QUARTERLY PROGRESS REPORT 3

Title: Equivalency of Double Liner System for Florida Coal Ash Landfills

Project Duration: December 1st, 2020 – November 30th, 2021
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FAMU – FSU Dept. of Civil and Env. Eng.

PROJECT WEB SITE:

http://eng-web1.eng.famu.fsu.edu/~abichou/equivalency.html

Project Goals and Progress Update:

- We **first** reviewed the process used by EPA to calculate leakage flow rates through the federal proposed composite liner system and through the Florida Class-I landfill double liner system. **(100% Progress)**
- **Second**, we reviewed all previous documentations (FDEP reports, published journal and conference papers) used by the State of Florida to successfully obtain approval for their double liner system as Florida's Subtitle D alternative. **(100% Progress)**
- **Third**, we started using the findings of first twotasks to recalculate theoretical leakage flow rates through Florida and EPA liner systems to assess if any errors were committed, by not actually comparing the two liner systems, but comparing only theoretical leakage rates through parts of each liner system. **(100% Progress)**
- **Finally**, we collected actual leachate flow rates into the leak detection system (LDS) at Florida's active andclosed double-lined Subtitle D landfills to update the performance and see if liner leakage rate equations should be updated. We have obtained data directly from landfills and from FDEP database. We have collected leak detection system from 25 landfills. Each landfill data contains separate data from several landfill cells. **(75% Progress)**

Next, we will showcase some of the work accomplished during this reporting on Quarter 3:

1. Update on Data Collection Activities:

To compare the design leakage to the actual leakage real-time date has been obtained from 25 double lined landfills in Florida. Some of the data was obtained directly from the landfillswhereas the remaining data has been acquired from the FDEP Oculus database. The data obtained from the landfills was the amount of leachate collected in through the LCS and LDS, Rainfall Data, lining system profile, and areas of all the cells associated or contributing to the collected leachate data. The Landfills for which data has been obtained:

Table. 1 Landfills with Data given by the landfills.

Landfill	District	County	Remarks
Test Site A	SW	Hernando	Data Processing Complete
Test Site B	SED	Palm Beach	Data Processing Complete
Test Site C	SW	Orange	Data Processing Complete
Test Site D	SD	Hillsborough	Data Processing Complete
Test Site E	CD	Sarasota	Data Processing Complete
Test Site F	CD	Volusia	Data Processing Complete

In addition to the 6 landfills mentioned above we obtained data for 8 landfills from the OCULUS database for which data was extremely hard to find and process. The permit documents had to be scavenged to find the leachate data in some cases. More data was obtained from 1995 FDEP study. List of the present landfills in addition to the ones mentioned earlier are listed below.

Landfill	District	Source	Data Status
Test Site G	SWD	Oculus Database	Data Processing Complete
Test Site H	NED	Oculus Database	Data Processing Complete
Test Site I	NED	Oculus Database	Data Processing in Progress
Test Site J	NED	Oculus Database	Data Processing in Progress
Test Site K	SED	1995 FDEP Study	Data Processing Complete
Test Site L	SED	1995 FDEP Study	Data Processing Complete
Test Site M	CD	1995 FDEP Study	Data Processing in Progress
Test Site N	SED	1995 FDEP Study	Data Processing Complete
Test Site O	SWD	Oculus Database	Data Processing Complete
Test Site P	SWD	Oculus Database	Data Processing in Progress
Test Site Q	NED	Oculus Database	Data Processing in Progress
Test Site R	SWD	Oculus Database	Data Processing in Progress

2. Leakage Rate Calculation:

2.1. RCRA Subtitle D Leakage Estimations: The Equivalency Leakage Rate

The design leakage rate or what we have called the Federal Minimum Design Standard is calculated for RCRA Subtitle D standard in accordance with equations developed be Giroud for composite liner consisting of a geomembrane and soil/GCL as shown in Figure 1. This leakage rate is the minimum performance that an alternate lining system should be compared to. In other words, the leakage rate through any other **EQUIVALENT** proposed lining system should be **LOWER** than the Federal Minimum Design Standard in accordance with RCRA Subtitle D.

