

Waste Tech 2002 - Landfill Conference
Florida Bioreactor Demonstration Project - Instrumentation

Dr. Debra R. Reinhart, PE
Nicole Berge
University of Central Florida
PO Box 162993
Orlando, Florida 32816-2993
407 823 2156
reinhart@mail.ucf.edu

Dr. Timothy G. Townsend
Jason Timmons
Department of Environmental Engineering Science
320 Black Hall
University of Florida
Gainesville, Florida 32611
(352) 392-0846
Fax (352) 392-3076
ttown@eng.ufl.edu

Dr. Philip McCreanor
School of Engineering
1400 Coleman Ave
Mercer University
Macon, GA 31207-0001
(478) 301-2044
Fax (478) 301-2166
mccreanor_pt@mercer.edu

Abstract

The New River Regional Landfill (NRRL) in north Florida is hosting a Florida Bioreactor demonstration project. The primary goal of the landfill bioreactor demonstration project is to design, construct, operate, and monitor 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 in Florida, with appropriate consideration of science, engineering, environmental and economic issues.

The demonstration will include recirculation of leachate, injection of air into portions of the landfill, and the ability to monitor gaseous emissions from the bioreactor. The landfill bioreactor has been instrumented for the purpose of collecting in situ measurements of such parameters as leachate head on the liner, waste moisture content, waste load, gas composition, and temperature of the waste. This paper provides a description of in-situ monitoring instrumentation and preliminary results obtained to date.

Introduction

The primary goal in pursuing landfill bioreactor technology is the operation of solid waste landfills in a manner resulting in accelerated stabilization of the waste. Landfill bioreactor operation includes, among other things, the addition of moisture to the solid waste to create an environment favorable for the microorganisms responsible for waste decomposition. This approach differs greatly from the traditional Resource Conservation and Recovery Act (RCRA) Subtitle D approach of managing solid waste landfills in a fashion that discourages waste decomposition by minimizing moisture entrance into the landfill. A primary feature of landfill bioreactor is the recirculation of landfill leachate, or possibly other liquids, to the solid waste. The recirculation of leachate will be a major component of the bioreactor operation in this project. Another feature of a landfill bioreactor that has been proposed for the acceleration of waste decomposition and landfill stabilization is the addition of air. Aerobic stabilization is the same process applied to decomposing waste in a compost system. An evaluation of the use of aerobic processes for the rapid stabilization of landfilled waste will be a major focus of this project. The project will incorporate a system that will allow air and water to be injected and gas to be extracted.

The Florida Bioreactor Demonstration is located at the New River Regional Landfill (NRRL) in north Florida. The NRRL serves sources in five surrounding counties, receiving primarily mixed residential, commercial, and industrial waste. Waste receipt presently averages 800 tons/day. The landfill consists of three contiguous lined cells totaling approximately 26 acres. Cell 1 is equipped with a composite bottom liner consisting of a 60-mil High Density Polyethylene synthetic geomembrane and 36 inches of compacted clay soils overlain by 24 inches of 10^{-3} -cm/sec sand. Cell 2 is provided with a double liner system consisting of a primary leachate collection system overlaying a geomembrane with a leak detection system and geomembrane beneath the primary liner. Cell 3 leachate collection system configuration, starting from the bottom, is compacted clay, geomembrane, biplanar geonet, geomembrane, triplanar geonet, geotextile, and finally a granular drainage media. A fourth cell is currently under construction and duplicates the Cell 3 leachate collection and liner system.

The basic components of the NRRL bioreactor demonstration project include:

- A leachate recirculation system of wells installed in all of Cell 1 and part of Cell 2 (for a total of ten acres),
- Modification of the leachate collection system to allow collection of leachate from distinct areas within the landfill,
- A temporary membrane cap installed on the slopes and the top of the landfill area subjected to treatment,
- A combination air injection and gas extraction system to allow the landfill to be operated both aerobically and anaerobically (all gas emissions will be collected and characterized), and
- In situ instrumentation to permit monitoring of moisture content, temperature, gas composition, and leachate and gas flowrates; landfill surface profiling to evaluate settlement; and parallel studies to investigate head on the liner and pressure at the liner due to overlying wastes.

