Effects of Florida Leachates on Geosynthetic Clay Liners (GCLs)

TAG Meeting 1

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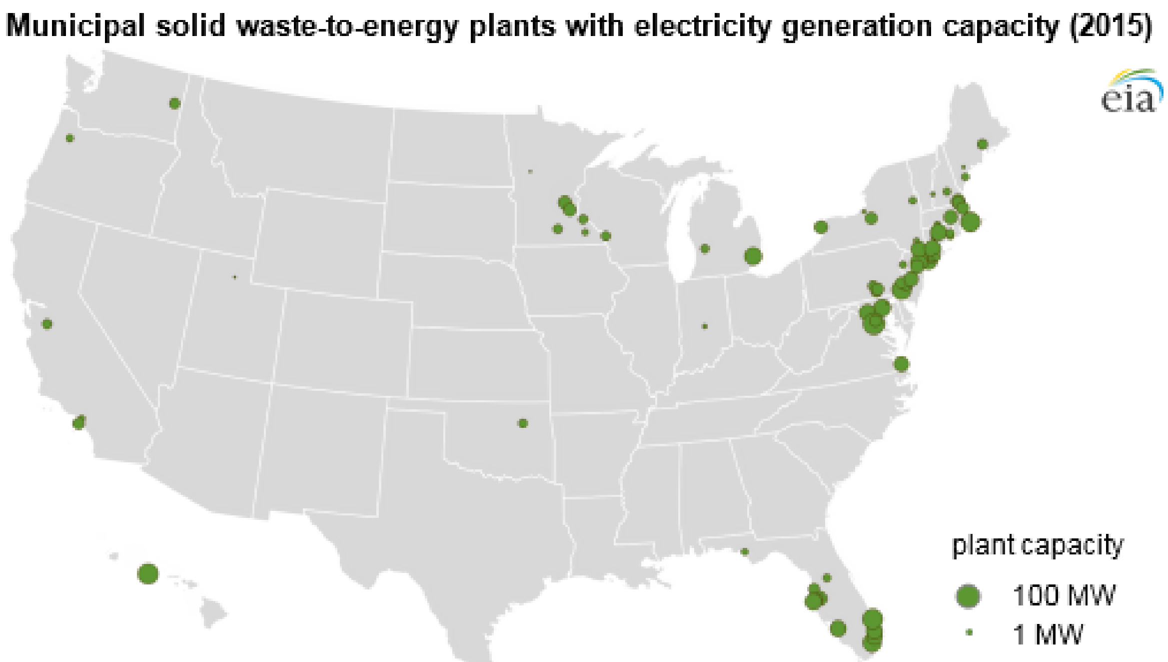
MSW Incineration in Florida

- MSW incinerator (MSW-I) residues are being landfilled in MSW landfills or mono-filled in Florida.
- Leachates from these types of waste are different from regular MSW leachate and **DO affect** the performance of Geosynthetic Clay Liners (GCLs), widely used in Florida.



MSW-I Leachates

- Townsend et al. (2015) analyzed 300,000 leachate sample dataset from landfills in Florida including MSW-I ash monofills and co-disposal landfills.
- They reported that MSW-I ash content in the disposed waste has a significant effect on leachate composition, resulting in a higher concentration of total dissolved solids (TDS) along with decreased concentrations of alkalinity, ammonia, and organic matters.
- Rocca et al. (2012) reported that **divalent cation** concentrations can reach **10,000 ppm for calcium and 2,000 ppm for magnesium**. These high concentrations of divalent cations significantly increase the likelihood of cation exchange in the Na-Bentonite used in GCLs

Objectives

- **Practical:** add more data to the literature on GCLs and polymer modified GCLs (very limited)…… More independent data is needed
- **First:** develop new alternative index tests or criteria to predict the long term hydraulic performance of GCLs under different leachate bio-chemistry.
- **Second:** understand how leachates like the MSW-I landfill leachate affect the performance of GCLs and Polymer Modified GCLs.

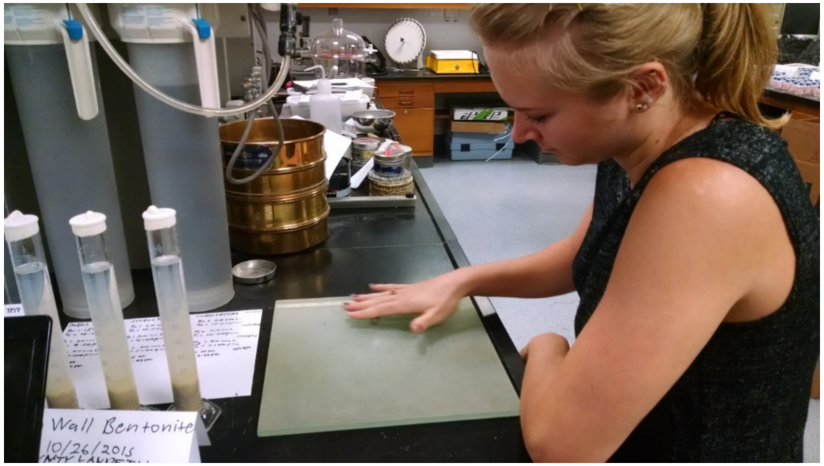
Overall Scope

- To achieve the first objective:
  - Conduct extensive set of tests that include GCLs samples from different vendors
  - MSW-I leachate samples from different landfills, and synthetic leachate samples that cover a wide range of possible leachate composition.
  - The change in index and hydraulic properties of the GCLs when exposed to the different leachates will be comprehensively evaluated.
- To achieve the second objective:
  - Use a variety of imaging and analysis techniques such as cation exchange capacity (CEC) scanning electron microscopy (SEM), and X-ray diffraction (XRD) to document the difference in fabric properties and mineralogy of bentonites in GCLs and Polymer Modified GCLs before and after being exposed to these representative aggressive leachates.

