Application of New Leaching Protocols for Assessing Beneficial Use of Solid Wastes in Florida

Technical Awareness Group Meeting

June 30th, 2015

UF
UNIVERSITY of FLORIDA

Hinkley Center
for Solid and Hazardous
Waste Management

Background

- Historically a number of different tests have been used to evaluate chemical release from waste materials
- Four years ago the US EPA released a suite of standardized leaching methods with the objective of creating a uniform framework for waste characterization
  - One of the main applications for these tests is characterization in beneficial use assessments
- There were questions in Florida and throughout the country as to how these tests could be implemented and the data interpreted

Presentation Objectives

- Review background and project objectives
- Present results of leaching work
- Provide hands on demonstration of applications
- Conduct beneficial use assessment using results of LEAF testing
- Foster a discussion on the applications of LEAF tests moving forward

Examples of LEAF in Beneficial Use Assessments

- Florida
  - Water Treatment Residues
  - Waste to Energy Ash
- United States
  - FGD in Gypsum Wallboard
  - Coal Fly Ash in Concrete

Leaching Test Review

- Traditionally two leaching tests have been used for regulatory characterization of wastes
  - Toxicity Characteristic Leaching Procedure –

  TC Hazardous Waste Classification
  - Synthetic Precipitation Leaching Procedure –

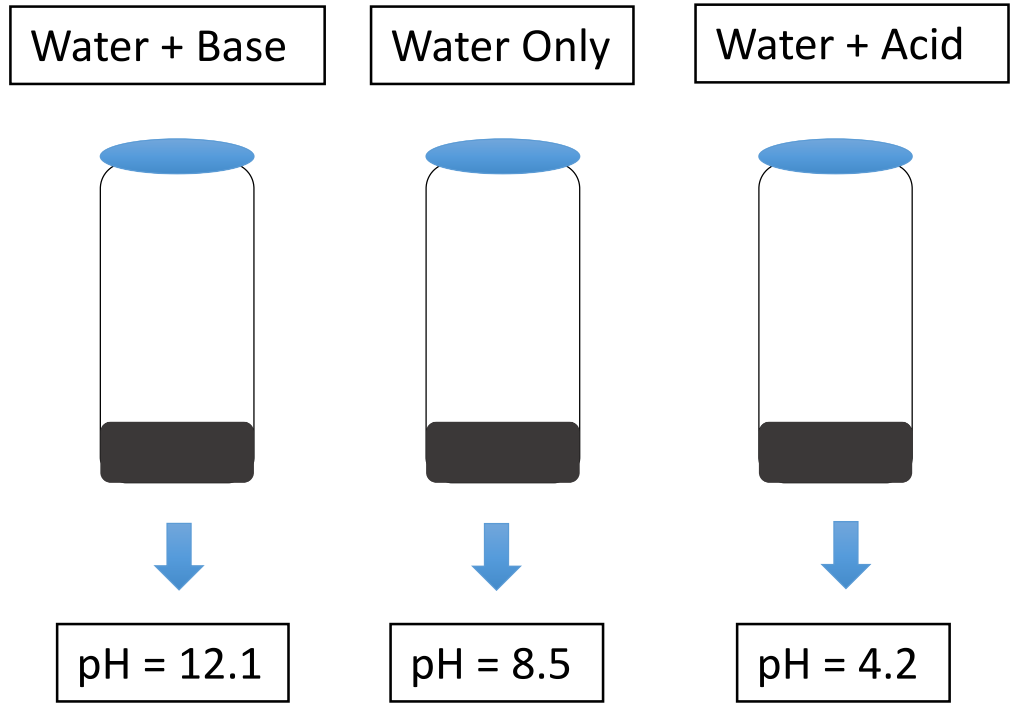
  Out of landfill/beneficial uses
- The LEAF has four different methods aimed a evaluating different leaching parameters:
  - EPA Method 1313 – pH dependent leaching test
  - EPA Method 1314 – column leaching test
  - EPA Method 1315 – tank or monolith leaching test
  - EPA Method 1316 – batch leaching as a function of liquid to solid ratio

Method 1313

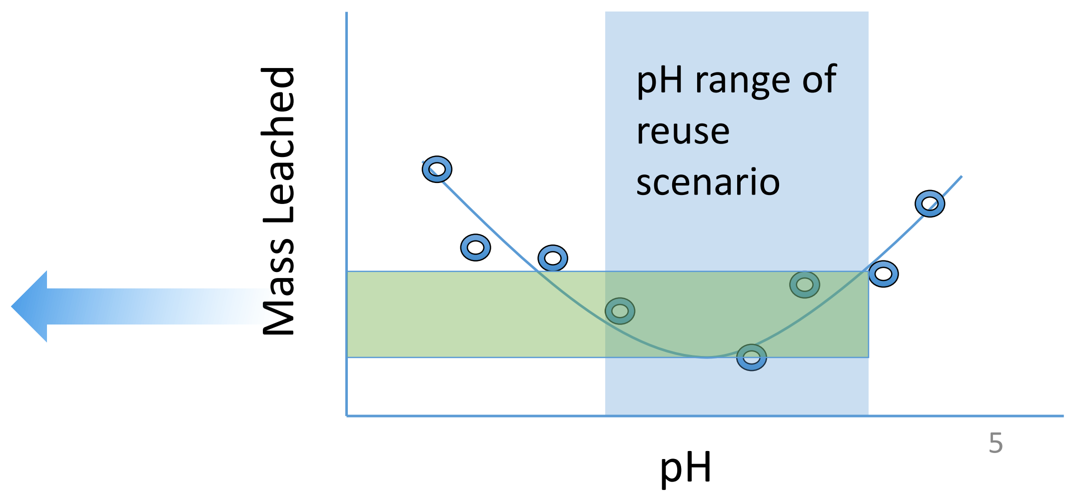
Parallel batch extraction done at a 10:1 liquid to solid ratio (10ml/g-dry) at up to 9 <u>final</u> pH values

Samples rotated for 24-72 hours

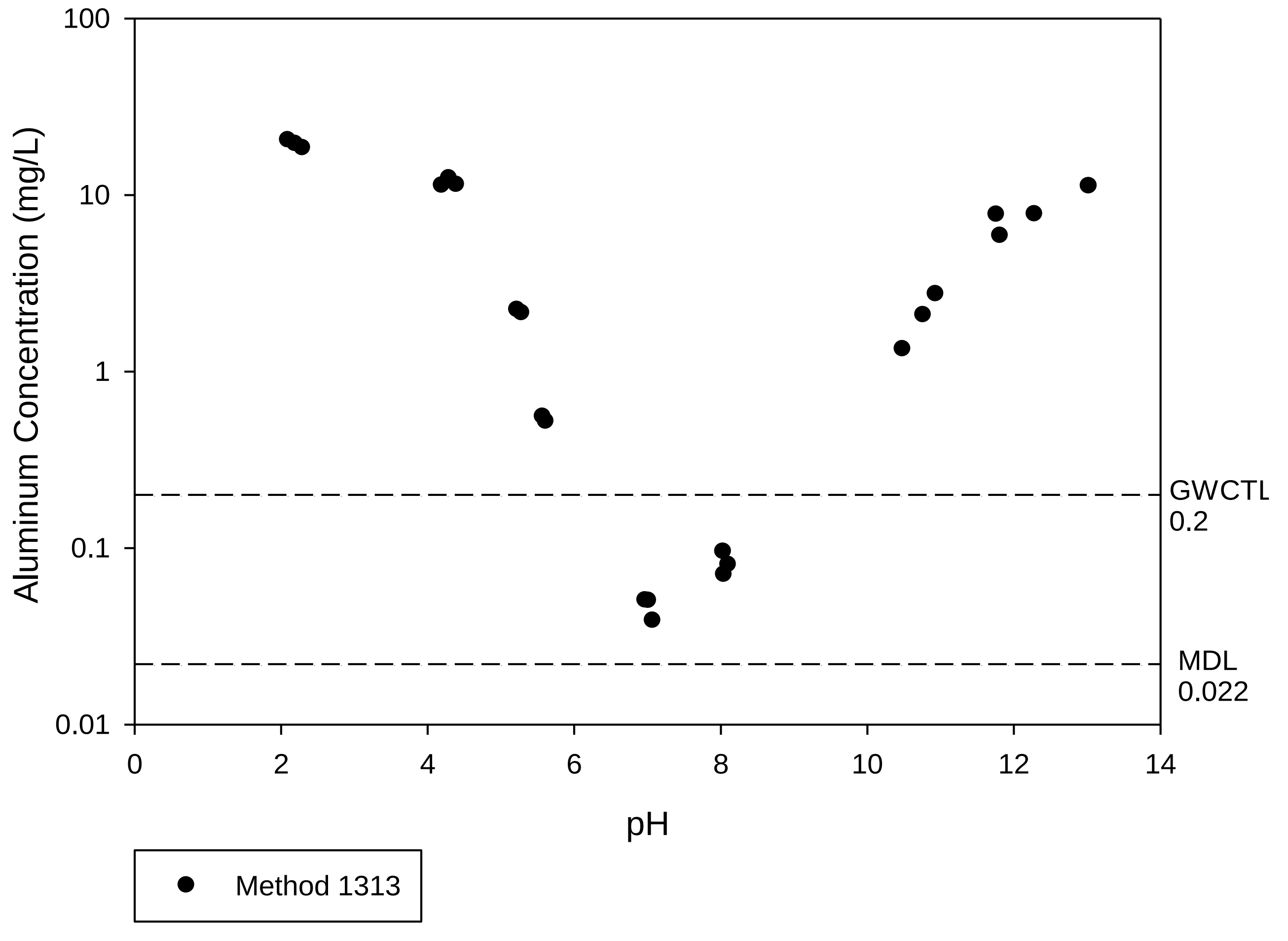
Goal: determine the leachability of the material for a range of pH values