This paper presents a description of the installation and operation of landfill instrumentation utilized as part of this demonstration.

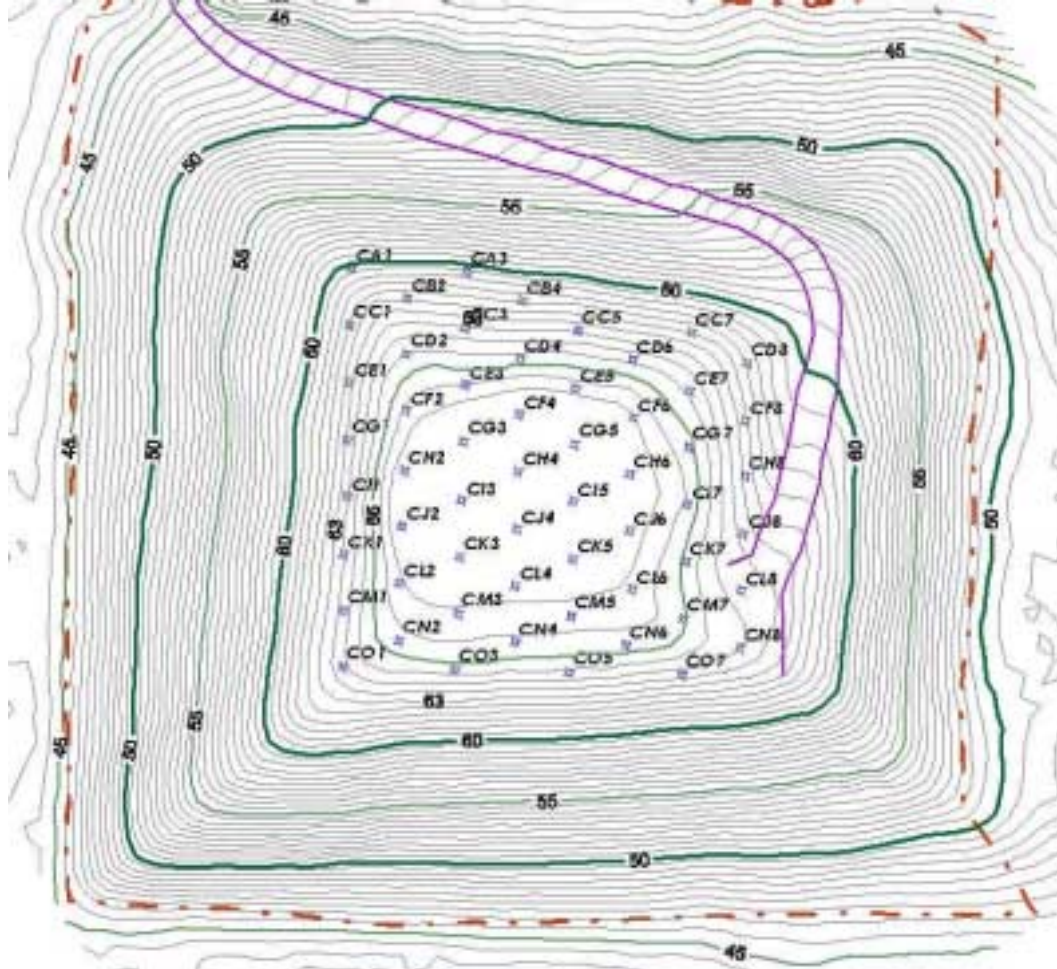
Moisture, Temperature, and Gas Sensors

In situ bioreactor conditions will be monitored using probes placed in monitoring wells located between injection wells. The moisture/temperature/gas (MTG) sampling sensors are approximately 8 in. in total length with a maximum diameter of approximately 2.75 in. at the end cap. Type-T thermocouple wire was used. Gas is sampled through a ¼ in. ID (3/8-in. OD) rigid wall tube brought to the surface. Moisture and temperature measurements will be accessed with a 1/8-in. diameter, four-conductor shielded cable. A more complete description of the moisture sensor is provided in a following section.