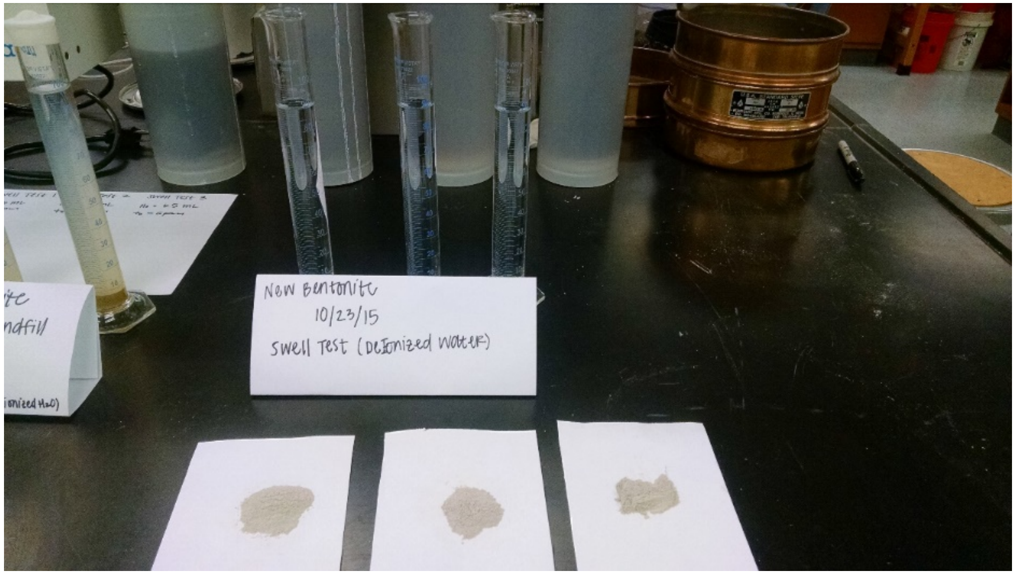
Activities

- An extensive testing campaign to assess the performance of GCLs in Florida.
- Leachates from MSW landfills, MSW-I Monofills, co-disposal landfills are being collected.
- In addition, synthetic leachates will be prepared to represent liquids from 100% MSW, 50-50% MSW and MSW-I, 25-75% MSW and MSW-I, and 100% MSW-I landfills.
- Seven GCL samples were obtained from the three main GCL vendors
- All vendors had us sign Non-Disclosure Forms
- We expect to collect more in the near future

Index Testing (Atterberg Limits)

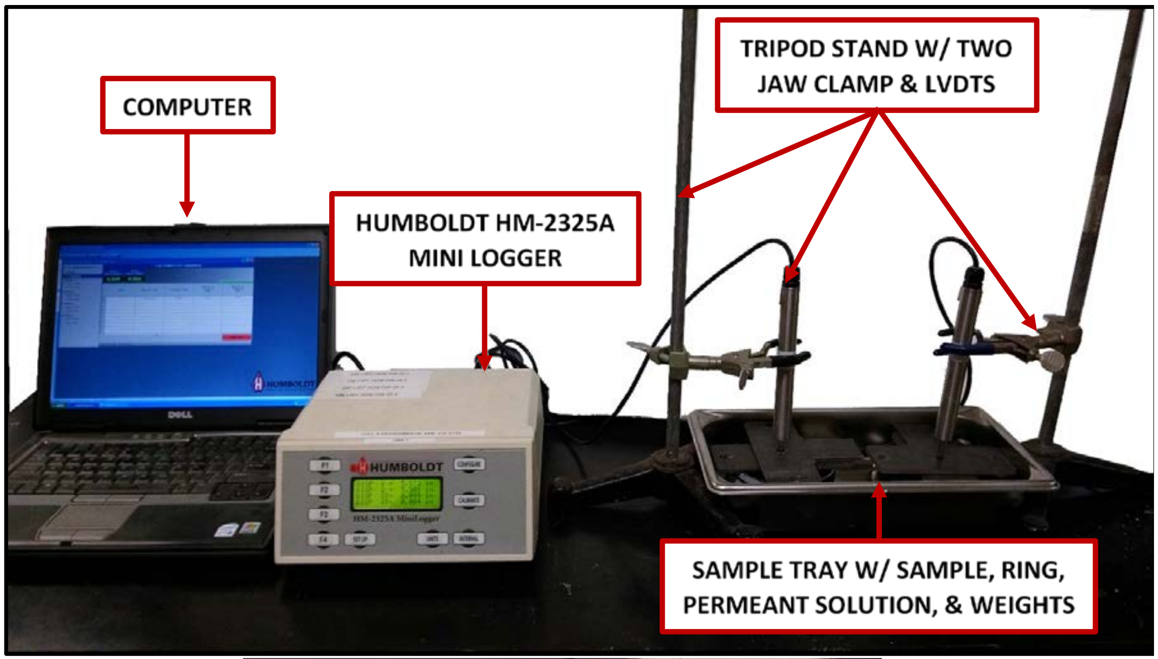


Index Testing (Swell Index)



Whole GCL 1-D Swell Tests

One-Dimensional Swell test is a new test developed by Abichou et al. (2016), and is used to assess the swelling potential of actual GCL instead of the powder bentonite only. The 1-D swell test examines the intact GCL by measuring the vertical displacement or swelling by restricting any horizontal swelling in accordance with ASTM D 4546 guidelines.