Expected leaching within pH range

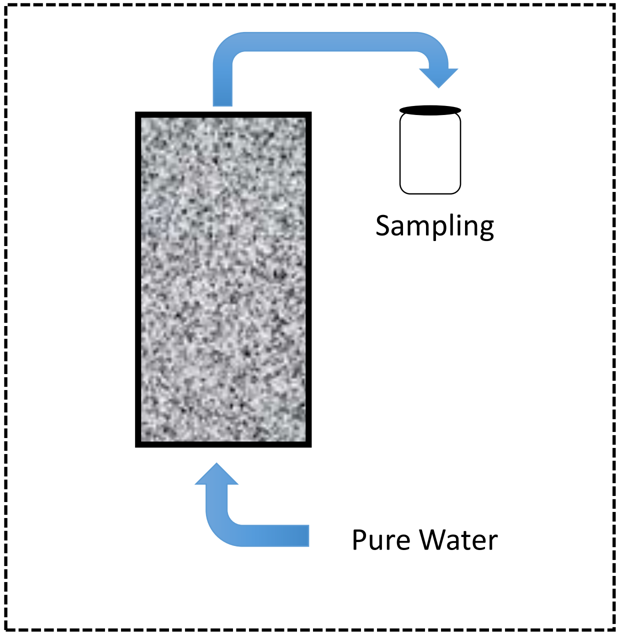


Example Method 1313 Results Water Treatment Residues

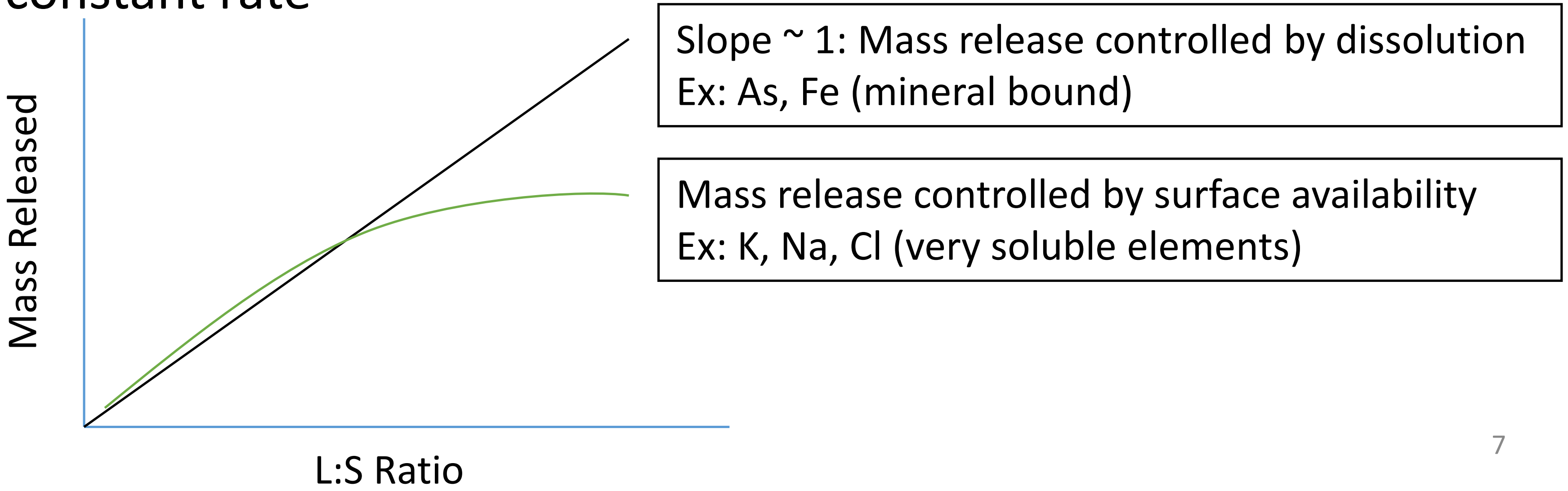


Method 1314

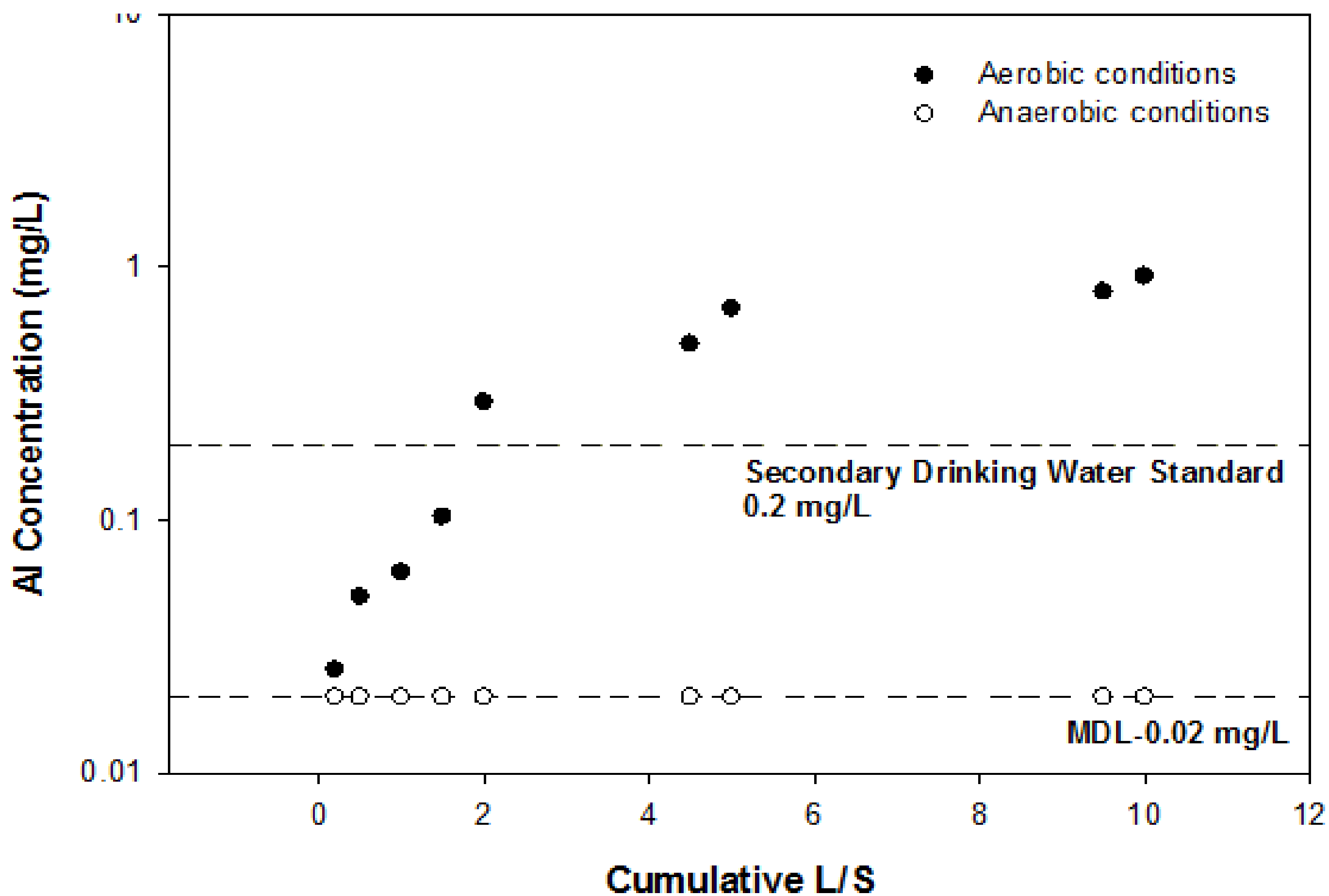
Column leaching test with constant upward flow of pure water. Samples are taken at prescribed days to achieve specific L/S ratios



Goal: Determine which constituents wash out quickly and which dissolve into the water at a constant rate

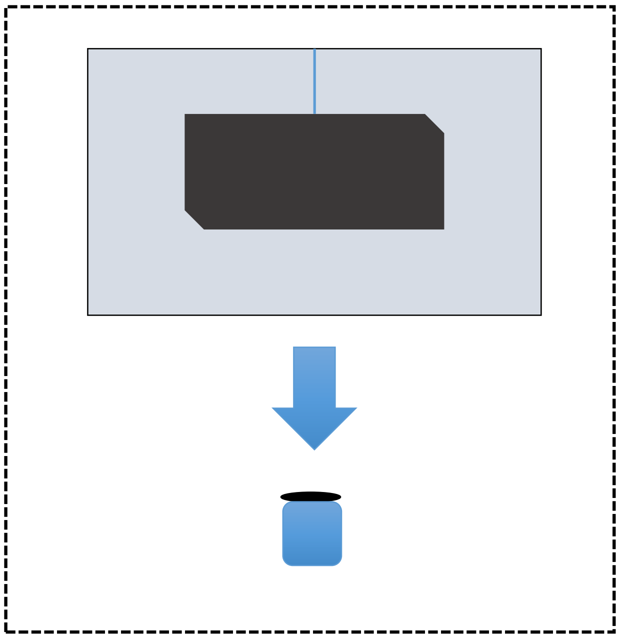


Example Method 1314 Results Water Treatment Residues

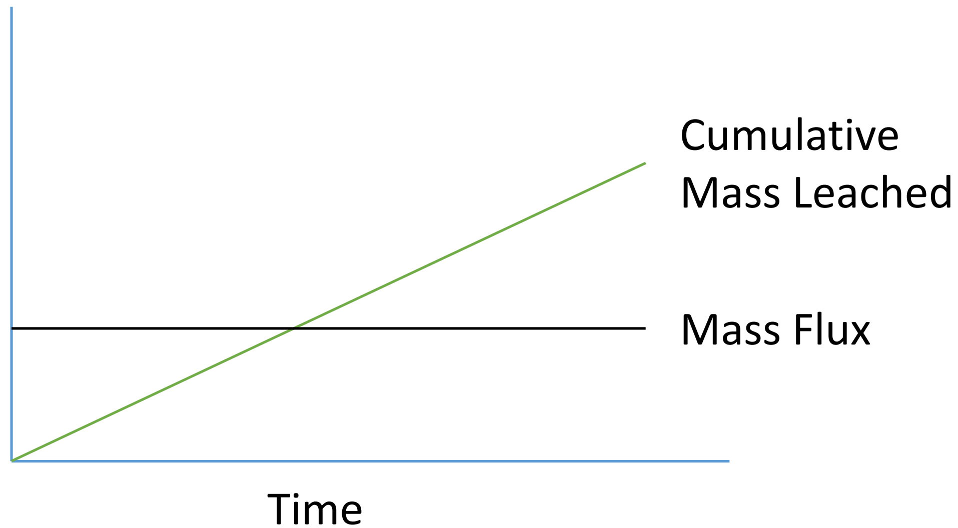


Method 1315

Monolithic material sample (e.g. a brick) or a compacted granular material is submerged in a tank of water and allowed to soak for prescribed times. Water is periodically sampled and analyzed for constituents of concern. New water replaces the old.