Sensors and leachate/air injection wells were installed using a CME 85 rig to drill 4-in. open flight auger holes. Two-in schedule 40 PVC injection wells were installed in clusters of three, reaching approximately 20, 40 and 60 feet. The monitoring wells were drilled to similar depths and a MTG probe placed at the bottom of each well. Eighty-seven cluster wells were drilled for a total of 268 wells. Forty-five injection well clusters were drilled for a total of 135 wells. The monitoring wells consisted of 42 clusters for a total of 133 wells. Figure 1 provides well locations.

Sensor leads and gas-sampling tubes were bundled and passed through a 3-in. diameter pipe. The pipe slides over the cables and part way into the shaft. Approximately one foot of pipe was left protruding above the landfill surface. The shaft was then backfilled with sand and bentonite. A boot will seal the protruding pipe section to the landfill cap.

Data will be processed using dataloggers and multiplexers and delivered to on-site computers. Data have been collected from the sensor packs in order to establish baseline conditions prior to leachate recirculation. Temperature data presented in Figure 2 suggest



that biological activity is occurring, with higher temperatures found at the lower depths of the landfill. High methane content (>50%) was also observed at these depths.

Figure 1. Monitoring Well Locations at the NRRL Bioreactor Demonstration Project.

In Situ Moisture Content Instrumentation

Measurement of in situ moisture content remains a challenge because of the heterogeneous nature of landfills and the variability of leachate characteristics. The agricultural sector has in large part been responsible for developing moisture-sensing devices for irrigation monitoring purposes. Some of the technologies that are utilized in soil moisture measurement are the neutron probe, time domain reflectometry (TDR), time domain transmissivity (TDT), and electrical resistance technology. After reviewing the advantages and disadvantages of each, the latter three technologies have been utilized at the NRRL. Because of its low cost (approximately \$25/unit as compared with \$500/TDR unit), the MTG, which is based on electrical resistance technology, is the primary means of monitoring moisture content at the NRRL. However, twelve TDR units have been installed in parallel with MTG sensors for comparison purposes. In addition, TDT units are being evaluated in the laboratory.

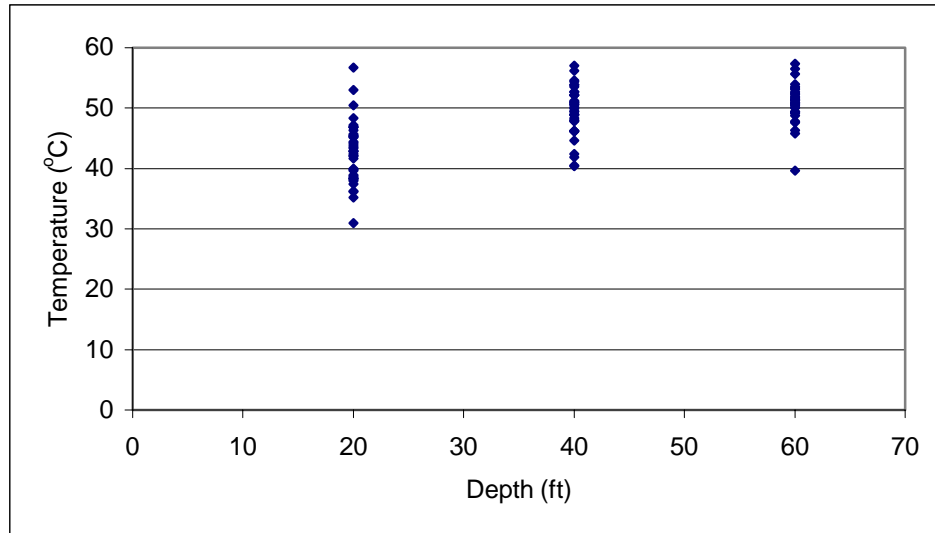


Figure 2. NRRL In Situ Temperature Data as a Function of Depth.

TDR is analogous to the concept of radar where a signal is emitted and the analysis of the reflected signal gives characteristics of the medium or object under examination. With TDR the signal that is emitted is an electromagnetic wave and the physical characteristic that is analyzed by the propagated waves is the relative permittivity or the dielectric constant of the medium. TDR theory states that the time for a transmitted electromagnetic pulse to be reflected is dependent on the relative permittivity or dielectric constant of the medium, a characteristic that can be related to moisture content. TDT is similar to TDR with the exception that the signal is not measured as it is reflected but rather as it transmitted.