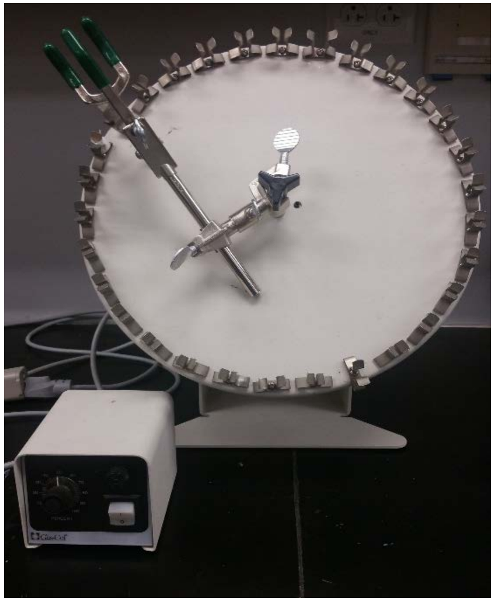


Hydraulic Conductivity Tests
ASTM D 5084

Hydraulic Conductivity Tests will be conducted on GCL specimens in flexible-wall permeameters following the procedures in ASTM D 5084-03 and ASTM D 6766-06. Low effective stress conditions will be simulated in the hydraulic conductivity testing. These tests will be performed with different permeants on all GCL samples

Cation Exchange Testing

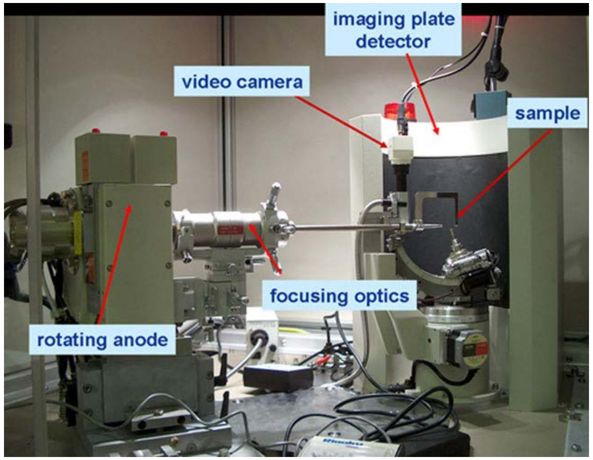
- Soluble cations (SC), bound cations (BC), and cation exchange capacity (CEC) will be determined following the procedures in the draft ASTM standard: “Standard Test Method for Measuring Exchangeable Cations and Cation Exchange Capacity of Inorganic Fine Grained Soils”, which is being balloted by ASTM Subcommittee D18.04. Chemical analysis of extracts from the SC and BC tests will be conducted using inductively coupled plasma optical emission spectroscopy (ICP-OES) following USEPA Method 6010 B. BC mole fractions will be calculated as the ratio of total charge per unit mass of bentonite associated with a particular cation to the CEC.



Microscopic Testing of GCLs

Before and After Exposure to Leachates

- To mechanistically understand how the GCLs change after exposure to leachates, three representative GCLs will be observed using a Scanning Electron Microscope (**SEM**) and a Transmission Electron Microscope (**TEM**) in the National High Magnetic Field Laboratory (MagLab) at Florida State University.
- Renishaw micro-Raman spectroscopy system with temperature control (Linkam 600) and an X-ray powder diffraction (**XRD**) system will be used to characterize the change of chemical bonds in the GCLs due to the change of cations with leachate.
- To further understand why the high concentration of cations affects the GCL performance, a dynamic light scattering (**DLS**) system in combination with electrophoresis will be used to measure the zeta potential of the solid particles in the GCLs



Manufacture GCL Properties

GCL	Bentonite		Top Geotextile	Bottom Geotextile	Reinforcement
	Type	Texture			
A-1	Sodium	Granular	nonwoven	woven	needle-punched
A-2	Sodium	Granular	nonwoven	nonwoven	needle-punched
C-1	Sodium	Granular	nonwoven	woven	needle-punched
G-1	Sodium	Granular	nonwoven	woven	needle-punched
G-2	Sodium	Granular	nonwoven	scrim-nonwoven	needle-punched
GP-1*	Sodium-Polymer	Granular	nonwoven	scrim-nonwoven	needle-punched

