HINKLEY CENTER FOR SOLID AND HAZARDOUS WASTE MANAGEMENT
Project Summary

Title: Leachate Collection System Clogging in Florida: A Reality Check.
Project Duration: September 1st, 2013 – August 31st, 2014
Investigators: Tarek Abichou and Mike Watts
FAMU – FSU College of Engineering
Department of Civil and Environmental Engineering

Objectives: The overall objective of this study is to use a "film growth approach" to simulate clogging in Florida landfills. The change of hydraulic properties and porosities of leachate drainage materials due to calcium carbonate buildup will be predicted using Florida specific leachate composition data and leachate generation data for typical landfills operated in different micro-climates of the state. The effects and the extent of the co-disposal of MSW and WTE by-products will also be assessed. The results of this investigation will be used to examine the adequacy of the current design methodology of leachate collection systems in the state of Florida. The findings of this study will then be used to estimate the service life of LCSs in different regions of Florida.

Methodology:

Task 1 – FDEP Database, and other Literature (Leachate composition, Leachate generation, Leachate Leak Detection System, etc.)

The first step of the project will be to team-up with the Florida Department of Environmental Protection (FDEP) and conduct an extensive review of the FDEP database and characterize the changes in leachate generation and quality in Florida landfills. We will also perform a literature and available databases searches for leaching characteristics of MSW, WTE by-products, and their mixtures to identify the chemistry and the biology of the liquids **before reaching LCS in landfills**.

Task 2 – Model calcium carbonate (calcite) growth in LCS

Based on input generated in Task 1, the change in the porosity and hydraulic conductivity of the components of leachate collection system will be predicted. The results of this task will consist of tabulated clogging predictions for the different leachate strengths associated with Florida landfills (monofills, co-disposal), the type of drainage materials currently being used (sands, gravel, geotextile, geonet,…), and the different leachate generation rates (GPD per acre).

Task 3 – Analysis of LCS clogging results

As soon as Tasks 1 and 2 are completed, key landfills and key locations, to be used as case studies, will be identified. The case studies identified in this manner will be carefully evaluated to assess the performance of the leachate collection system for the past few years. A technical review of the design of the leachate collection system at each chosen landfill site will be performed in Task 3. Data from these locations will be used to calibrate the clogging model predictions.

Task 4 – Revisiting Florida Regulations concerning design and maintenance of LCS

Based on Task 1 to Task 3, the predicted change in hydraulic properties, along with the existing leachate collection system layout (design), will be used to re-evaluate the head on liner for all the selected case studies. The results of this investigation will be used to examine the adequacy of the design methodology of leachate collection systems at those particular locations. The findings of this study will also be used to estimate the service life of LCSs in different regions of Florida.

.

Rationale: The purpose of LCSs is to collect and remove the leachate from the bottom of landfill and therefore minimize the leachate head which provides the driving force for the leakage of contaminants to the surrounding environment. Since the contaminating lifespan of a landfill may be decades or even centuries, the performance of the LCS is critical for a well-designed modern landfill and there is a need to be able to predict the service life of a given system.

Introduction and Objectives

Modern municipal solid waste (MSW) landfills commonly require a leachate collection system (LCS) over a low permeability composite liner to control the escape of contaminants from the landfill. The purpose of LCSs is to collect and remove the leachate from the bottom of landfill and therefore minimize the leachate head which provides the driving force for the leakage of contaminants to the surrounding environment through defects in the geomembrane component of a composite liner or due to advective transport though a simple clay liner (Rowe et al. 2004, Rowe 2005). Since the contaminating lifespan of a landfill may be decades or even centuries (Rowe et al. 2004), the performance of the LCS is critical for a well-designed modern landfill and there is a need to be able to predict the service life of a given system. For modern MSW landfills, the leachate head in LCSs is normally required to less than 0.3 m, (Rowe et al. 2004). Thus the service life of the LCS could be defined as the time it takes before the design head is exceeded. The estimation of the service life of LCSs with different design configurations requires an understanding of the clogging mechanisms and the effects of the different factors on the clogging.

One generation of LCS involved installing what are commonly called “French drains” or “finger drains” which involved gravel drains, often with perforated drainage pipes (with or without a geotextile wrapping. These drains are usually placed at a spacing that typically ranged from 50 m to 200 m on the base of the landfill. The drains provided some control of the leachate head on the base of the landfill but their effectiveness can decrease rapidly with time due to “clogging”. For modern MSW landfills, the leachate head in LCSs is normally required to less than 0.3 m, (Rowe et al. 2004). Thus the service life of the LCS could be defined as the time it takes before the design head is exceeded. The estimation of the service life of LCSs with different design configurations requires an understanding of the clogging mechanisms and the effects of the different factors on the clogging.