Electrical resistance soil moisture sensors are comprised of a pair of electrodes inserted into a porous matrix. The two predominant types of devices (gypsum block and granular matrix sensors) use a soluble salt that serves to insulate the sensor from fluctuations in the salinity of the external environment. For both sensor types the salt that is used is highly soluble calcium sulfate (Gypsum). When inserted into the medium to be measured the sensors come into hydraulic contact with the soil solution, which is absorbed, or released depending on the matric potential gradients set up between the sensor and the surrounding media. Ideally a steady state or equilibrium condition is attained between the sensor and the medium. The absorbed moisture dissolves a portion of the calcium sulfate salt. In this moistened state the sensor consists of a non-conducting matrix, highly resistant air pockets and a relatively conductive liquid. The resistance of the sensor is ultimately a function of the soil water content. Past use of these sensors has shown that once wetted, they tend to remain wet.

For the NRRL, a sensor was built to operate in conjunction with a datalogger to measure the moisture content of the surrounding media. The sensor was designed to measure the electrical resistance of the moisture between two electrodes embedded in a granular insoluble media. The resistance has been found to be inversely proportional to moisture content.

The sensor body is an 8-in section of 2-in. diameter PVC well screen (2 in. ID, 2.375 in. OD) (see Figure 3). A slot size of 1/8 in. was used. Two 4-in thick by 2-in diameter solid PVC plugs were cut for the top and bottom of the sensor. In the bottom plug a 1/8-in diameter hole was drilled 1/4 in deep and a corresponding diameter, fully penetrating hole drilled in the top plug. A small indentation was filed in one of the edges of the top plug to allow access for the mesh wire. A 7.5-in long, 2-in diameter slotted (0.2-in wall thickness) schedule-40 PVC length of pipe was cut. A 6-in by 6.4-in rectangle of market-grade stainless steel mesh (the mesh was sized according to the particle size) was prepared. A short piece of 18-gauge copper wire was soldered onto the long edge of the mesh near the middle. A 7.7-in piece of #6 stainless steel threaded rod was cut. All the PVC fittings were primed. The bottom plug was glued into one end of the PVC slotted pipe. The mesh was inserted into the slotted pipe with the 6-in edge running parallel to the pipe axis and with the copper wire at the top. One end of the #6 rod was dipped in PVC cement and then lightly tapped into the hole in the bottom plug. The rod was centered and the sensor then filled with sand to a height just exceeding that of the mesh. The upper plug was then glued in place. The wire and # 6 rod were attached to electrical connectors serving as the electrodes of the sensor.



Figure 3. MTG Granular Moisture Sensor.

Initial resistance readings show complete saturation in the northwest portion of the bioreactor cell at depths of 45 to 50 ft from the landfill surface as suggested by resistance reading varying from 8 to 35 ohms. The northeast half of the cell is relatively dry. Readings at shallower depths are quite variable.

Roctest TPC Total Pressure Cells

During the summer of 2000, Roctest total pressure cells (TPC) were installed in Cell 3 of the NRRL. The purpose of the TPCs is to measure the loads found on the liner system of an operating landfill during and after waste lift placement. While Cell 3 is outside of the

current bioreactor area, it was felt that data obtained would be helpful in interpreting results of bioreactor operation.

The TPCs are traditionally designed to measure pressures in fills, embankments, piers, culverts and stresses found in concrete structures. The TPCs measure the vertical force exerted on the liner system resulting from waste placed in the landfill. In addition to load measurement, the TPCs are equipped with thermistor units that will yield temperature data at the liner.

The TPCs are constructed of steel with a sealed distribution pad. This pad is composed of two steel plates welded together and filled with degassed oil. The oil-filled distribution pad is connected via a long steel tube to a vibrating wire pressure transducer (see Figure 4). The design of the pad ensures that it is affected exclusively by forces normal to the pad (vertical forces).