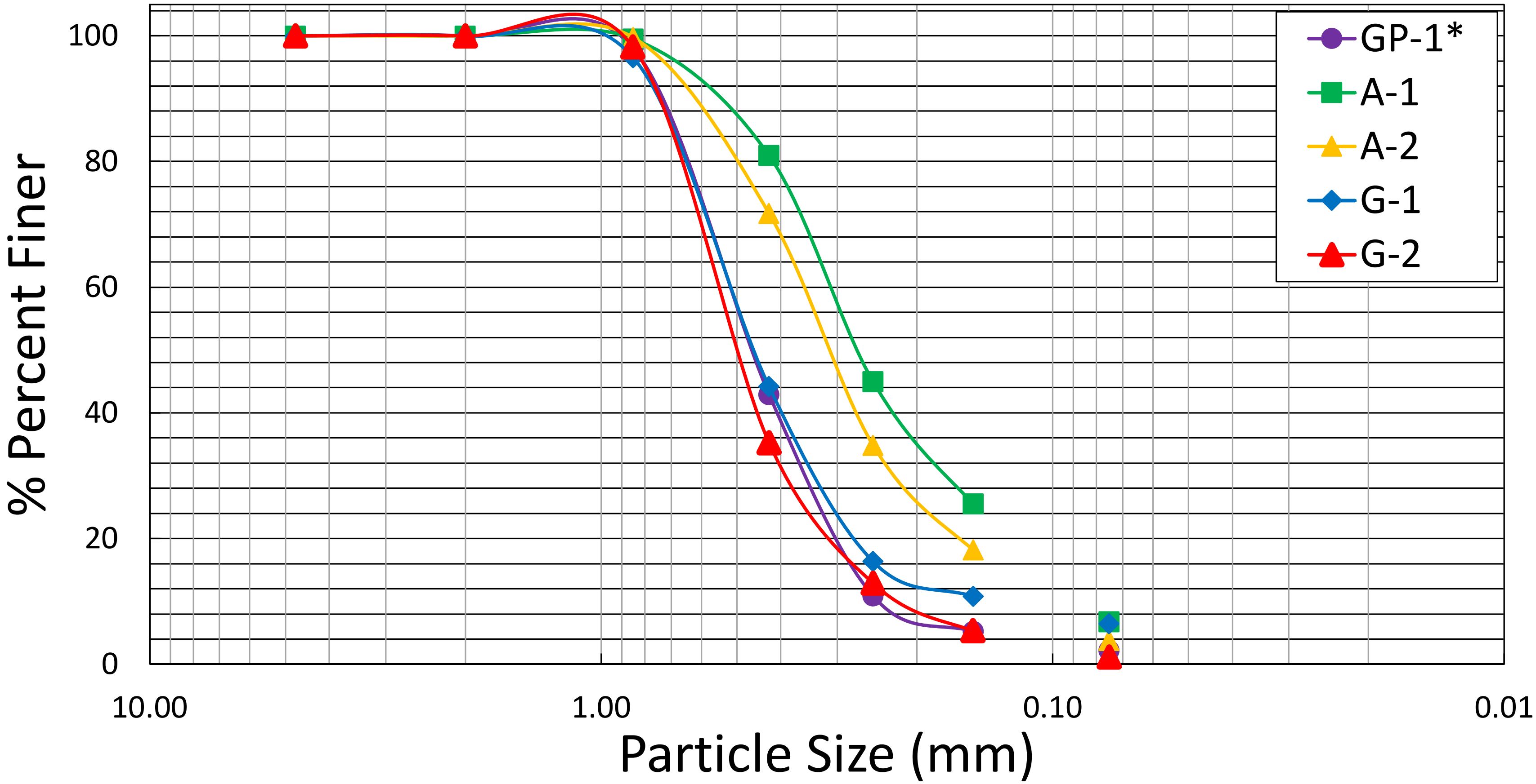
*Polymer Modified

Manufacture GCL Properties

GCL	Swell Index	Hydraulic Conductivity	Internal Shear Strength	Tensile Strength	
	SI (2 mL/2g)	k (cm/sec)	(kPa)	(lb/in)	(N/cm)
A-1	24	5*10-9	500	30	53
A-2	24	5*10-9	500	50	87
C-1	24	5*10-9	500	30	53
G-1	24	5*10-9	500	30	-
G-2	24	5*10-9	500	45	-
GP-1*	24	5*10-9	500	45	-

*Polymer Modified

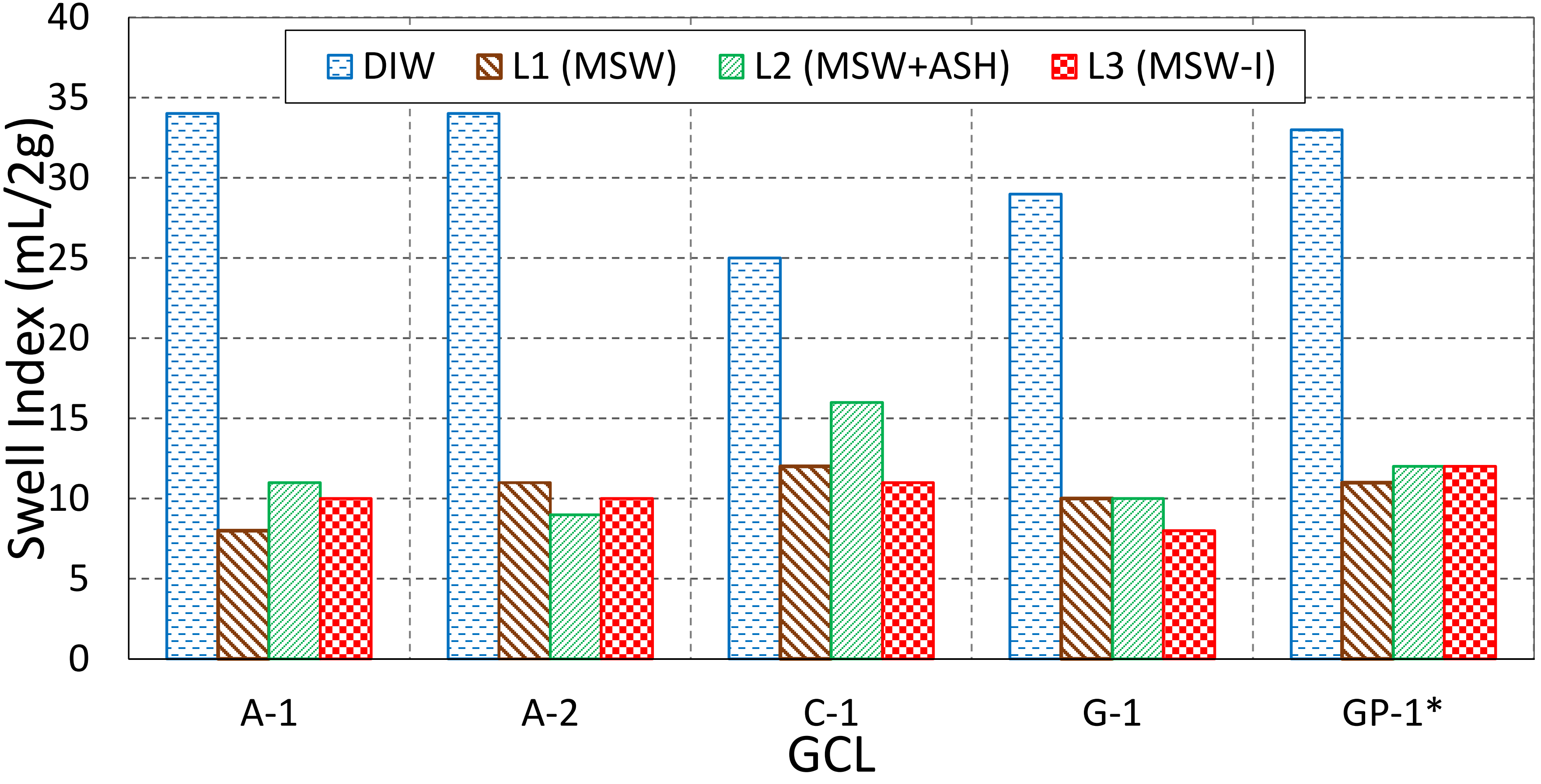
Grain Size Distribution (ASTM E 112)