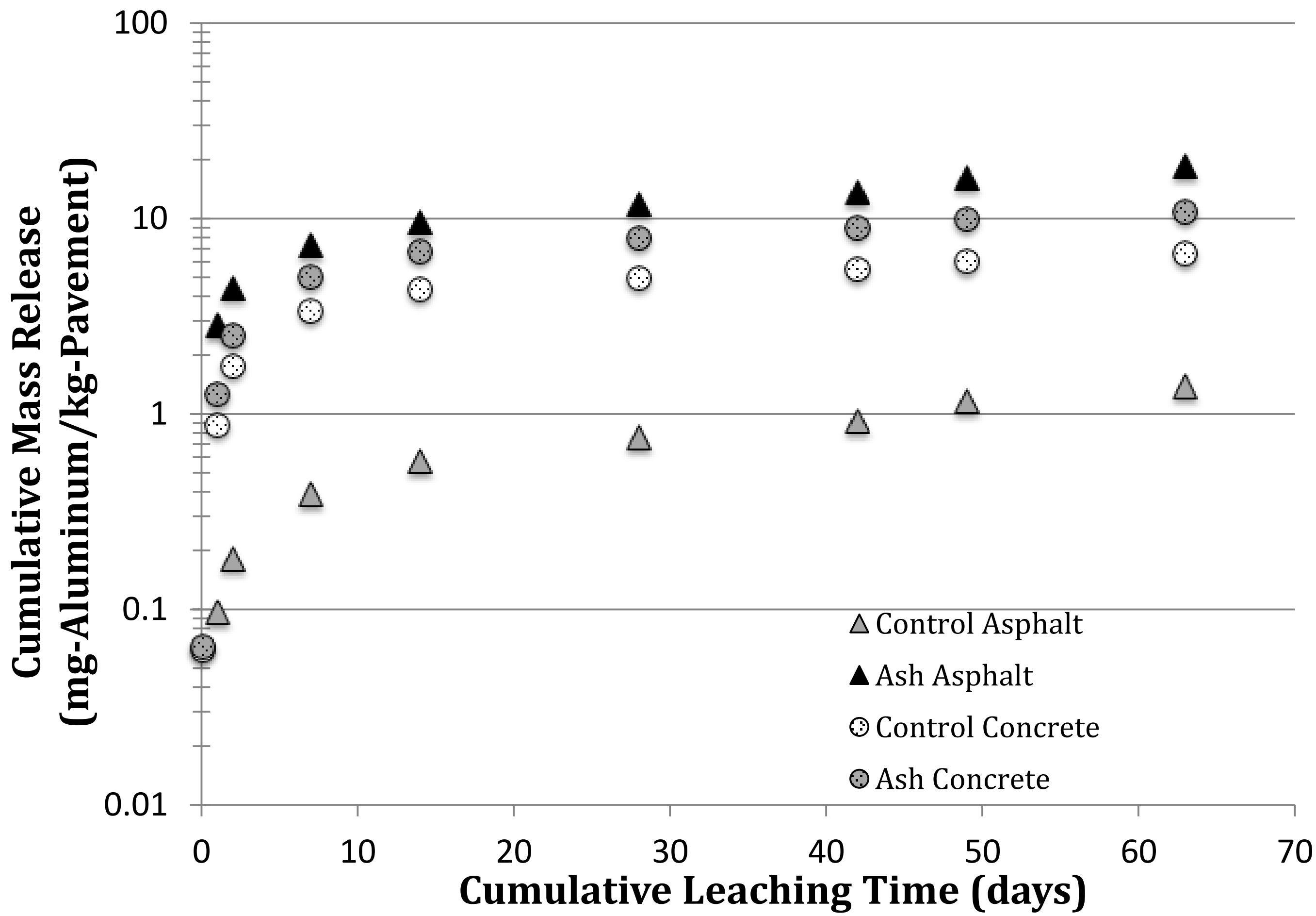


Goal: Determine time-dependent release rates under monolithic conditions



This information can help in predicting mass release in the long run

Example Method 1315 Results
WTE Bottom Ash Amended Pavements

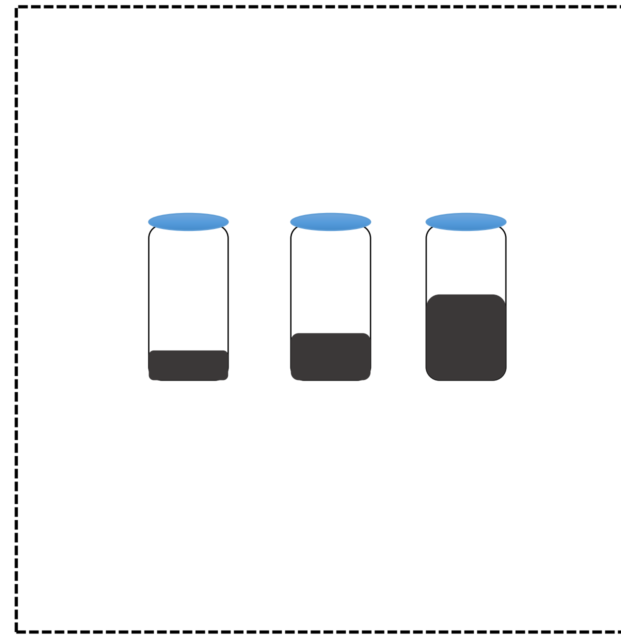


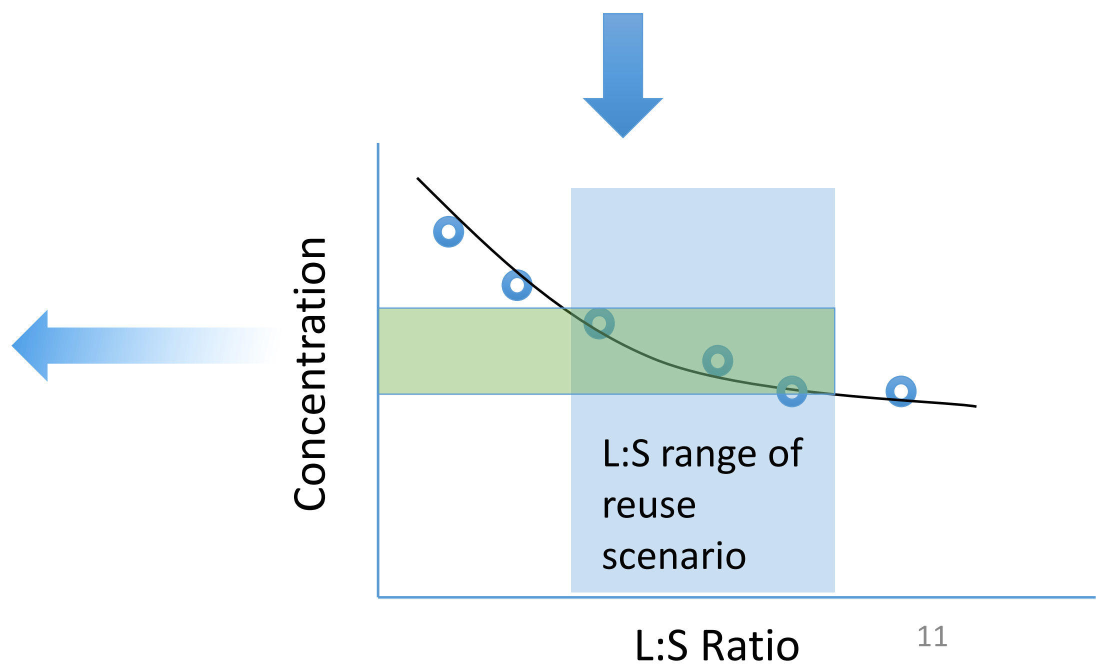
Method 1316

Interpreting Results

Parallel batch performed at five different liquid to solid ratios.

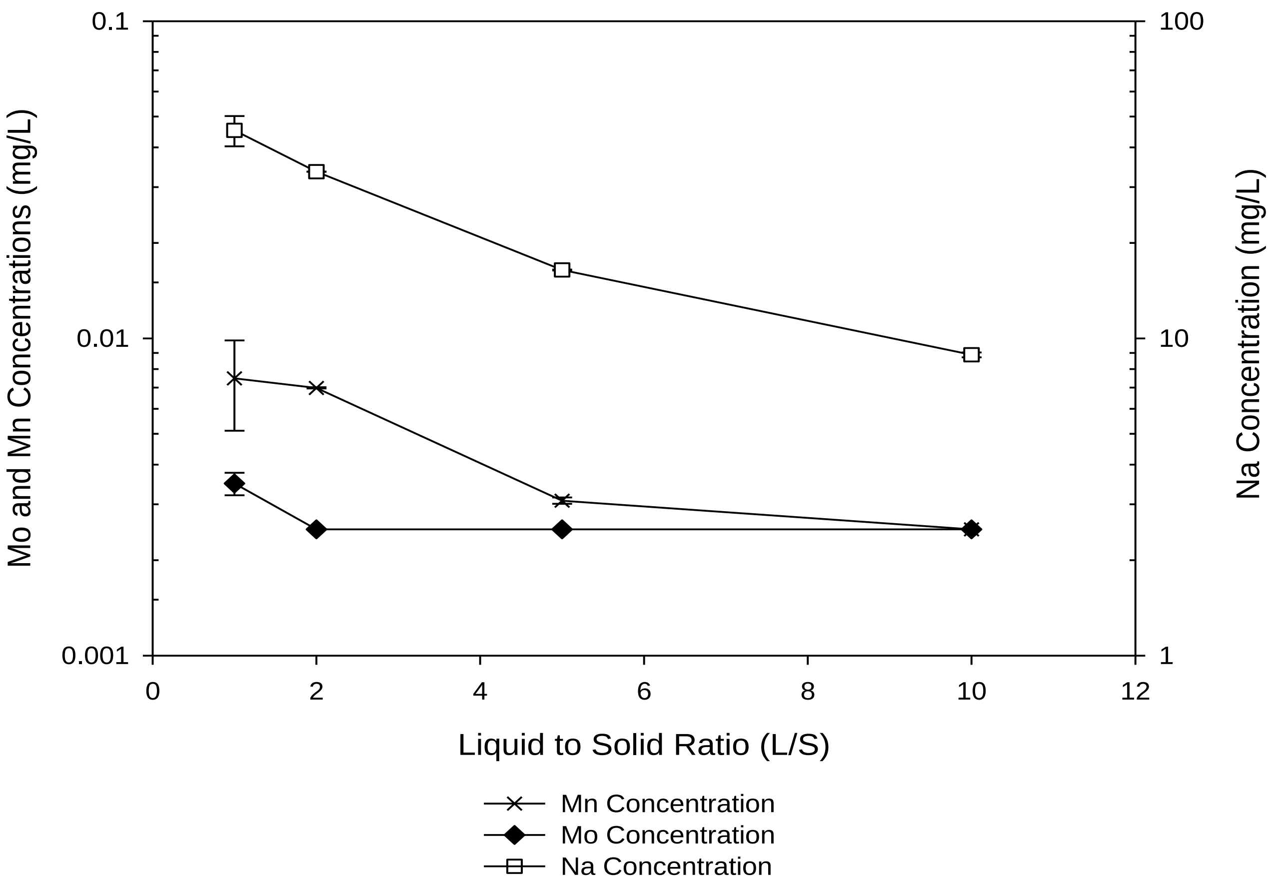
Similar to 1314 but more rapid.





Expected leaching within L:S range

Example Method 1316 Results Water Treatment Residues



Project Objective

- Examine previous beneficial use assessments in Florida and assess how LEAF may have impacted decision making

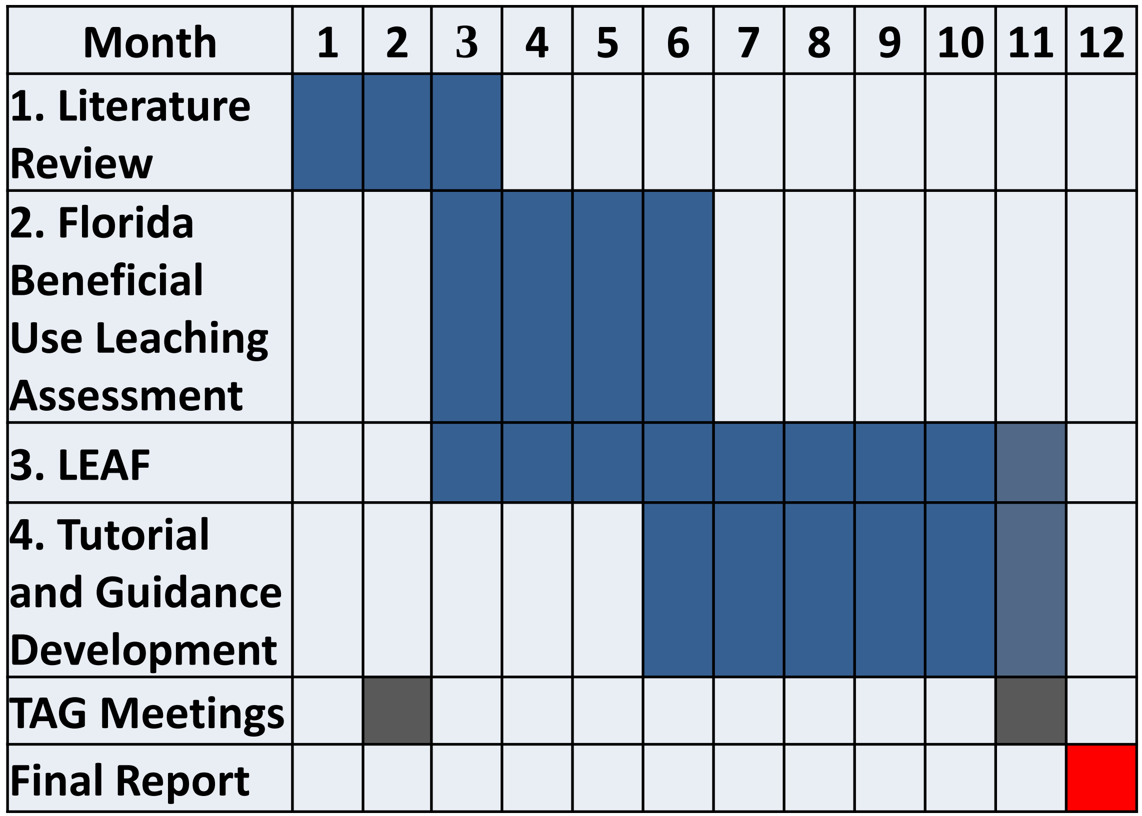
Project Objective

- Perform leaching tests on three specific waste streams and use LEAF results as part of a comparative beneficial use assessment
- Present examples to project TAG
- Produce LEAF guidance document and tutorials