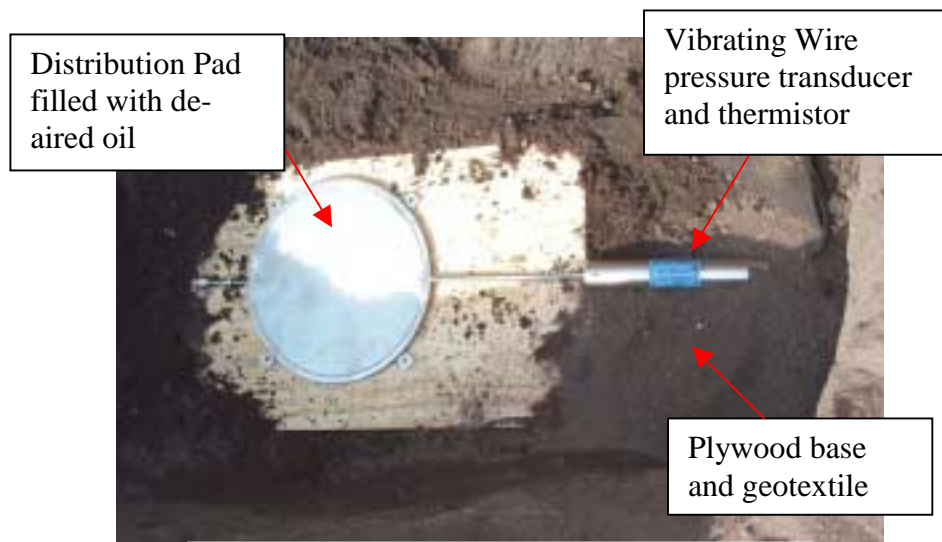


Figure 4. Roctest Total Pressure Cell.

To install the TPCs, the drainage system of the landfill cell was excavated to just above the synthetic drainage material. A plywood board was placed on the drainage material to stabilize the instrument. A reading was recorded before backfilling the excavation. The depth of sand at which the hole was excavated was recorded and the instrument was buried as seen in Figure 5.

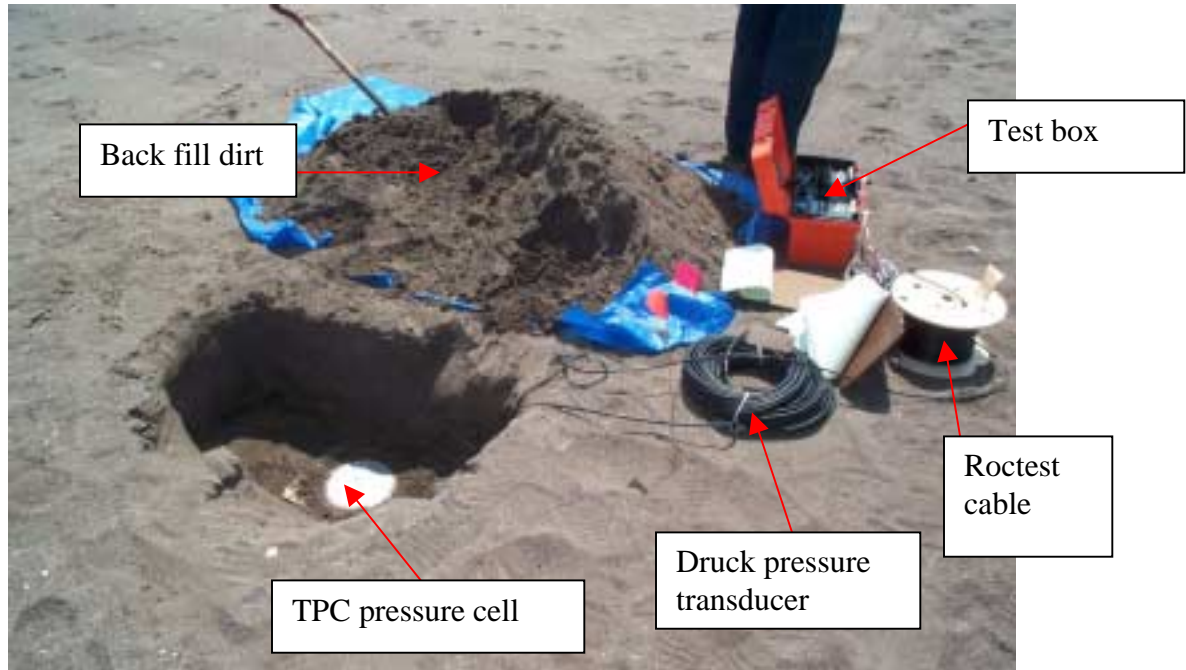


Figure 5. Total Pressure Cell Installation.