Swell Index Tests (ASTM D 5890)							
GCL	**DIW**	**Leachates**					
		L1 (MSW)	**L2 (MSW+ASH)**	**L3 (MSW-I)**	**L4**	**L5**	**L6**
A-1	34	8	11	10	-	-	-
A-2	34	11	9	10	-	-	-
C-1	25	12	16	11	-	-	-
G-1	29	10	10	8	-	-	-
G-2	-	-	-	-	-	-	-
GP-1*	33	11	12	12	-	-	-

*Polymer Modified

Swell Index Tests (ASTM D 5890)

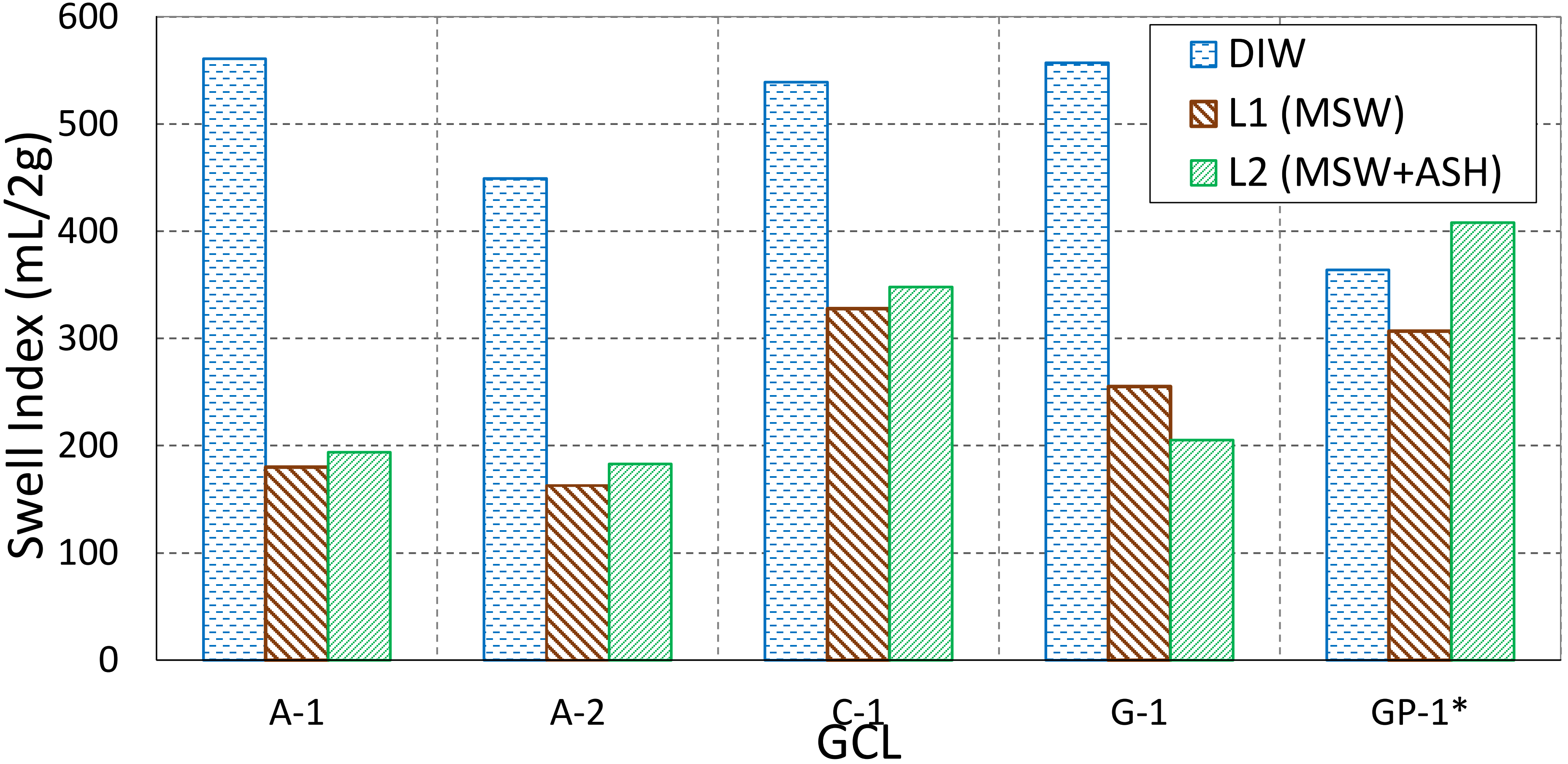


Liquid Limit Tests (ASTM D 4318)

GCL	DIW	Leachates					
		L1 (MSW)	L2 (MSW+ASH)	L3 (MSW-I)	L4	L5	L6
A-1	561	180	194	-	-	-	-
A-2	449	163	183	-	-	-	-
C-1	539	328	348	-	-	-	-
G-1	557	255	205	-	-	-	-
G-2	-	-	-	-	-	-	-
GP-1*	364	307	408	-	-	-	-

*Polymer Modified

Liquid Limit Tests (ASTM D 4318)