Project Timeline

RSM, street sweepings, drinking water sludge, wood ash, …

→ Videos
→ Report
→ Application scenarios



Focus on ash:
→ Wood
→ WTE
→ Blend

Waste for Evaluation and Demonstration

- Wood and Tire ash from Ridge Generating Station
- Previously characterized material
  - SPLP, Totals, Column Testing
- Wood ash used as soil amendment in agricultural applications

Present Assessment

- SPLP
- Total concentration
- **LEAF**
  - 1313 - pH dependent leaching
  - 1314 - Liquid to solid ratio (continuous)
  - 1315 - Diffusion from compacted material
  - 1316 - Liquid to solid ratio (batch)

Previous Risk Assessment: Direct Exposure

		Florida Thresholds (mg/kg)	
Element	**Totals Avg. ± std (mg/kg)**	**Residential SCTL**	**Commercial SCTL**
Al	3.94 ± 0.7 (g/kg)	80,000	NA
As	37.2 ± 6.0	2.1	12
Ba	39.3 ± 7.0	120	130,000
Ca	223 ± 50 (g/kg)	-	-
Cd	2.71 ± 0.5	82	1,700
Co	129 ± 30	4,700	110,000
Cr	46.3 ± 5	210	420
Cu	162 ± 30	110	76,000
Fe	34.7 ± 5 (g/kg)	23,000	480
K	6.67 ± 0.8 (g/kg)	-	-
Mg	5.42 ± 1 (g/kg)	-	-
Mn	307 ± 80	1,600	22,000
Na	1.8 ± 0.02 (g/kg)	-	-
Ni	16.7 ± 4	110	28,000
Pb	63.1 ± 10	400	920
V	5.49 ± 2	15	7,400
Zn	18.2 ± 3 (g/kg)	2,300	560,000

(Tolaymat et al., 2008)

Previous Risk Assessment: Groundwater

Element	SPLP Mean ± STD	GWCTL
Al (mg/L)	<0.007	0.2
Na (mg/L)	32.5 ± 3.9	160
Zn (mg/L)	1.72 ± 0.19	5.0
As (µg/L)	<5	10
Ba (µg/L)	218 ± 80	2,000
Co (µg/L)	<11	420
Cr (µg/L)	7.0 ± 0.4	100
Cu (µg/L)	<14	1,000
Fe (µg/L)	116 ± 50	300
Mn (µg/L)	< 11	50
Ni (µg/L)	< 15	100
Pb (µg/L)	52.3 ± 9	15

(Tolaymat et al., 2008)

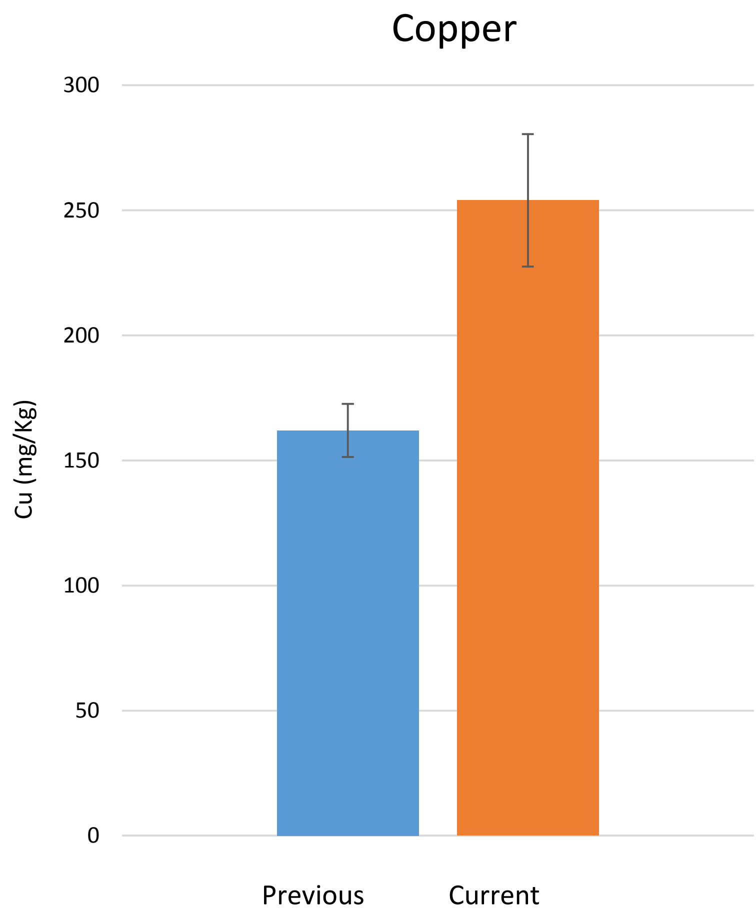
Results of Present Day Testing

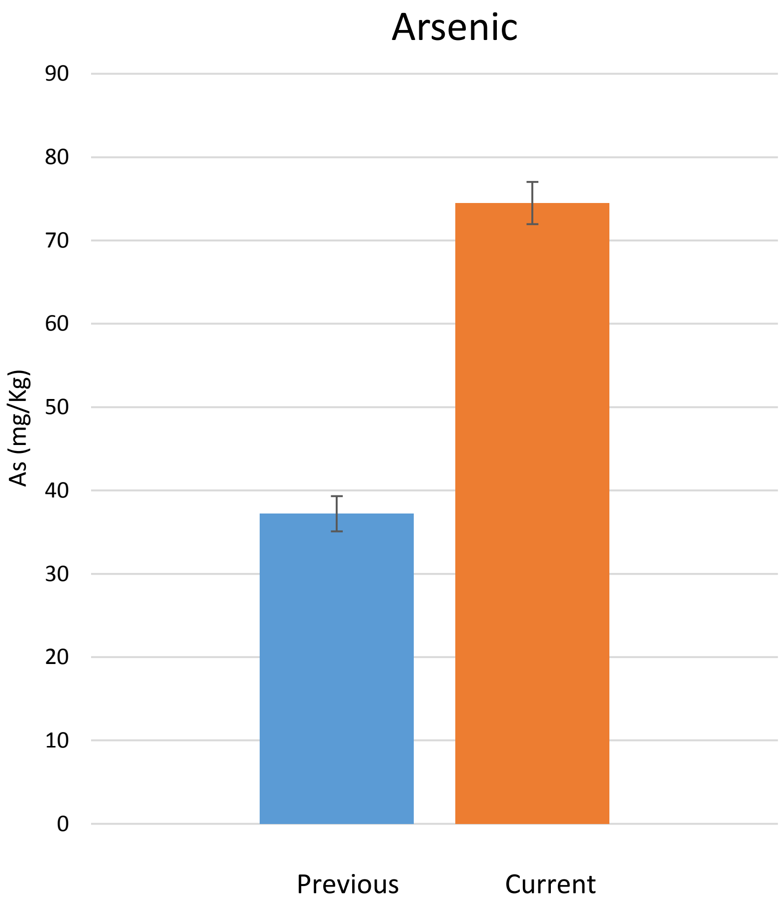
Present Day SPLP and Totals

- Results are similar to that of the previous assessment
- Elevated lead leaching observed, though available lead is relatively low based on totals
- Copper and arsenic still exceed SCTLs

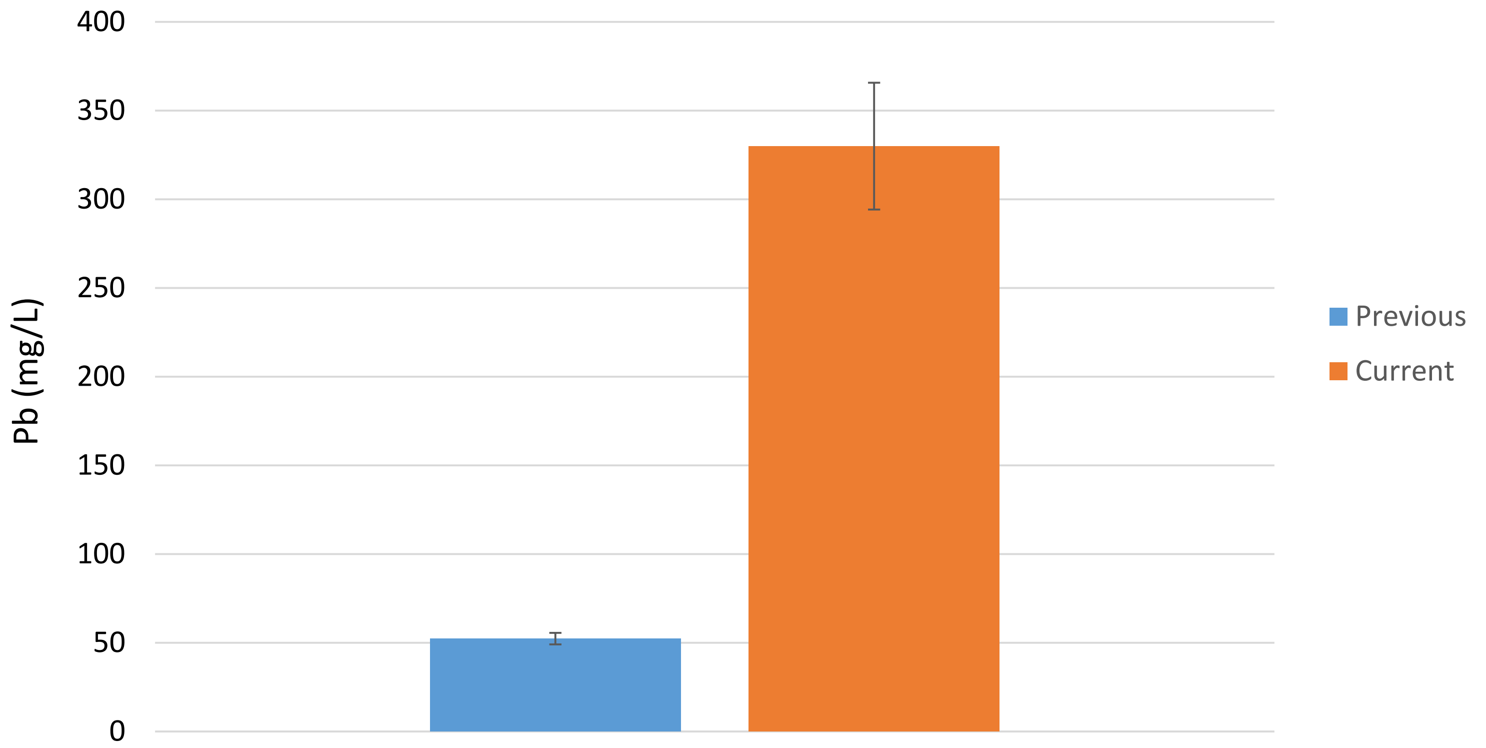
Element	SPLP Mean ± STD (µg/L)	GWCTL	
Pb	330 ± 101	15	
Element	Totals Avg. ± std (mg/kg)	Residential SCTL	Commercial SCTL
Cu	254 ± 75	110	76,000
As	74.5 ± 7.2	2.1	12