The high mass loading of leachate constituents (volatile fatty acids, suspended solids, and dissolved inorganic constituents like **calcium**) to the geotextile and granular material in the drains give rise to substantial biofilm growth, deposition of particulate material such as silts and fine sands, and biologically induced chemical precipitation (primarily calcium carbonate for drains within the landfill) that can substantially reduce the hydraulic conductivity of drains (Rowe 1992, Koerner et al. 1993, Rowe 1998a,b). The reduced hydraulic conductivity of drains lead to leachate mounding in the waste between the drains and substantial leakage of contaminants through the base of the landfill (Rowe 1998a). The latest generation of LCSs design involved a continuous drainage blanket of granular material with perforated drainage pipes at a regular spacing and, often, a geotextile between the waste and granular porous media (Fig. 1). They also typically consist of perforated HDPE pipes within a granular drainage blanket (Fig. 1).

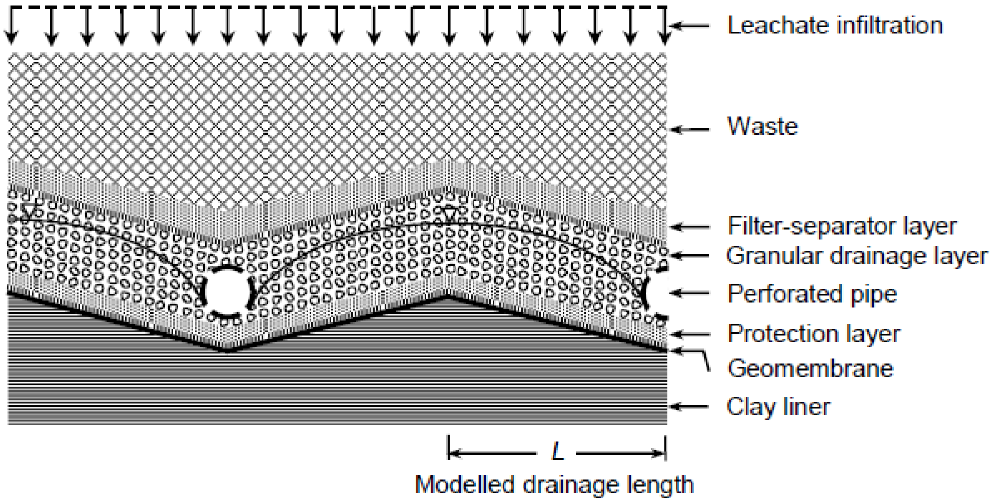

Fig. 1. Sketch of Typical Landfill Bottom Cross Section.

Field studies of landfill LCS have provided direct evidence that the granular layer can experience a significant decrease in porosity and hydraulic conductivity due to the formation of clog material within the pore space of the porous media. This is called clogging. Clogging is defined as: A build-up of biofilm, chemical precipitates and small (e.g. silt and sand) particles that are deposited in pipes, granular material (e.g. sand or gravel), and geotextiles that are used in drainage systems. This buildup progressively reduces the hydraulic conductivity of the system and hence its ability to drain fluids (e.g. leachate).

Studies on numerous landfills suggest that incrustations can form in the drainage media due to high populations of microorganisms in leachate and the precipitation of minerals out of solution, thus reducing the void space of the media. Field exhumation of sand and coarse gravel from in-service leachate collection systems showed significant clogging (organic and inorganic material) in the **saturated** component of the drainage layer.

Specifically, the Hinkley Solid and Hazardous Management Center has sponsored two studies on clogging of LCS:

- In 1998, an effort examined the extent of clogging that had occurred in an MSW landfill LCS that had been in operation for six years. LCS designs and safety factors at existing Florida landfills were also analyzed to recommended design practices and safety factors. Surveying landfill designers and FDEP Officers as well as assessment of existing Florida landfill designs indicated that in general, Florida landfill LCSs are well-designed, state-of-the-art facilities. However, analysis of existing Florida LCS configurations suggested safety factors ranging from 0.025 to 0.1 which have been associated with less than optimal long-term LCS performance. Both designers and regulators expressed concerns over clogging of the LCS components but, material deterioration has not been addressed in past designs.

- In 2004, a project was funded to assess biogeochemical deposits in LCS. This research was conducted to evaluate clogging of leachate collection systems due to co-disposal of MSW and combustion residues from WTE facilities. Data from this research confirmed that co-disposal of MSW and WTE residuals in a major cause of the production of precipitates in leachate collection systems.