Typical results from the TPC are presented in Figure 6. The data clearly demonstrate the incremental pressure step increases that result from lift placement. When coupled with landfill surface measurements obtained using a Global Positioning System unit to evaluate settlement, a highly accurate waste specific weight can be determined.

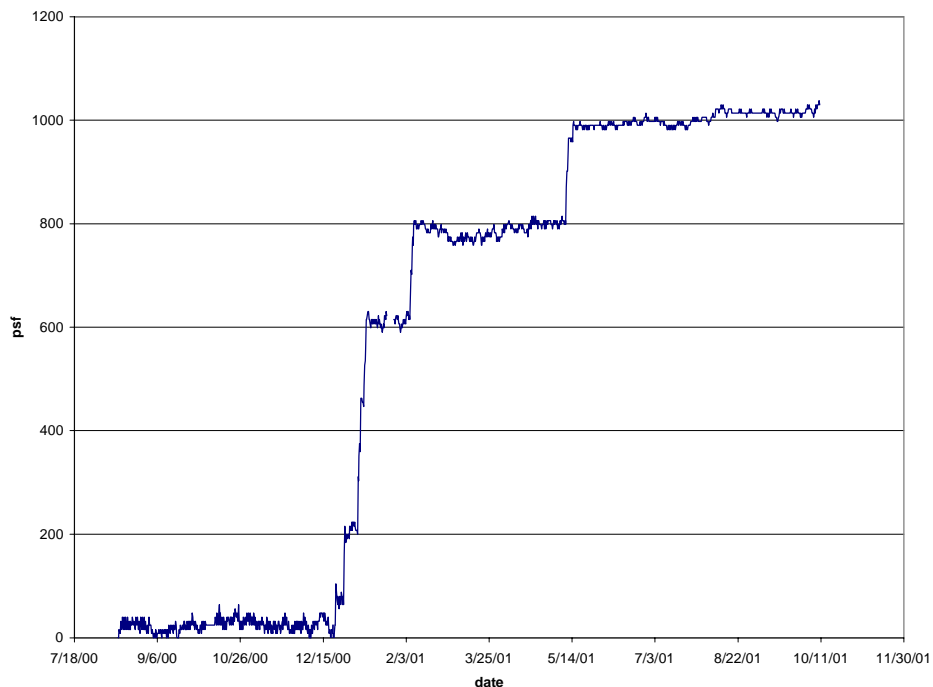


Figure 6. Pressure Measurements Obtained Using the Total Pressure Cell.

Leachate Head on the Liner Monitoring

The depth of leachate on the liner is a primary regulation in the US to protect groundwater and is a major concern for regulators approving bioreactor permits. Control of head on the liner requires the ability to maintain a properly designed leachate collection system, monitor head on the liner, store or dispose of leachate outside of the landfill, and remove leachate at rates two to three times the rate of normal leachate generation. Because the waste within the bioreactor test area had been placed prior to the initiation of this project, it is difficult to monitor this parameter. However, pressure transducers are being evaluated for this purpose in a 100-ft x 100-ft portion of Cell 2 (where waste had not yet been placed), as well as in Cell 3. For Cell 2, a total of 128 transducers was installed in May 1999, equally divided between the KPSI Series 700 and Druck Series 1230 pressure transducers. Cell 3 has 88 Druck pressure transducers, installed in June 2000. Figure 7 shows the placement of the pressure transducers on the liner.