Total Concentration Copper and Arsenic





SPLP Results - Lead



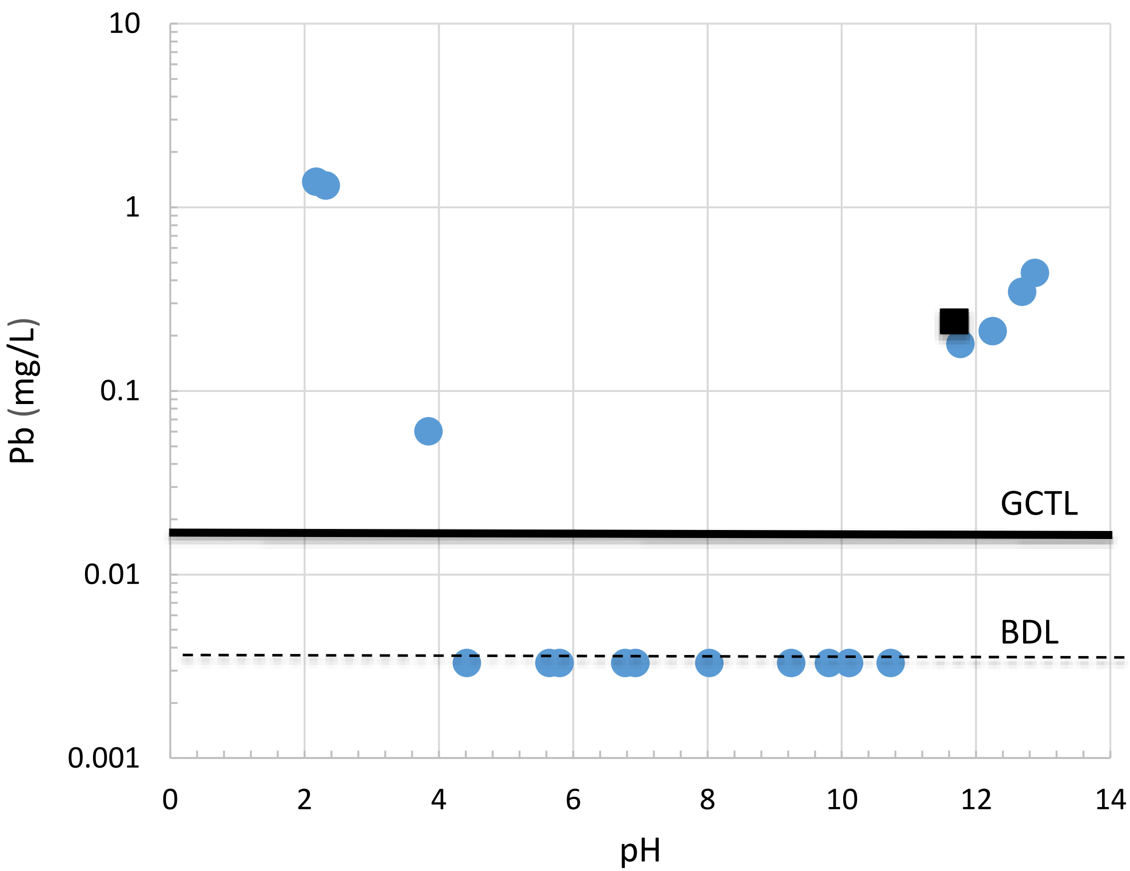
What Can We Learn From LEAF?

- What are the factors that contribute to elevated release of lead despite its relatively low concentration?

What Can We Learn From LEAF?

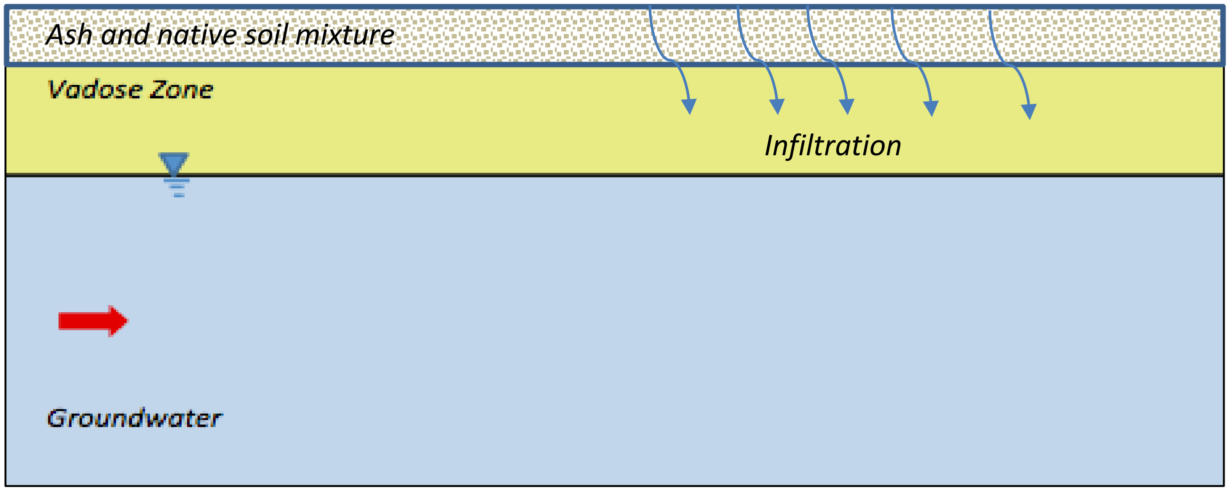
- Does percolation of water through the material influence leached concentrations relative to the SPLP?
- How could changes to the pH of the material effect the leaching of the wood tire ash

Leaching as a Function of pH
Lead



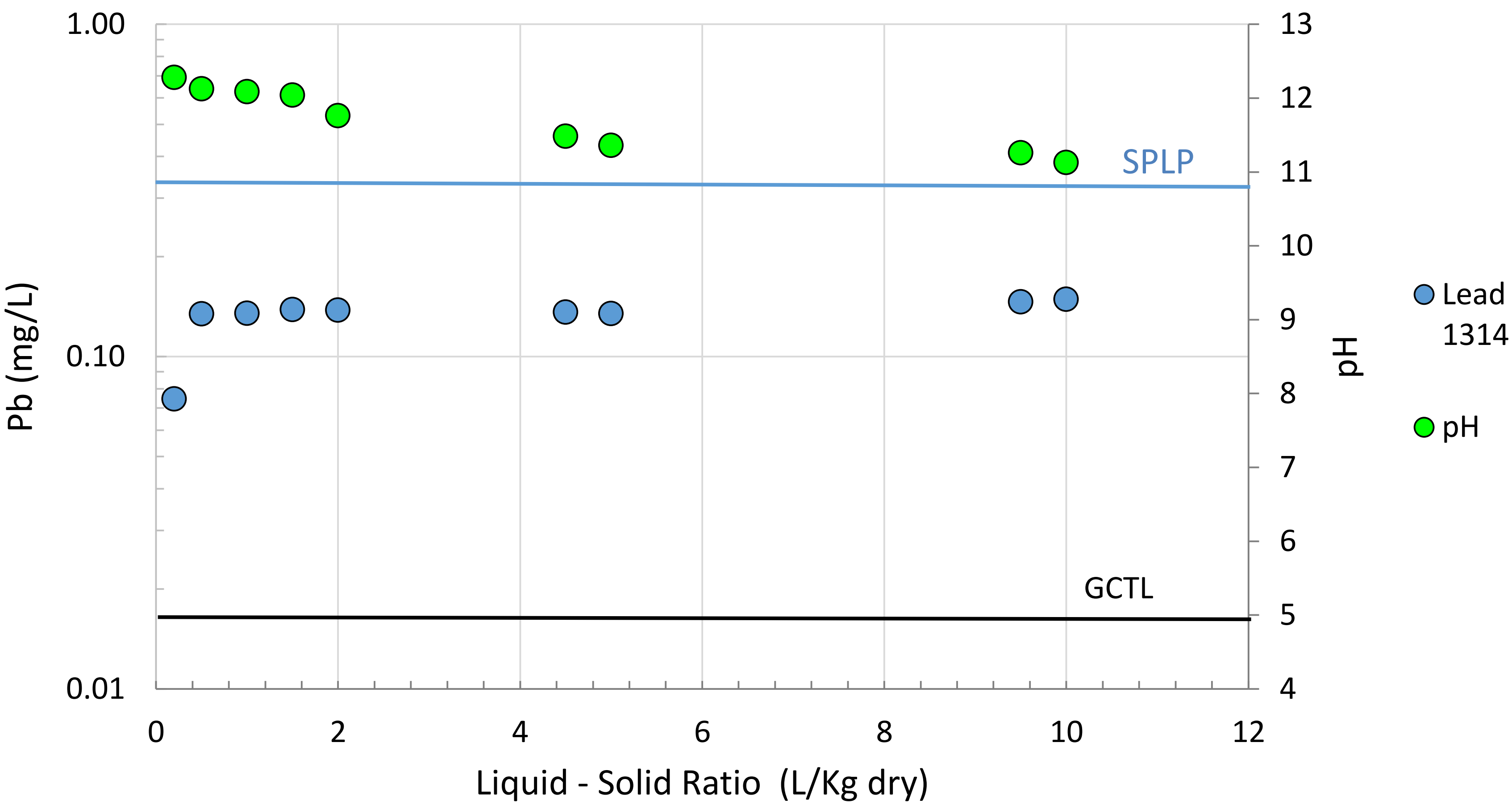
- Amphoteric behavior
- pH of SPLP extract 11.0 – 0.33 mg/L ■
- The high pH of the samples facilitates the leaching of Pb even though there is little present