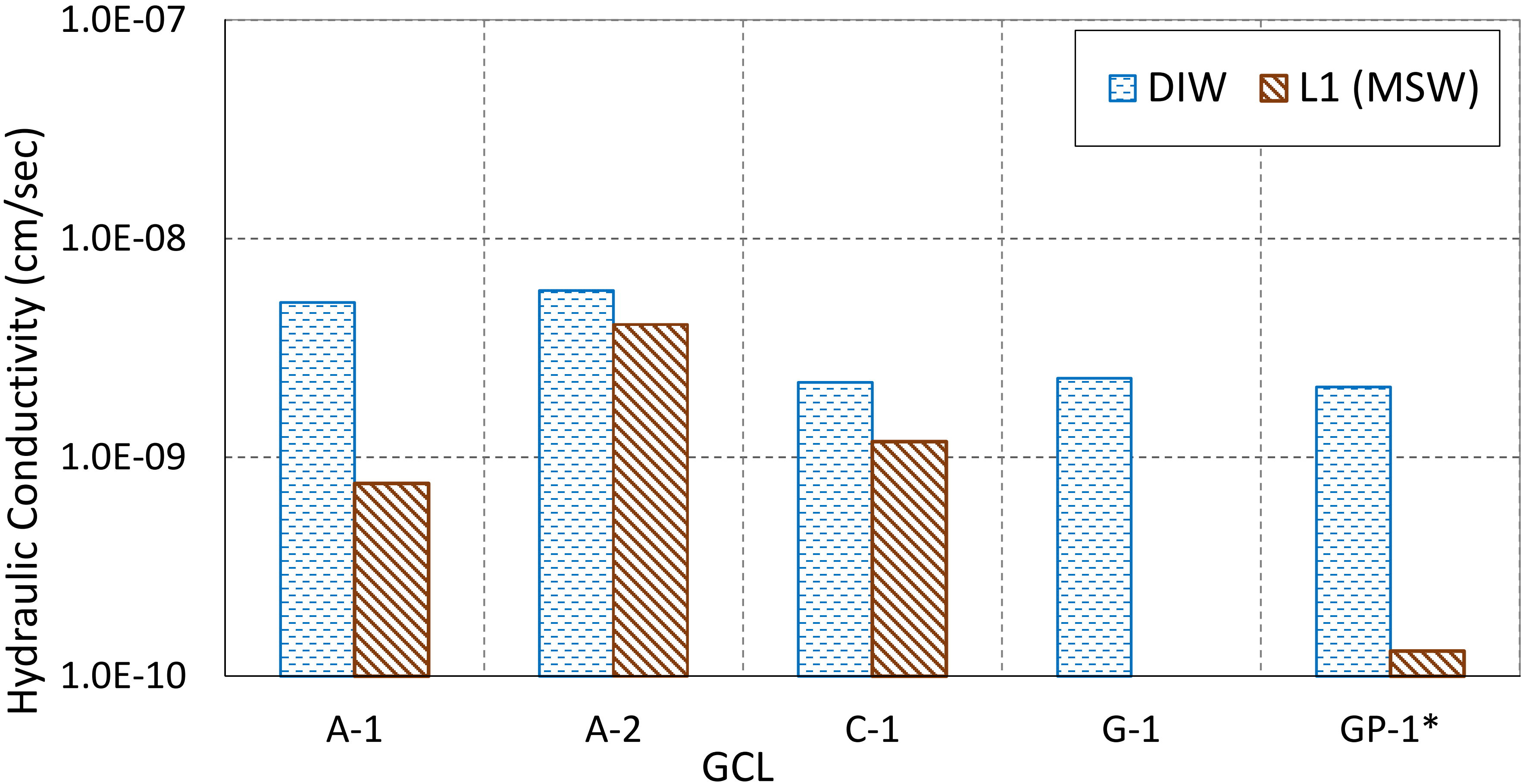


Hydraulic Conductivity Tests (ASTM D 5887)

GCL	D IW	Leachates					
		L1 (MSW)	L2 (MSW+ASH)	L3 (MSW-I)	L4	L5	L6
A-1	$5.1*10^{-9}$	$7.6*10^{-10}$	-	-	-	-	-
A-2	$5.8*10^{-9}$	$4.1*10^{-9}$	-	-	-	-	-
C-1	$2.2*10^{-9}$	$1.2*10^{-9}$	-	-	-	-	-
G-1	$2.3*10^{-9}$	-	-	-	-	-	-
G-2	-	-	-	-	-	-	-
GP-1*	$2.1*10^{-9}$	$1.3*10^{-10}$	-	-	-	-	-

*Polymer Modified

Hydraulic Conductivity Test (ASTM D 5887)