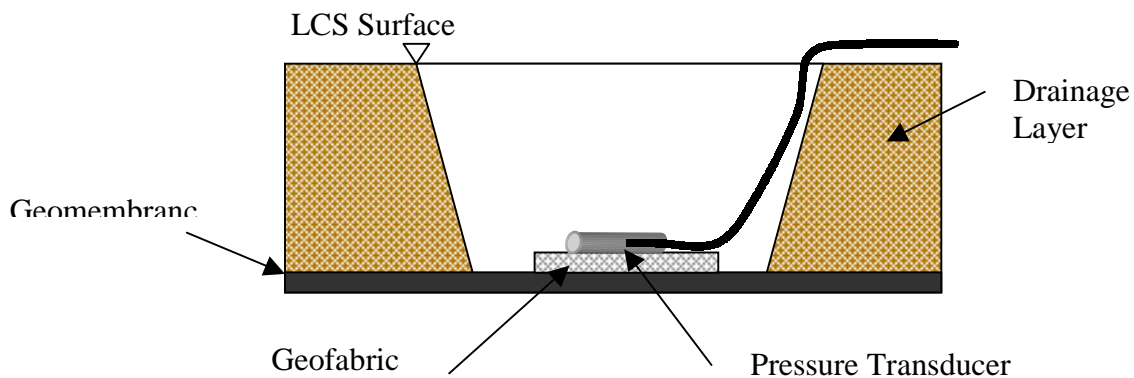


Figure 7. Installation of Pressure Transducers on the NRRL Liner.

Transducers are provided with a watertight and submersible connection between the cable and the body. Pressure measurements are taken using a standard differential voltage signal calibrated over a gage pressure range of 0 to 5 feet and an excitation voltage of 2.5 volts. The cables from each transducer run outside of the landfill area and connect to a datalogger and relay multiplexer. The datalogger interprets electrical signals emitted by the transducers and stores them. The multiplexer increases the number of transducers that can be scanned by the datalogger from 16 to 64. A cellular phone is attached to the datalogger to enable downloading data from long distances. The station is powered by a 12-volt DC battery that is continuously recharged by a solar panel.

To date a significant number of pressure transducers have failed for a variety of reasons (as high as 75 % at Cell 3). Initially transducers were coated with marine grease and encapsulated in plastic sleeves to minimize biological growth. In some cases, the use of grease may have interfered with transducer operation. Subsequent installations used copper discs to minimize growth. In addition a lightning strike has destroyed a number of Cell 3 transducers. It is also suspected that the pressure of compactors and overlying waste may be deforming some of the transducers and causing erroneous readings. In general however, transducer results suggest that preferential flow of leachate plays an important role in leachate transport to the collection system. Results are highly variable

and the “parabolic” head profile projected by mathematical equations has not been observed. Figure 8 provides a plot of typical data obtained using the pressure transducers.

Data Interpretation

Geographic information systems (GIS) allow for the processing of spatially referenced data into useful information pertaining to the system of concern. Unlike computer assisted drafting (CAD) programs, such as AutoCAD, GIS programs link geographical data to information/properties specific to that location. For example, monitoring well data can be represented by both location and monitoring results. GIS programs also are capable of performing mathematical analyses on spatial data. Thus, by using a GIS-based model, both spatial and mathematical analyses of a system are possible, making the use of GIS programs to analyze engineering systems an attractive option.

