas and depths and were examine for moisture content and degree of biodegradation.

By operating the bioreactor landfills anaerobically, methane generation rate rapidly increased with moisture addition. However, rapid vertical settlement of the landfill required great maintenance efforts for the gas collection system.

Air addition in the bioreactor landfill affected not only methane and oxygen compositions in the landfill gas but also trace gas components of the landfill gas. Trace gas components of aerobic exhaust such as volatile organic compounds (VOCs), nitrogen oxide (N_2O), carbon monoxide (CO), and hydrogen sulfide (H_2S) were investigated by comparing their concentration in landfill gas before and during aeration. VOCs and N_2O in aerobic exhaust were not significantly different from those before air injection (in anaerobic condition). However, H_2S concentrations decreased and CO concentrations increased when air injection began.

Waste Stabilization and Settlement

Laboratory studies confirmed that aerobic bioreactor conditions stabilize the waste more rapidly when compared to the anaerobic bioreactor. The same studies also found that leachate quality had improved in aerobic landfills compared with anaerobic landfills. The waste mass losses of aerobic and anaerobic lysimeters were calculated using leachate and gas quality data. Mass lost from the waste was primarily converted into gas. The mass of waste excavated from the lysimeters was compared to the calculated mass loss. A good correlation was found between predicted and actual mass loss obtained from excavation of all lysimeters. At the NRRL bioreactor, a 10 % average settlement was observed. The settlement data from different well depths shows the degree of settlement varied with the depth. The settlement of waste was greater near injection wells. The following major observations were made: (1) waste was well degraded within the 6 years, research period; (2) the moisture content was substantially increased; and (3) substantial settlement was observed because of leachate addition.

5. Training and Education

One of the objectives for the project was to provide a resource and training opportunity for students in the State University System, for landfill operators, and for engineers in Florida. Graduate students from both the University of Florida and the University of Central Florida used research from the project as the major subjects of their theses or dissertations. Other graduate students participated on the project and were given practical and application-oriented experience. The program also provided research experience to many undergraduate students who contributed laboratory and field assistance. Many of the former students are now practicing professionals in the environmental field. The following list provides information on former and current students, along with other personnel, who participated in the Florida Bioreactor Demonstration Project.

To promote training and education of landfill operators and other interested professionals, bioreactor workshops were held in 2004 and in 2006. The workshops included an overview of the design, management, operation and regulations associated with bioreactor