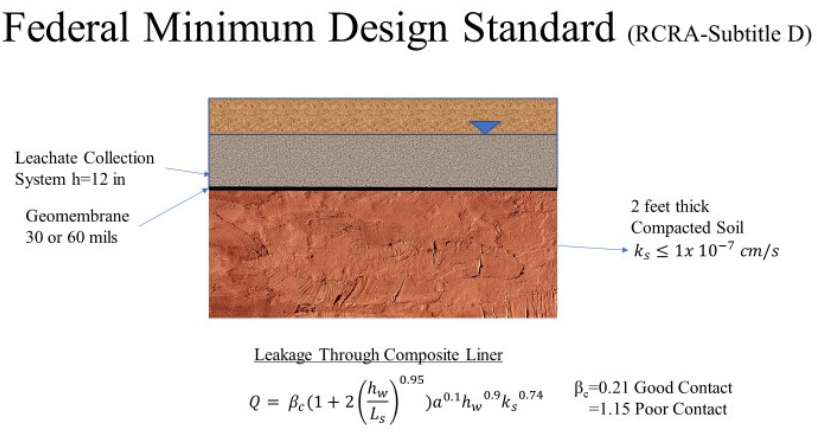


Figure 1. Federal Minimum Design Standard Leakage Rate.

The design leakage rate through RCRA Subtitle D composite lining system consisting of a geomembrane with a 1 hole per acre (area of hole 1 cm^2), underlain by 2 feet (0.61 m) of compacted clay with a minimum saturated hydraulic conductivity of $1x10^{-7}$ cm/sec, and overlain with a leachate collection layer with a leachate head of 1 foot (0.30 m) on top of the liner is calculated to be a round 0.9439 gallons per acre per day (gpad). Any equivalent lining system should have a lower leakage rate of at most 1 gpad.

Table. 2 Leakage calculation for RCRA-D.

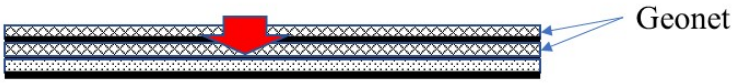
Variable	Value	Units
Area of Hole	1	cm^2
Leachate Head above primary Liner	0.3	m
Hydraulic Conductivity of Soil beneath Liner	$1x10^{-9}$	m/sec
Assuming Medium Contact, β	0.68	
Thickness of Soil	0.61	m
Leakage through Composite Liner	0.9439	gpad

2.2.Florida Double Liner Leakage Estimations: The Performance Leakage Rate

For the Florida Double Liner Systems, the leakage rate is calculated in THREE separate steps. The first step consists of estimating the leakage rate through the primary liner system. The second step consists of using the calculated leakage rate from the primary liner system to estimate the ponding depth on the secondary liner system. The THIRD is to estimate the leakage rate through the secondary liner system.

2.2.1. *Leakage Rate through the primary system Q_1:*

Case 1 Free Flow: Geonet Drainage Layer on Both Sides of Geomembrane



Free Flow through geomembrane Hole

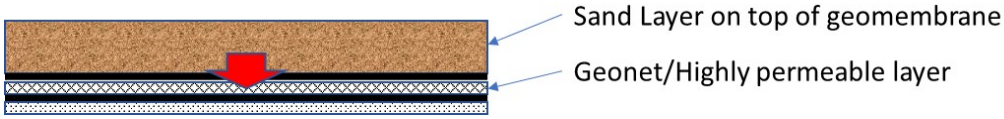
The leakage rate is calculated as follows:

$$Q1 = CC_B a\sqrt{2gh}$$

Where:
h=head of liquid over hole
C_B= Dimensionless coefficient, 0.6
C=constant

Reference: Bonaparte, R. , Giroud, J.P., and Gross, A.B., Rates of Leakage Through Landfill Liners, San Diego, California: Geosynthetics 1989 Conference, 1989

Case 2 Leakage through Geomembrane Overlaying a Highly Permeable Layer: Geonet Below Geomembrane and Sand Above Geomembrane



The leakage rate is calculated as follows:

$$Q1 = 3Ca^{0.75}h^{0.75}{k_d}^{0.5}$$

Where:
k_d=Hydraulic conductivity of soil on top of geomembrane

Reference: Bonaparte, R. , Giroud, J.P., and Gross, A.B., Rates of Leakage Through Landfill Liners, San Diego, California: Geosynthetics 1989 Conference, 1989

Case 3 Same as Case 2, but With Restricted Flow in the Leak Detection System: Can only be used if hydraulic conductivity of layer below geomembrane is less than 10-4 cm/sec, and Head of liquid on top of geomembrane is less than the thickness of layer below geomembrane.