Elsewhere, there have been several laboratory studies that provide additional evidence that clogging occurs in granular porous media permeated with leachate. These clogging processes have been observed in other landfill materials such as geosynthetics (Koemer and Koerner, 1990, 1995; Brune et al.,1991; Cazzuffi et al., 1991; Fourie et al., 1994; Rowe, 1998a), mineral liners (Darkin et al., 2001; Hrapovic and Rowe, 2002), and collection and recirculation pipes (Turk et al., 1997; Fleming et al., 1999; Maliva et al., 2000; Manning, 2000). Armstrong (1998) and Rowe et al. (2000a,b) performed numerous laboratory column experiments to examine the effects of temperature, mass loading (in terms of flow rate), and grain size on the clogging rate of saturated gravel size material permeated with leachate.

Based on most field and laboratory findings: **calcium carbonate is the dominant fraction in the clog formation under anaerobic conditions in MSW landfills**. **Clogging is more rapid and more extensive in landfills where WTE and MSW are being co-disposed**. Rowe & Fleming (1998) developed a practical model to estimate the service life (ts) of LCSs. They conservatively assumed that all calcium entering the drainage layer immediately deposits as calcium carbonate in the system. This approach can also be used to predict the change in hydraulic conductivity of drainage materials (gravel, sand, geonet) with time. The change in the hydraulic conductivity and the porosity is based a “particle growth approach” combined with an extensive laboratory and field calibrations.

The overall objective of this study is to use a “particle growth approach” to simulate clogging in Florida landfills. The change of hydraulic properties and porosities of leachate drainage materials due to calcium carbonate buildup will be predicted using Florida specific leachate composition data, leachate generation data, for typical landfills operated in different micro-climates of the state. The effects and the extent of co-disposal of MSW and WTE by-products will also be assessed. The results of this investigation will be used to examine how adequate is the design methodology of leachate collection systems in the state of Florida. The findings of this study will use also be used to estimate the service life of LCSs in different regions of Florida. A simplified approach will be developed for use by the practicing engineers for estimating the service life and designing of LCSs in MSW landfills containing different, drainage materials and ashes/MSW ratios.

Proposed Research Plan

The following tasks will be conducted to achieve the objectives of the proposed project.

Task 1 – FDEP Database, and other Literature (Leachate composition, Leachate generation, Leachate Leak Detection System, etc.)

The first step of the project will be to team-up with the Florida Department of Environmental Protection (FDEP) and conduct an extensive review of the FDEP database and characterize the changes in leachate generation and quality in Florida with age of landfill and with the change in the type of wastes being disposed. We will focus on leachate quality data from vertical wells **before the leachate enters the LCS**, because once the leachate enters into the LCS it is "treated" as in passes through the media. We will also perform a literature and available databases searches for leaching characteristics of MSW, WTE by-products, and their mixtures to identify the chemistry and the biology of the liquids reaching the LCS in landfills.

Since many Florida MSW landfills are double lined, Florida collects the most extensive data of leachate leaks from engineered liner systems in the country. Leachate quantities from the LCS will provide us with typical leachate generation from different landfills in Florida and therefore provide us with loading rates into LCS across the state. Data from leachate leak detection systems will also be collected from several landfills in the state, in conjunction with FDEP. The quantity of liquids from the Leachate Detection System is an excellent index of head build-up on liners and therefore clogging. This data, along with meetings with FDEP District office representatives, will help us identify landfills and/or regions with significant clogging.

Task 2 – Model calcium carbonate (calcite) growth in LCS

Based on documents compiled in Task 1, the change in the porosity and hydraulic conductivity of the components of leachate collection system will be evaluated. The results of this task will consist of tabulated clogging predictions for the different leachate strength associated with Florida landfills, and the drainage materials currently being used (sands, gravel, geonet,…). A numerical model (BioClog) was developed to examine changes in key municipal solid waste (MSW) leachate characteristics and the porosity of porous media (clogging) as the leachate passes through the drainage layer of a leachate collection system (LCS). The model considers multiple-species reactive leachate transport through porous media. It simulates biofilm growth and loss, deposition of suspended particles, and precipitation of minerals on the surface of porous media along the drainage path of leachate in the LCS (Fig. 2). The model will be used to simulate a long period of landfill life to examine the long-term performance of both the granular porous media and nonwoven geotextiles in LCSs.