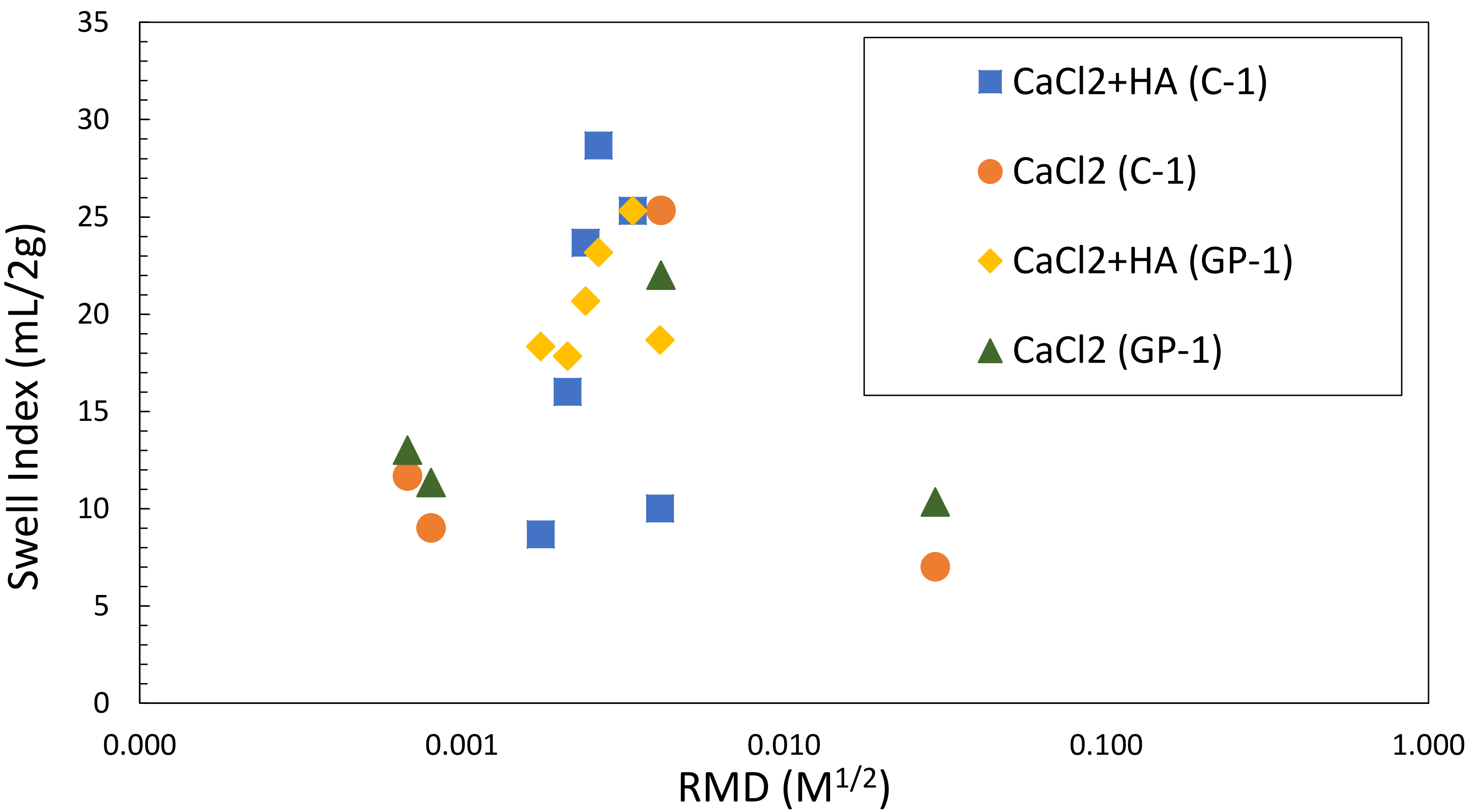
Synthetic Leachate

Permeant solutions	Chemical Characteristics							
	Ca (mM)	Mg (mM)	Na (mM)	K (mM)	pH	EC (µS/cm)	IC (mM)	RMD (mM1/2)
5 mM CaCl2	-	-	-	-	6.1	1160	19	-
10 mM CaCl2	8	0.010	0.358	0.012	6.1	1935	31	0.131
20 mM CaCl2	-	-	-	-	6.1	4037	65	-
50 mM CaCl2	53	0.013	0.139	0.017	6.4	10773	172	0.021
100 mM CaCl2	85	0.019	0.209	0.024	6.0	24960	399	0.025
200 mM CaCl2	173	0.041	12.174	0.048	6.0	44370	710	0.929