The leakage rate is calculated as follows

$$Q1 = 0.6Ca^{0.1}h^{0.9}{k_d}^{0.74}$$

Reference: Bonaparte, R. , Giroud, J.P., and Gross, A.B., Rates of Leakage Through Landfill Liners, San Diego, California: Geosynthetics 1989 Conference, 1989

2.2.2. *Ponding Head on Top of Secondary Liner Estimation*

The estimate leakage rare through the primary liner system (Q1, as calculated above) is used to first determine to wetted area (area with leachate head) as follow:
The width of wetted area beneath hole in primary liner is expressed as:

$$B_{ave} = \frac{2\sqrt{\frac{Q_1}{k_d}}}{\sin\alpha} * \sqrt{1 + \frac{2X_{ave}\sin\alpha}{\sqrt{\frac{Q_1}{k_d}}}}$$

The ponding depth on the secondary liner system is then expressed as:

$$D_{ave} = \frac{Q_1}{B_{ave}\, k_d sin \propto}$$

2.2.3. Leakage Rate Through Secondary Liner

The leakage rate through the secondary liner system, Q2, is then estimated using the same equation as for a composite liner system as follow:

$$Q_2 = \beta_c(1 + 2\left(\frac{D_{ave}}{L_s}\right)^{0.95})a^{0.1}{D_{ave}}^{0.9}{k_s}^{0.74}$$

3. List of Sites with Leakage Rate Calculation from Florida Double Liner Systems

Facility	Oculus Site ID	District	Data (years)	Number of LDS Collection Point	Data Source
1	49722	SWD	2015-2020	3	Oculus Database
2	33628	NED	2004-2008	1	Oculus Database
3	39815	NED	2009-2010	6	Oculus Database
4	31495	NED	2007-2012	4	Oculus Database
5	60080	SED	1992-1995	3	1995 FDEP Study
6	55093	SED	1994-1995	3	1995 FDEP Study
7	20906	CD	1993-1995	2	1995 FDEP Study
8	70436	SED	1994-1995	2	1995 FDEP Study
9	45799	SWD	2019-2020	6	Oculus Database
10	39859	SW	-	-	Oculus Database
11	40612	SW	-	-	-
12	37059	NED	-	-	-
13	40501	SD	-	-	-
14	51484	SWD	-	-	-
15	74766	SD	-	-	-
16	74956	SD	-	-	-
17	16256	CD	-	-	-
18	19823	CD	-	-	-
19	89544	CD	-	-	-
20	26122	CD	-	-	-
21	85764	CD	-	-	-
22	37570	NED	-	-	-
23	1688	NWD	-	-	-
24	16	NWD	-	-	-
25	6319	NWD	-	-	-
26	6660	NWD	-	-	-
27	12300	NWD	-	-	-
28	19134	SED	-	-	-
29	56824	SED	-	-	-

TAG meeting- Scheduled for October 1st:

We planned our second TAG meeting for October 1st , 2021

Metrics:

1. List of graduate student or postdoctoral researchers **funded** by **THIS** Hinkley Center project

Last name, first name	Department	Professor	Institution
Prashanth Reddy Biyyani	Civil & Environmental Engineering	Dr. Tarek Abichou	FAMU-FSU College of Engineering
Leslie Okine	Civil & Environmental Engineering	Dr. Tarek Abichou	FAMU-FSU College of Engineering

2. List undergraduate researchers working on **THIS** Hinkley Center project
   Present Undergraduate Researchers (None)
3. List research publications resulting from THIS Hinkley Center project (useformat for publications as outlined in Section 1.13 of this Report Guide). NOT YET
4. List research presentations (as outlined in 1.13.6 of this Report Guide) resulting from **THIS** Hinkley Center project.
   TAG Meeting presentation
5. List who has referenced or cited your publications from this project?
   NO
6. How have the research results from **THIS** Hinkley Center project been leveraged to secure additional research funding? **NO**
7. How have the results from **THIS** Hinkley Center funded project been used (**will be used**) by FDEP or other stakeholders? (1 paragraph maximum).

TAG members:

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