Infiltration and Leaching

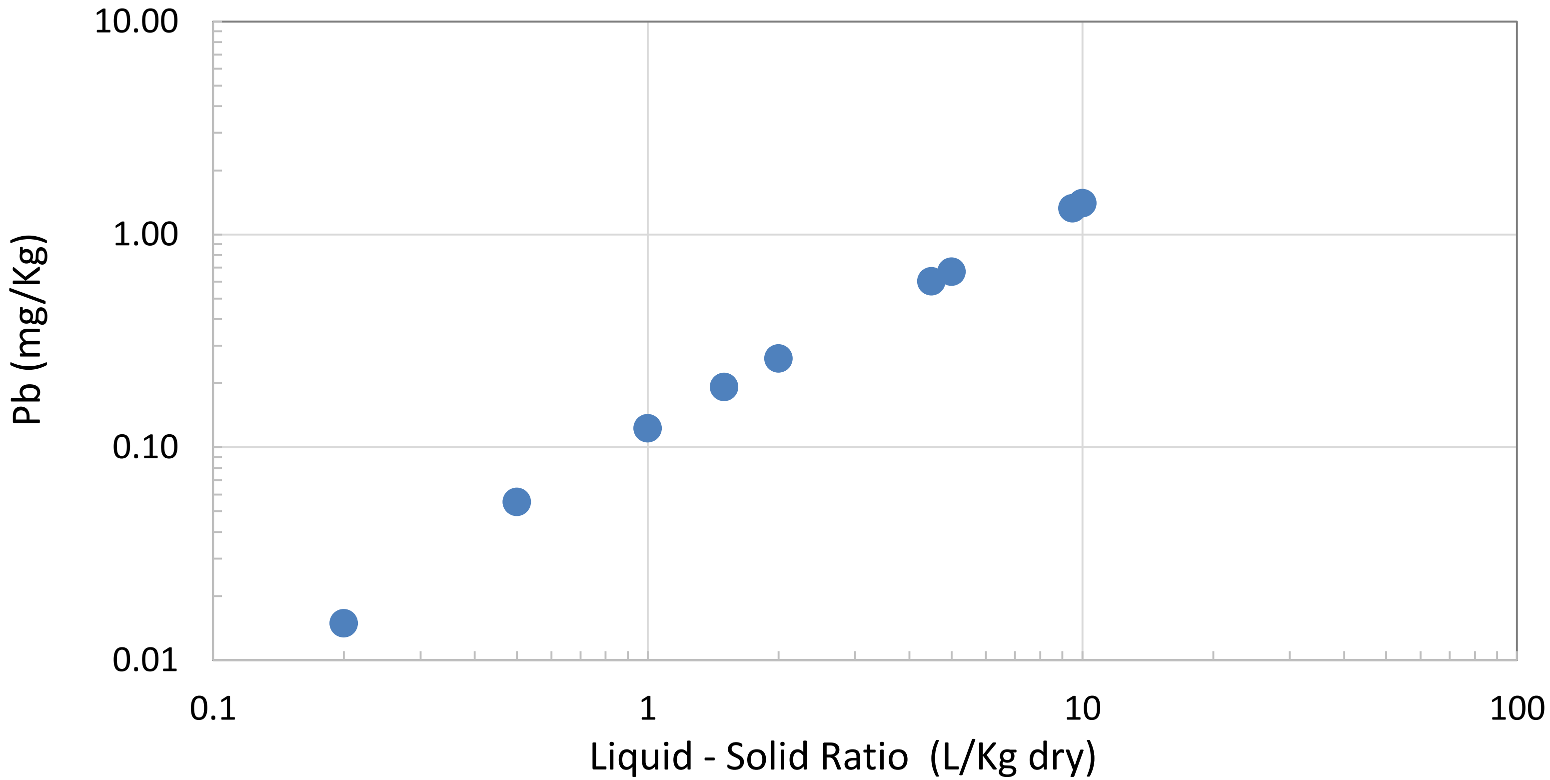


- Infiltration through a land applied material is a common leaching scenario
- Infiltrating water would be expected to take on the pH of alkaline material
- Would lead wash off the material, or show sustained release?
- Column test (1314) can be used to answer these questions

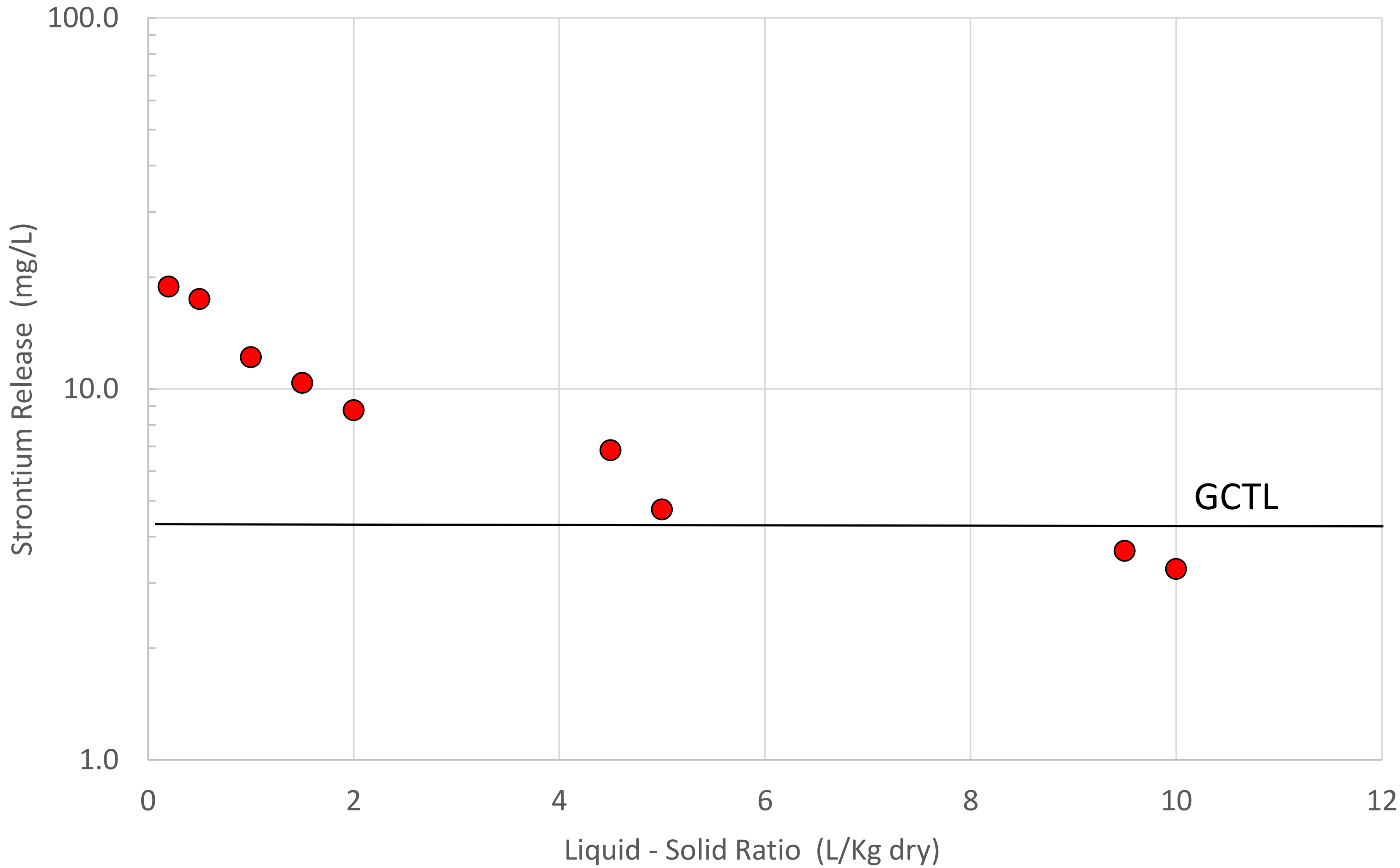
Column Test 1314 - Lead



Column Test 1314 – Lead Cumulative Release



Column Test 1314 - Strontium



Data Interpretation

- We see a consistent release of lead independent of the liquid to solid ratio (L/S)
- Lead was not found to be depleted or washed from the surface of the material
- This suggests that lead release is governed primarily by:
  - pH dependent solubility
  - diffusion from the material

Data Interpretation

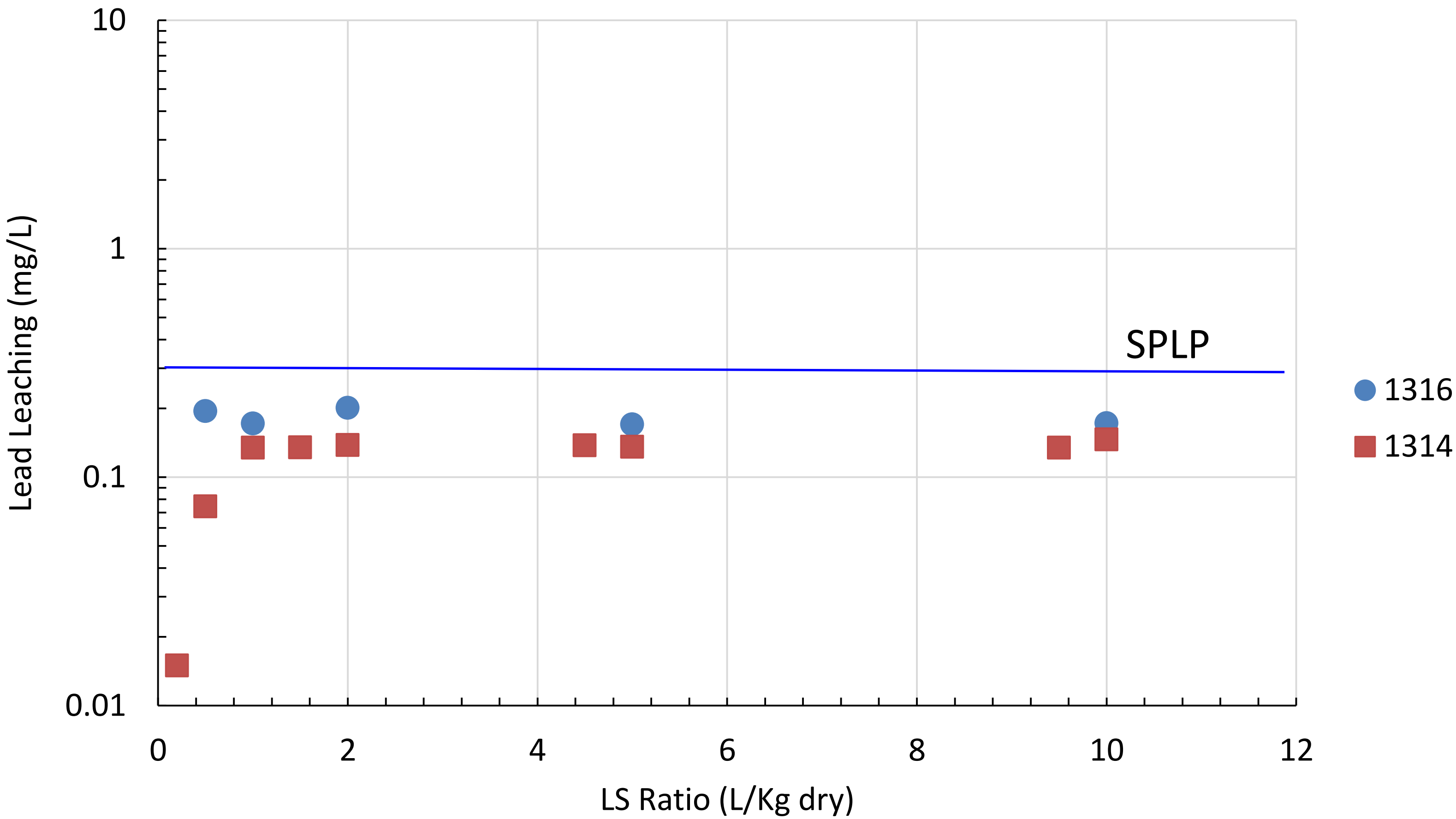
- Under these conditions, elevated lead leaching could be expected to persist for longer periods of time with this pH regime

- Strontium was below the GCTL for the SPLP and was found to be elevated above the GCTL at low L/S