The accumulation of clog mass within the porous media will be simulated in terms of the thicknesses of films around each grain. Both the organic and inorganic films will be considered. The filter-separator layer (nonwoven geotextile) between the waste and granular drainage layer will be modeled as one dimensional tubes. Due to the formation of a filter cake (McDowell- Boyer et al. 1986; Rollin 1996) on the surface of filter-separator layer, a portion of suspended particles will be filtered out of leachate before entering the filter-separator layer. Other geosynthetic drainage materials such as Geonet will also be considered. The porosity and specific surface of granular material and synthetic materials will be evaluated from the total film thickness based on a geometric model (Fig. 3, Yu and Rowe 2012).

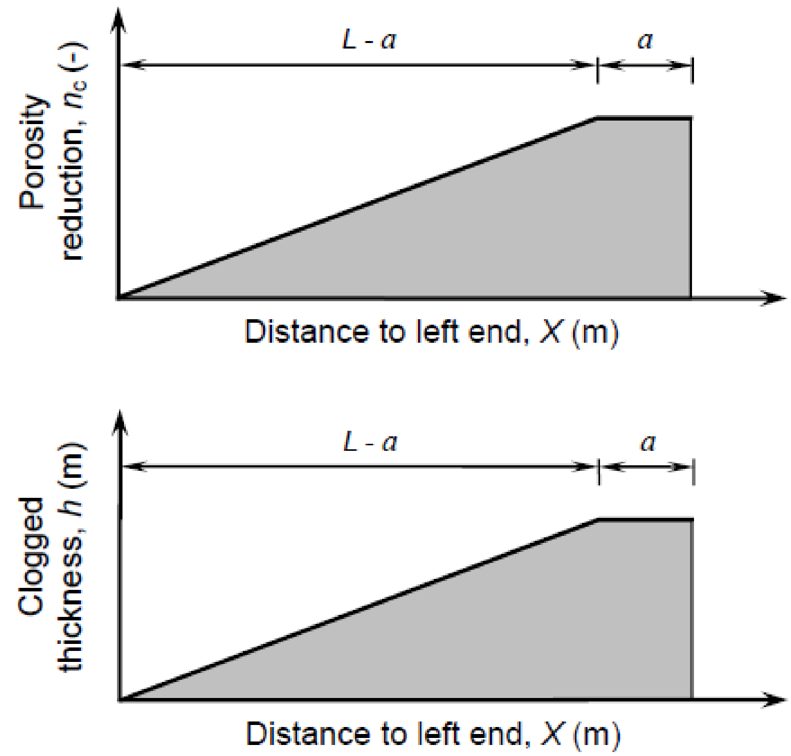

Fig. 2. Sketch of Model prediction of porosity reduction and clogged thickness estimation of typical LCS layer.

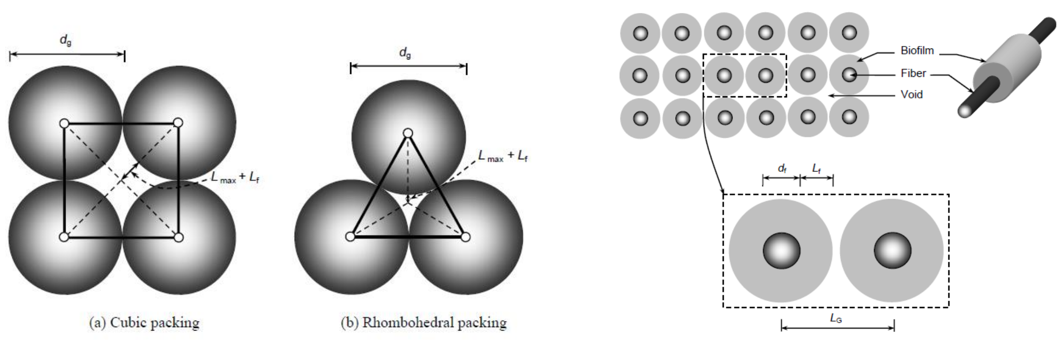

Fig. 3. Packings for particle growth model (left) and tube growth model for geotextiles and geonet (right).

Abichou et al. (2002) a used similar approach to determine the relationship between the micro-structure and hydraulic conductivity of simulated sand-bentonite mixtures (SSBMs) prepared with powdered and granular bentonite. Glass beads were used to simulate sand grains because of their superior optical properties. The micro-structure of SSBMs was observed using optical micrography and scanning electron microscopy (Fig. 5). For mixtures prepared with powdered bentonite, the observations indicate that bentonite coats the particles. As the bentonite content increases, the thickness of bentonite coating increases and reduces the area available for flow. The same approach will be used to account for the extent of calcium carbonate film buildup around granules and fibers in the LCS materials.