Batarseh, Eyad	Completed his PhD in environmental engineering at UCF and worked on the Florida Bioreactor Demonstration Project, "combined chemical and biological In-situ treatment of mature landfill leachate". At present he is working for CDM as an engineer.
Berge, Nicole	Completed her PhD in environmental engineering at UCF and worked on the Long-Term Treatment and Disposal of Landfill Leachate project. At present she is working as a post doctoral associate in the greater Boston area.
Cho, Youngmin	A graduate student pursuing a Ph.D. degree. He conducts researches at Polk North Central Landfill. His main research interests are horizontal leachate injection performance analysis and waste mechanics in bioreactor landfills
Dhesi, P	Completed his masters' degree at UCF. His research was focused on the study of addition of non-hazardous industrial and municipal wastewater to bioreactor landfills.
Dubey, Brajesh	Completed his PhD and post doc at UF on worked on environmental impacts of CCA treated wood. He is currently working as a faculty member at the University of Auckland.
Faour, A	Completed his masters' degree at UCF. His research was focused on the First-order kinetic gas generation model parameters for wet landfills
Gawande, Nitin	A PhD student and developed the model BIOKEMOD-3P, for simulating solid waste biodegradation. His model is able to simulate the experimental data of anaerobic biodegradation of solid waste in laboratory scale bioreactor. This model is also used to simulate simultaneous nitrification and denitrification processes in laboratory-scale microcosms.
Gou, Vicky	Completed his Masters' degree at UF. His research was focused on the non-methane organic compounds (NMOC) emitted from the decomposition of municipal solid waste (MSW) components.
Jain, Pradeep	Assisted with the construction, operation, and monitoring of the NRRL bioreactor during his PhD at UF. His research on the NRRL bioreactor contributed to a better understanding of the bioreactor. Currently Dr. Jain works for Innovative Waste Consulting Services as a professional engineer.
Jonnalagadda, Sreeram	Worked on the field evaluation of moisture sensors as part of Florida Landfill Bioreactor Demonstration Project. He graduated from the University of Florida in December 2004 and is presently working for SCS Engineers in Tampa, Florida.
Jordan, Aaron Alan	Completed his Masters at UF and worked on assessment of the risk posed by engineered wood products by land-applied mulch and conducted field and laboratory analysis of how effectively quicklime can treat soils contaminated with industrial solvents. He is currently working for HDR
Kadambala, Ravi	Assisted with building the modified vertical well leachate recirculation system of cell 4 at New River for his research. He also is currently assisting NRRL with the maintenance and operation of the bioreactor and perusing his PhD at UF.
Kim, Hwidong	While pursuing his PhD in environmental engineering at UF, he assisted in earth pressure cells and leachate recirculation pipes at the NRRL bioreactor. He started biochemical methane potential (BMP) assay of solid waste samples. He also compared aerobic and anaerobic bioreactor landfills using lab-scale lysimeters for his doctoral dissertation. Dr. Kim is currently working at UF as a postdoc.
Ko, Jae Hac	As a postdoctoral associate at UF, he conducted research at NRRL bioreactor and provide oversight for Polk North Central Landfill and Alachua County Southwest landfill. Dr. Ko continues those efforts as a postdoc.
Kumar, Dinesh	Worked as a post doctoral associate at UF. His conducted some of the air injection and high pressure leachate injection experiments at the NRRL. He is presently working at Delhi Municipal Corporation, India
Kumar, Sendhil	A graduate research assistant at UF, currently carrying out research tasks at the Polk North Central Landfill (NCLF). Also, involved in assisting the operation of the Bioreactor landfill at Polk NCLF.
Larson, Judd Adam	Completed his Masters at UF and worked on Polk County North Central Landfill Bioreactor. His responsibilities have been to make plans for installing the injection lines, researching proper monitoring equipment, and ensuring laboratory as well as field quality assurance and quality control for sample analysis. He is currently working at CDM.
Mcknight, Tobin	Presently working as an engineer at JEA. He completed his masters degree at UF working landfill settlement.
Musson, Stephen	Completed his PhD and worked on several projects including the Florida Bioreactor Demonstration Project and Polk County North Central Landfill Bioreactor. He is currently working as post doctoral associate in Cincinnati.
Powell, Jon	Assisted with the operation, and monitoring of the NRRL bioreactor during his PhD at UF. He is presently working as an engineer at the Innovative waste consulting services. He completed his Masters' degree at UF.

Semiz, Murat	Presently working as an engineer at CDM. He completed his masters degree at UF
Sheridan, Scott	Completed his masters' degree at UF. His research was focused on the Modeling solid waste settlement as a function of mass loss
Singh, Shrawan	A PhD student, working at the Alachua County Southwest Landfill. The focus of his PhD dissertation is to evaluate the effectiveness of various pretreatment methods for treating the stabilized bioreactor landfill leachate by nano filtration and reverse osmosis membrane systems.
Spafford, Mark	Completed his Masters' degree at UF. His work focused on the Performance evaluation of landfill liner systems using pressure transducers.
Spalvins, Erik	Completed his PhD at UF and worked on Simulated Landfill Lysimeters for Evaluating Leachate Quality. He is presently working at the EPA office in Georgia.
Timmons, Jason	Assisted in contraction of the NRRL bioreactor. His UF Masters project report studied the use of earth pressure sensors as a monitoring instrument at landfill. He is currently practicing engineer with Jones Edmonds and Associates in Tampa, FL
Tolaymat, Thabet	While pursuing his PhD in environmental engineering at UF, he installed the first set of leachate recirculation pipes at the Polk County Bioreactor. He provided design support for the NRRL bioreactor. Dr. Tolaymat is now with the US EPA office of Research and Development in Cincinnati where he heads up US EPA's bioreactor research program.
Wadanambi, Lakmini	Completed her Masters degree at UF. Her work focused on the leaching of lead from lead-based paint in landfill environments and leaching of CCA-treated wood.
Xu, Qigong	While pursuing his PhD in environmental engineering at UF. Currently he works for Innovative Waste Consulting Services as a professional engineer.

landfills. Participants visited field sites and observed new technologies in operation. Workshop attendees learned about bioreactor landfills from inception to post-closure. There were a number of participants from throughout the U.S., representing local and state government and industry. Academicians and students also attended. Knowledge on bioreactors attained from the project was shared through these educational activities. To meet the project's objectives, a document "***Bioreactor Landfill Operation: A Guide for Development, Implementation, and Monitoring***" was prepared to provide information useful for landfill operators considering implementing bioreactor technology as well as for those operating bioreactor landfills. The information contained within is based both on lessons learned as part of the Florida Bioreactor Demonstration Project, as well as knowledge and experience of the authors from other projects around the world.