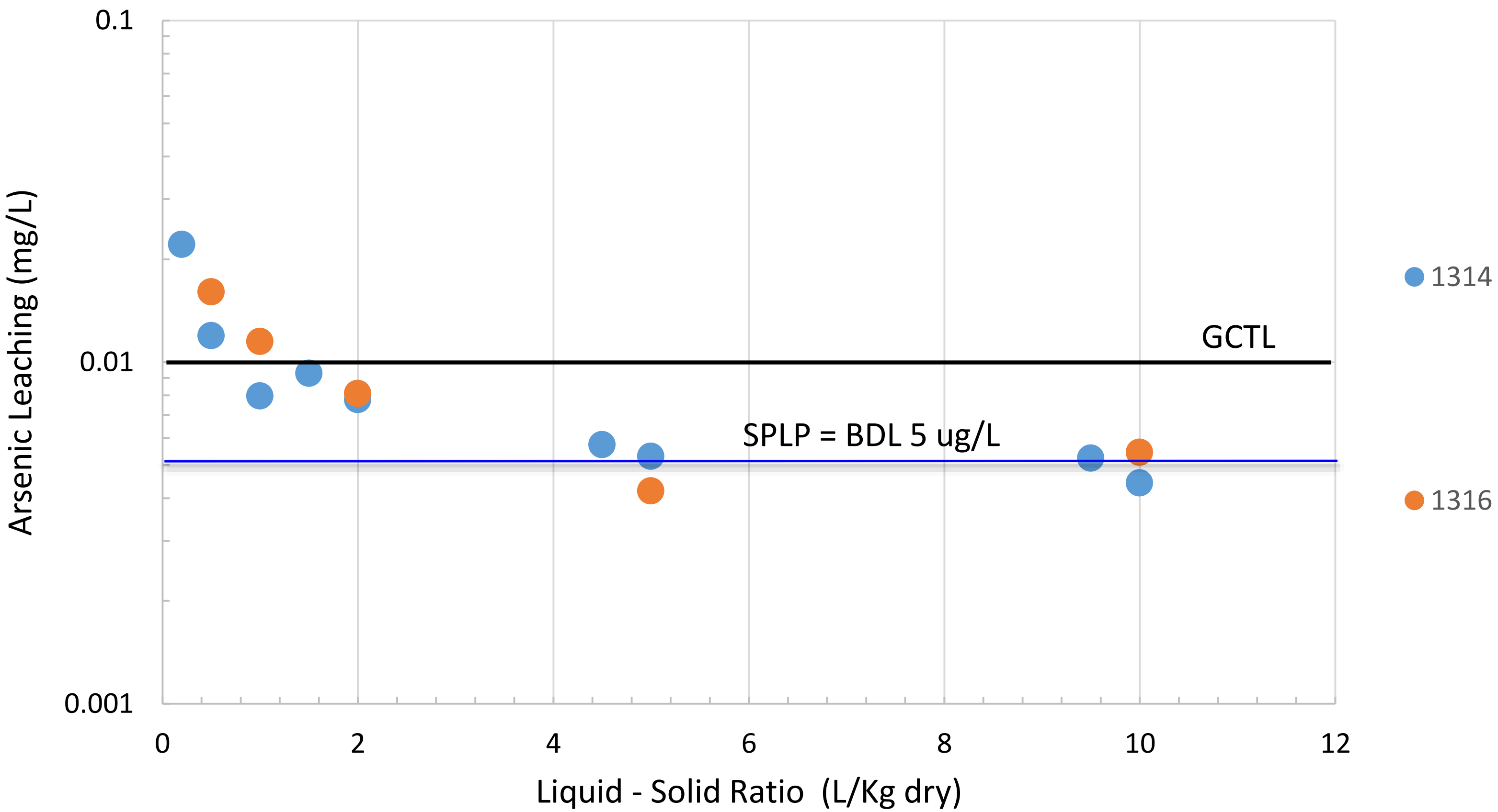
Method 1316

- Method 1316 was developed as a quicker, cheaper and easier to implement version of Method 1314
- Results from 1314 and 1316 are expected to be similar to 1316 values
- Here we examine the results from method 1316 for the wood and tire ash

Methods 1314 and 1316 - Lead



Methods 1314 and 1316 - Arsenic



Method 1316

- The results of method 1316 and 1314 match up relatively well
- For arsenic, similar to strontium, concentrations exceeded GCTLs at low L/S
- For lead, the leached values in the SPLP test are elevated above the 1316 results

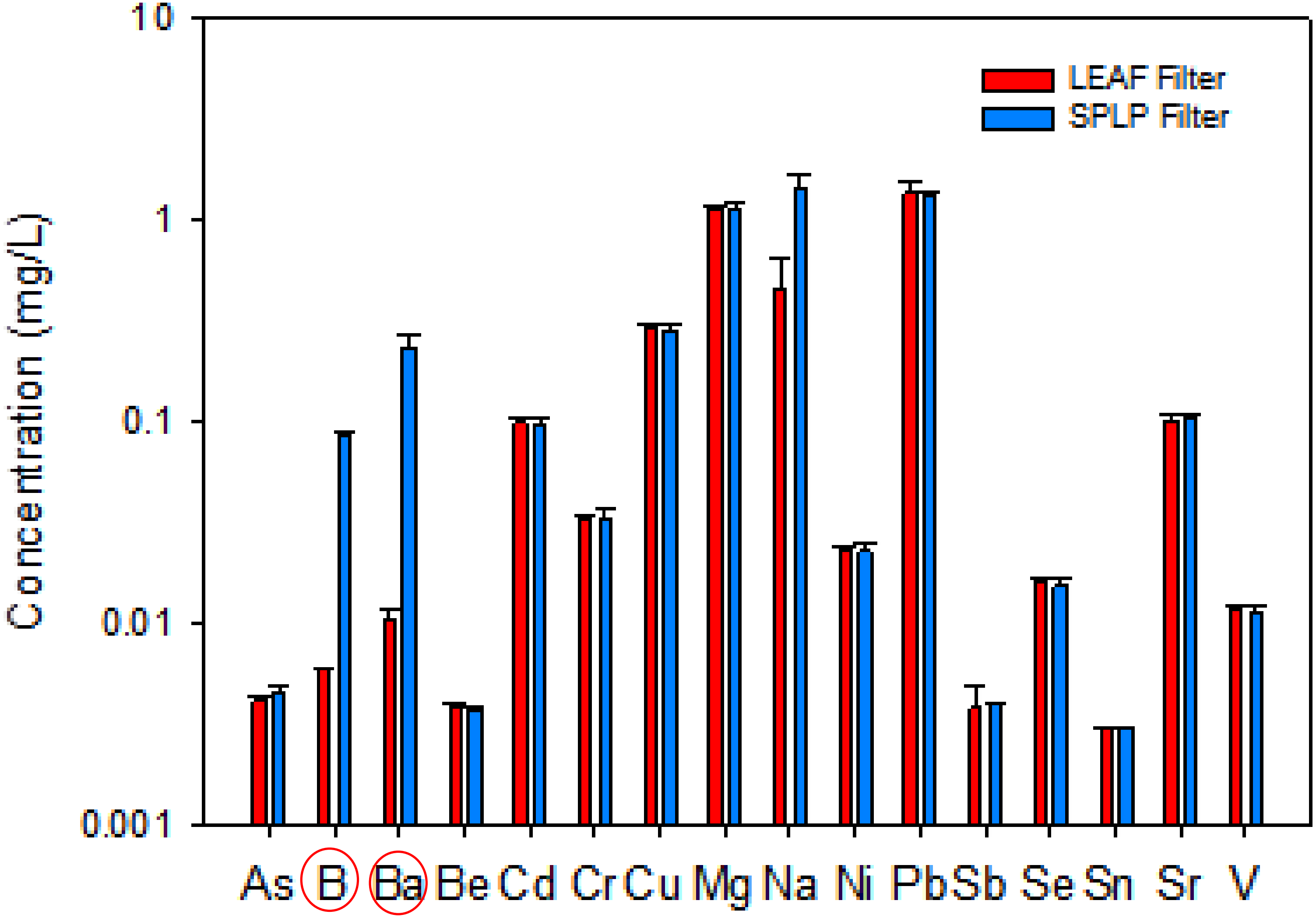
Why are the Results from SPLP higher than Method 1316?

- The liquid to solid ratio would typically result in a lower concentration seen in the SPLP
  - The SPLP has a higher L/S effectively "diluting" the amount of chemicals in solution
- Method 1316 max L/S = 10
- Method 1312 (SPLP) max L/S > 20
- However the filters used are different pore sizes and materials
  - SPLP 0.6-0.8 um nominally rated glass fiber filters
  - LEAF 0.45 um absolute rated polypropylene filters

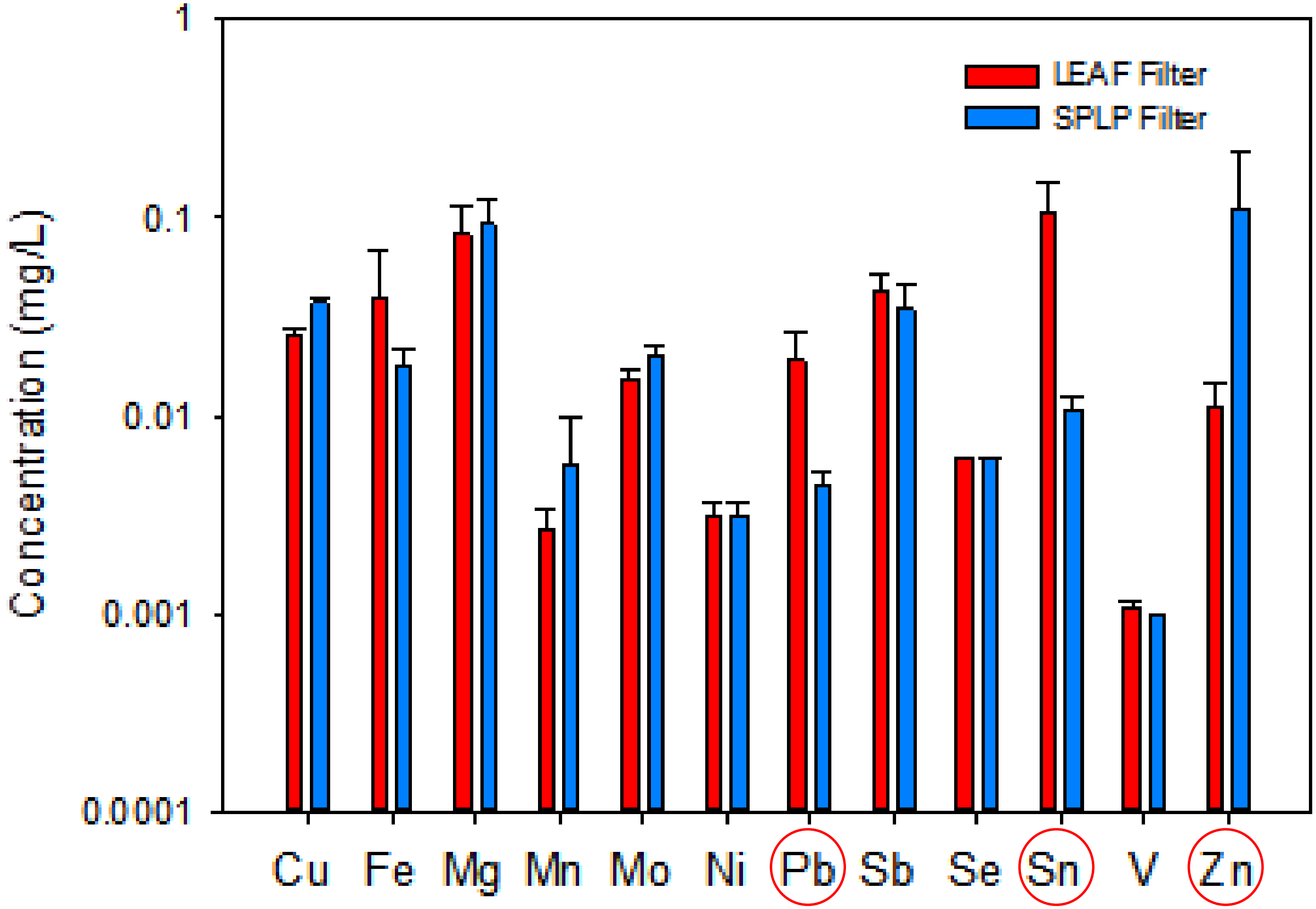
Filter Comparison

- Wastes were leached with water at a L/S of 10
- The same sample was filtered with the two different filters (SPLP and LEAF)
- For some elements a significant difference was seen
- Also seen in some of the drinking water sludge samples tested
- Highlighted in our paper recently published in Waste Management; *Evaluation of the impact of lime softening waste disposal in natural environments*