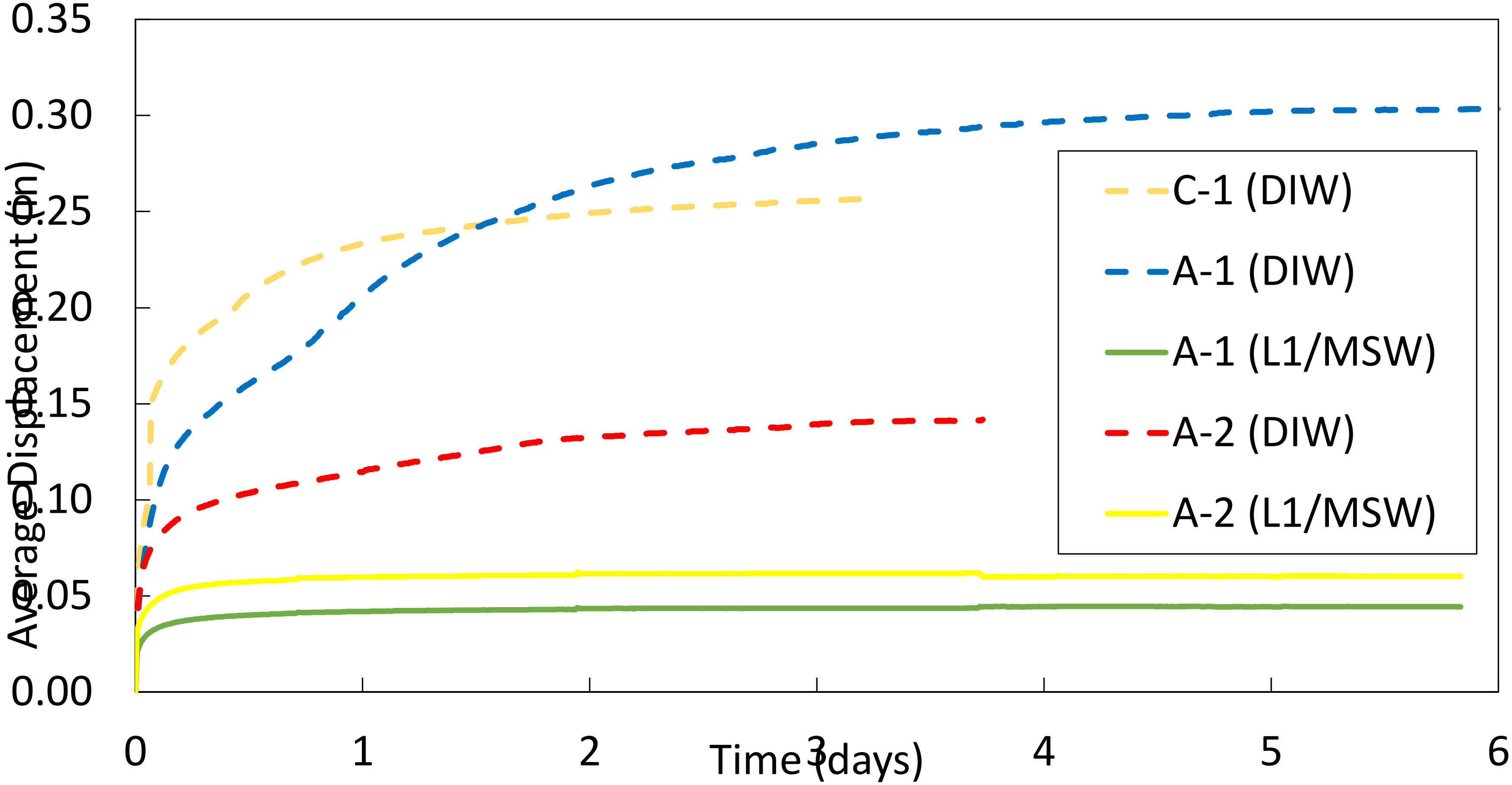
Synthetic Leachate

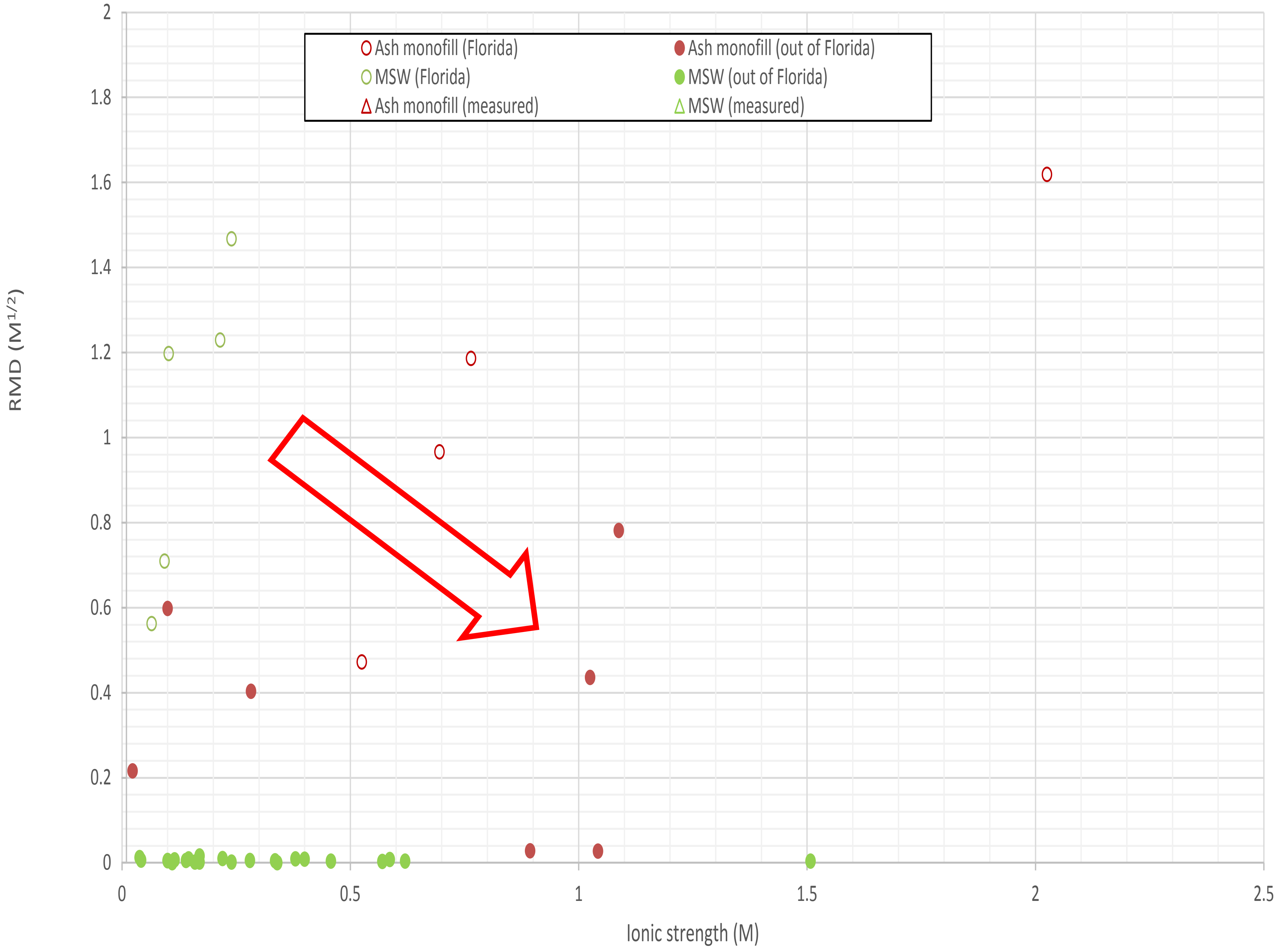
Permeant solutions	Chemical Characteristics							
CaCl2 (mM)+HA(mg/L)	Ca (mM)	Mg (mM)	Na (mM)	K (mM)	pH	EC (µS/cm)	IC (mM)	RMD ($mM^{1/2}$)
5 mM+100 mg/L	2	0.009	0.148	0.016	6.8	1310	20	0.107
10 mM+100 mg/L	5	0.013	0.162	0.019	6.7	2587	41	0.084
20 mM+100 mg/L	10	0.016	0.191	0.051	6.9	4170	67	0.077
50 mM+100 mg/L	24	0.025	0.287	0.042	6.3	10070	161	0.067
100 mM+100 mg/L	45	0.025	0.384	0.490	6.4	18747	300	0.130

Effects of Synthetic Leachate on Swell Index



Effects of Synthetic Leachate on 1-D Swell





Ash monofill (Florida)
Ash monofill (out of Florida)
MSW (Florida)
MSW (out of Florida)
Ash monofill (measured)
MSW (measured)
RMD (M1/2)
Ionic strength (M)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
0.5
1
1.5
2
2.5

Thank You!!!