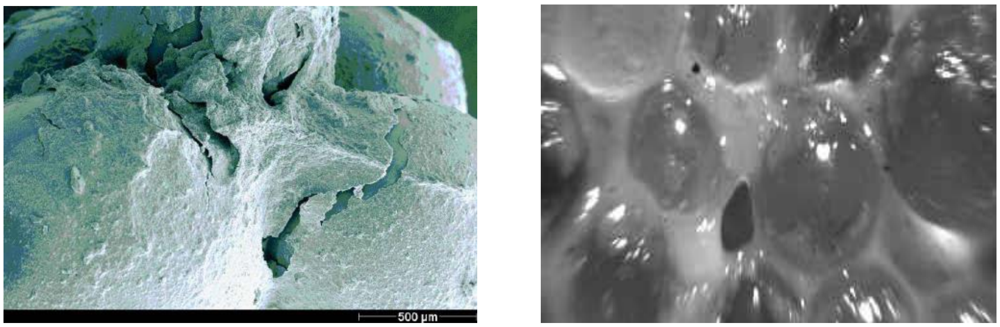

Fig. 5. SEM of glass beads coated with bentonite (Abichou et al. 2002)

<u>Task 3 – Analysis of LCS clogging results</u>

As soon as Tasks 1 and 2 are completed, key landfills and key locations, to be used as case studies, will be identified. The case studies identified in this manner, will be carefully evaluated to assess the performance of the leachate collection system for the past few years. A technical review of the design of the leachate collection system at each landfill of these sites will be performed in Task 3. Data from these locations will be used to calibrate the clogging model predictions. The results of this investigation will be used to examine how adequate is the design methodology of leachate collection systems at that particular site.

<u>Task 4 – Revisiting Florida Regulations concerning design and maintenance of LCS</u>

Based on Task 1 to Task 3, the predicted change in hydraulic properties, along with the existing leachate collection system layout (design), will be used to re-evaluate the head on liner for all the selected case studies. This analysis will help us develop an approach to better design leachate collection systems capable of performing their function during the entire life of the project. The findings of this study will also be used to estimate the service life of LCSs in different regions of Florida. A simplified approach will be developed for use for practicing engineers for estimating the service life and the design of LCSs in MSW landfills containing different, drainage materials and ashes/MSW ratios.

Project Management

The proposed tasks will be completed over a 1 year project period, with an anticipated start date of September 1, 2013. The proposed schedule of activities is presented below, including meetings with the project's Technical Awareness Group before the start of the project (post-award) and two meeting during the project execution period (6 months, and a final review of project findings).

	Quarter 1	Quarter 2	Quarter 3	Quarter 4
FDEP Database, and other Literature (Leachate composition, Leachate Leak Detection System, etc.)				
Model calcium carbonate (calcite) growth in LCS				
Analysis of LCS clogging results				
Revisiting Florida Regulations concerning design and maintenance of LCS				
TAG Meetings (one post-award)				
Quarterly/Final Reporting				

The PIs will be responsible for mentoring and assisting the graduate research assistant with critical data collection. The PIs will also be responsible for preparing all required quarterly and final reports.

Expected Benefits

Some models were developed to simulate the changes in key municipal solid waste (MSW) leachate characteristics during the lifetime of a landfill. Others describe the effects on the porosity of porous media (clogging) as the leachate passes through the drainage layer of a leachate collection system (LCS) as a function of time. Such models consider multiple-species reactive leachate transport through porous media. They simulate biofilm growth and loss, deposition of suspended particles, and precipitation of minerals on the surface of porous media. Modern municipal solid waste (MSW) landfills commonly require a leachate collection system (LCS) over a low permeability composite liner to control the escape of contaminants from the landfill. The purpose of LCSs is to collect and remove the leachate from the bottom of landfill and therefore minimize the leachate head which provides the driving force for the leakage of contaminants to the surrounding environment through defects in the geomembrane component of a composite liner or due to advective transport though a simple clay liner. Since the contaminating lifespan of a landfill may be decades or even centuries, the performance of the LCS is critical for a well-designed modern landfill and there is a need to be able to predict the service life of a given system.

Deliverables

Findings from the research will be disseminated through publication in scientific journals, presentations at state and national conferences, discussions at TAG, and the developed project website. It is anticipated that the proposed work will lead to at least one conference presentation and at least one journal publication. The PI will commit to all dissemination and publication responsibilities as required by the Hinkley Center. Subsequent proposals to other funding sources such as NSF, EPA, EREF are planned.