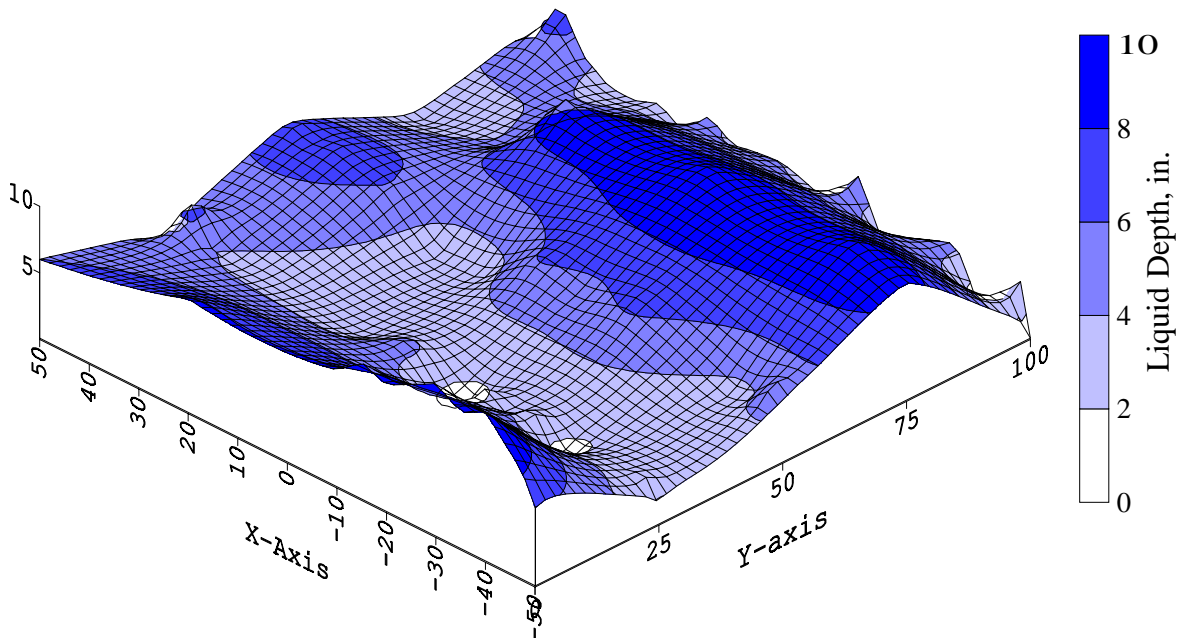


Figure 8. Typical Pressure Transducer Data Results at Cell 2 – NRRL (0 indicates location of LCS pipe).

To determine spatially averaged moisture content of a landfill, a conceptual 3-D GIS model was developed. The model performs a spatial interpolation of the in-situ moisture content data throughout the landfill and then averages the average moisture contents at each spatial interpolation step by performing a series of algebraic operations on interpolated layers of moisture content data for each level of moisture sensors. This procedure will also be applied to variables other than moisture content, such as temperature and gas composition.

The first step in implementing the GIS model developed is to input into ArcView GIS 3.2 (the GIS program used) all global positioning system (GPS) data for all monitoring well locations and their respective depths within the landfill, as well as GPS locations defining the extents of the landfill. The resulting 3-D image of the bioreactor landfill with monitoring well locations is presented in Figure 9. The next step is to input data obtained for each monitoring well location and to perform the procedure described above.

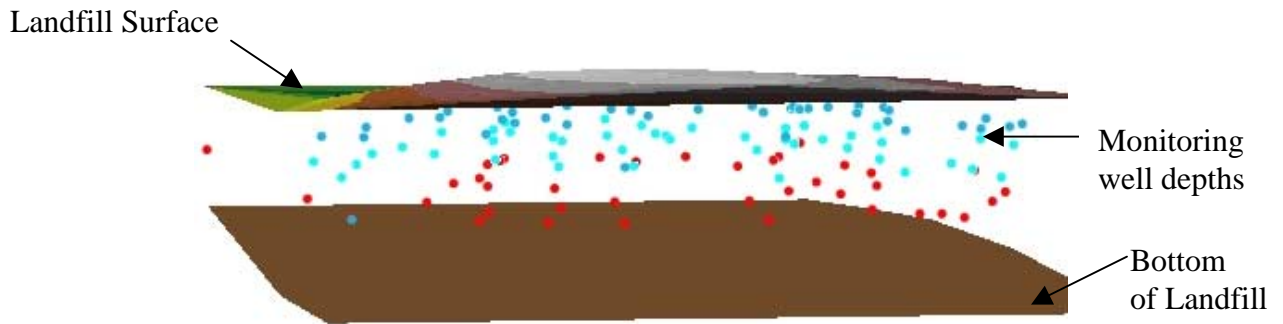


Figure 9. 3-D Drawing of the Bioreactor Landfill with Monitoring Well Locations.

Conclusions

Instrumentation of a bioreactor landfill is vital to the successful demonstration of this technology. Without the availability of moisture content, gas quality, temperature, and pressure data, little understanding of the complex processes within a landfill is possible. Technical and economic issues remain that challenge the use of instrumentation at a landfill. This paper presents the experiences with instrumentation to date at the NRRL Florida Bioreactor Demonstration Project. As the project progresses, much will be learned both about bioreactor technology and implementation of instrumentation.