Filter Comparison Mine Tailings



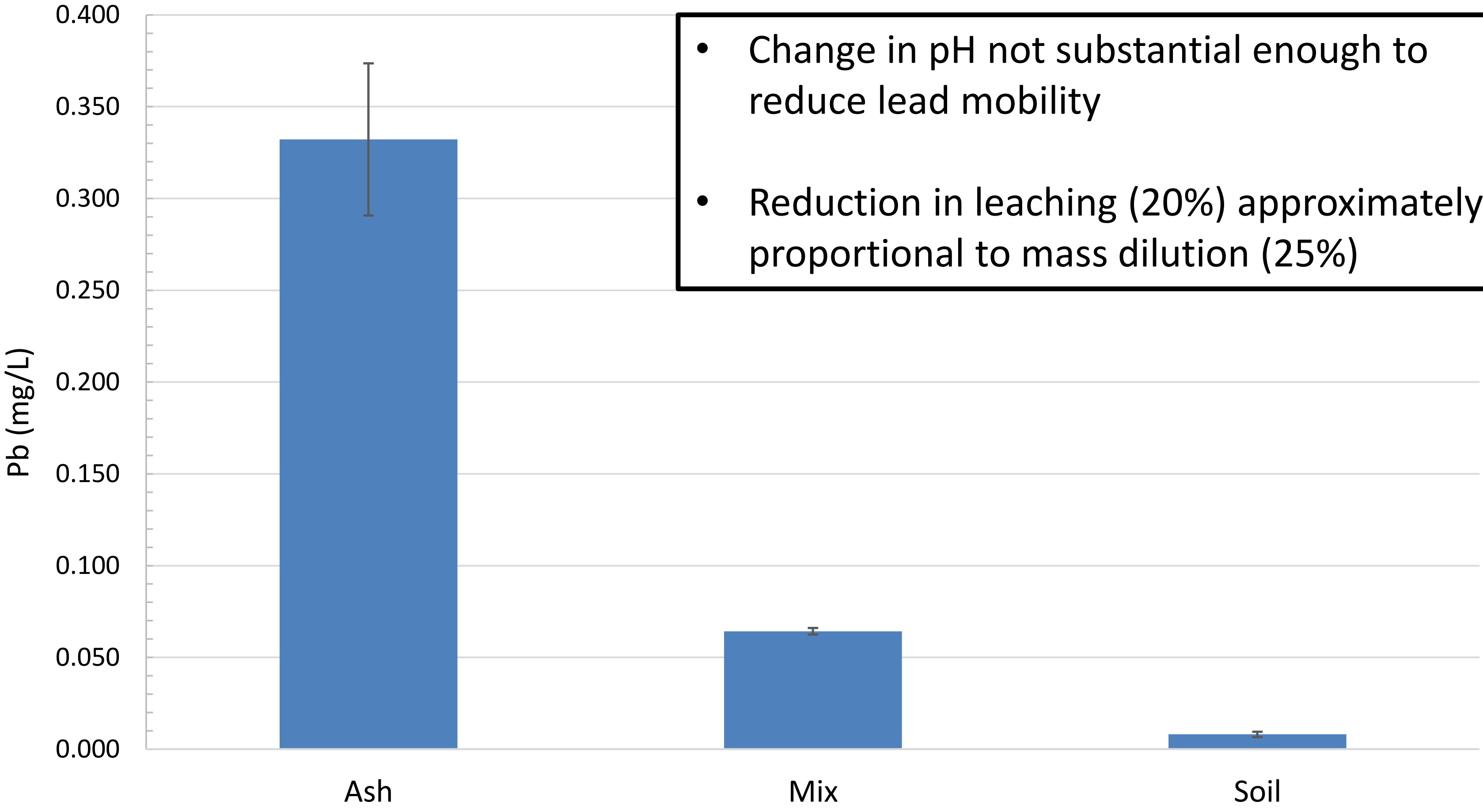
Filter Comparison E-Waste



Ash and Soil Mixture

- The previous results allow us to examine the leaching of the ash material on its own
- In a beneficial use scenario, land applied ash would be mixed with existing soil
- As a result, we can expect
  - Mass dilution
  - Lowered final pH
- To assess these changes, SPLP was conducted on a mixture of wood-tire ash (25%) and a representative Florida soil (75%)

SPLP Results: Ash-Soil Mixture

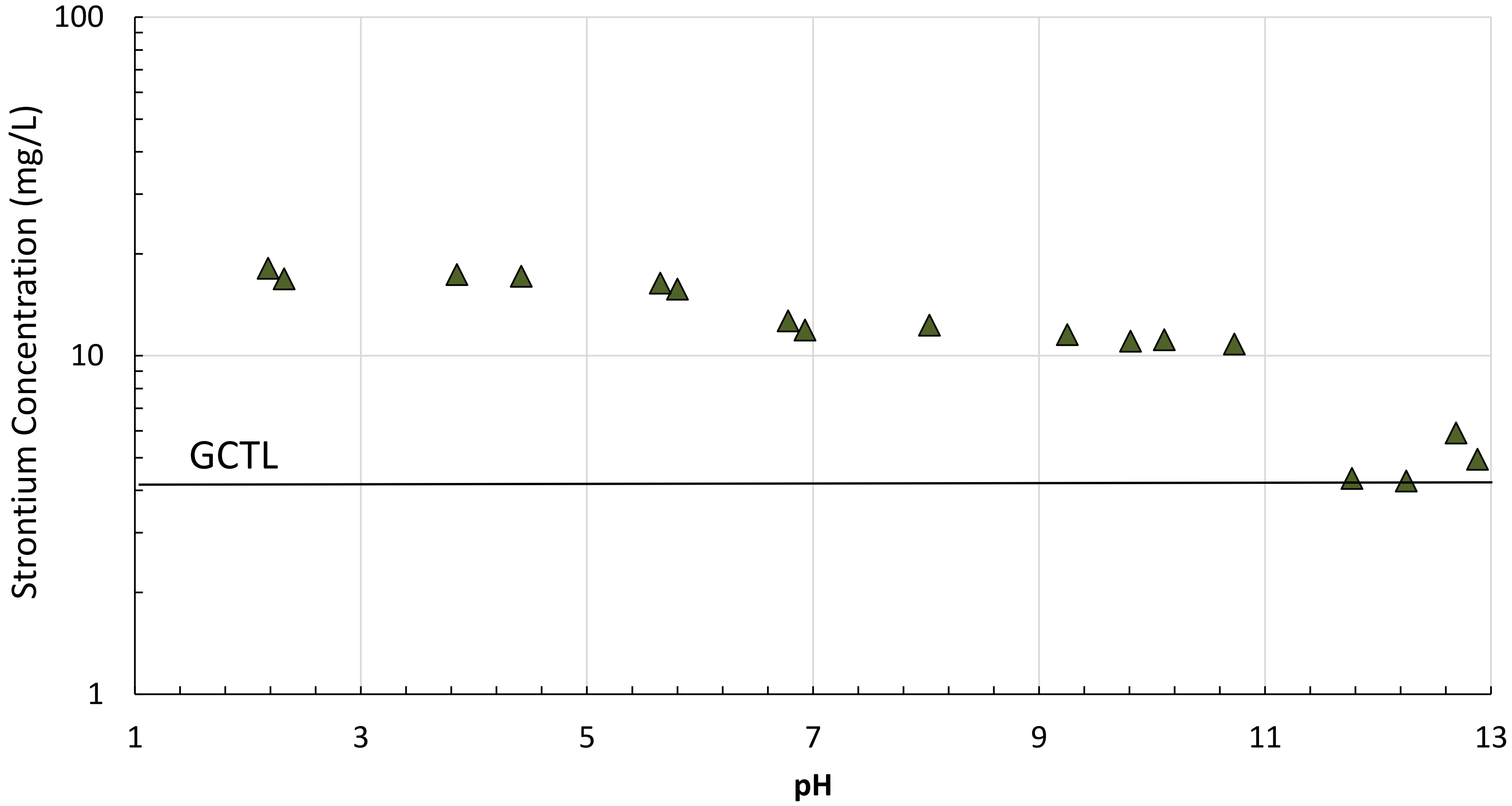


- Change in pH not substantial enough to reduce lead mobility
- Reduction in leaching (20%) approximately proportional to mass dilution (25%)

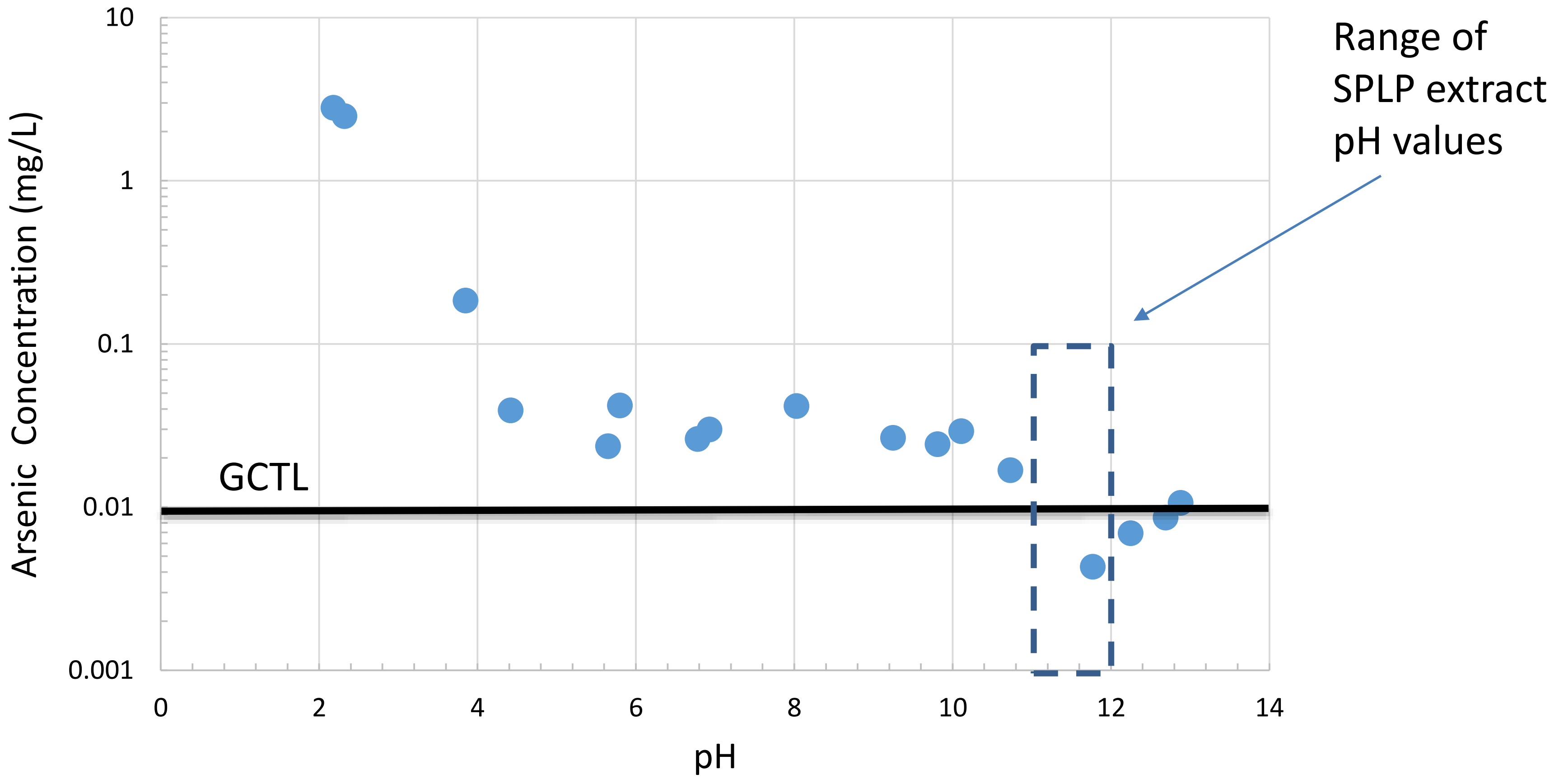
pH Dependent Leaching Behavior

- If the pH of the material was able to be reduced by limiting the percentage of material blended into the soil, or through other means (such as aging), how would the leaching of the wood tire ash be affected?
- The results of method 1313 allow us to better answer this question

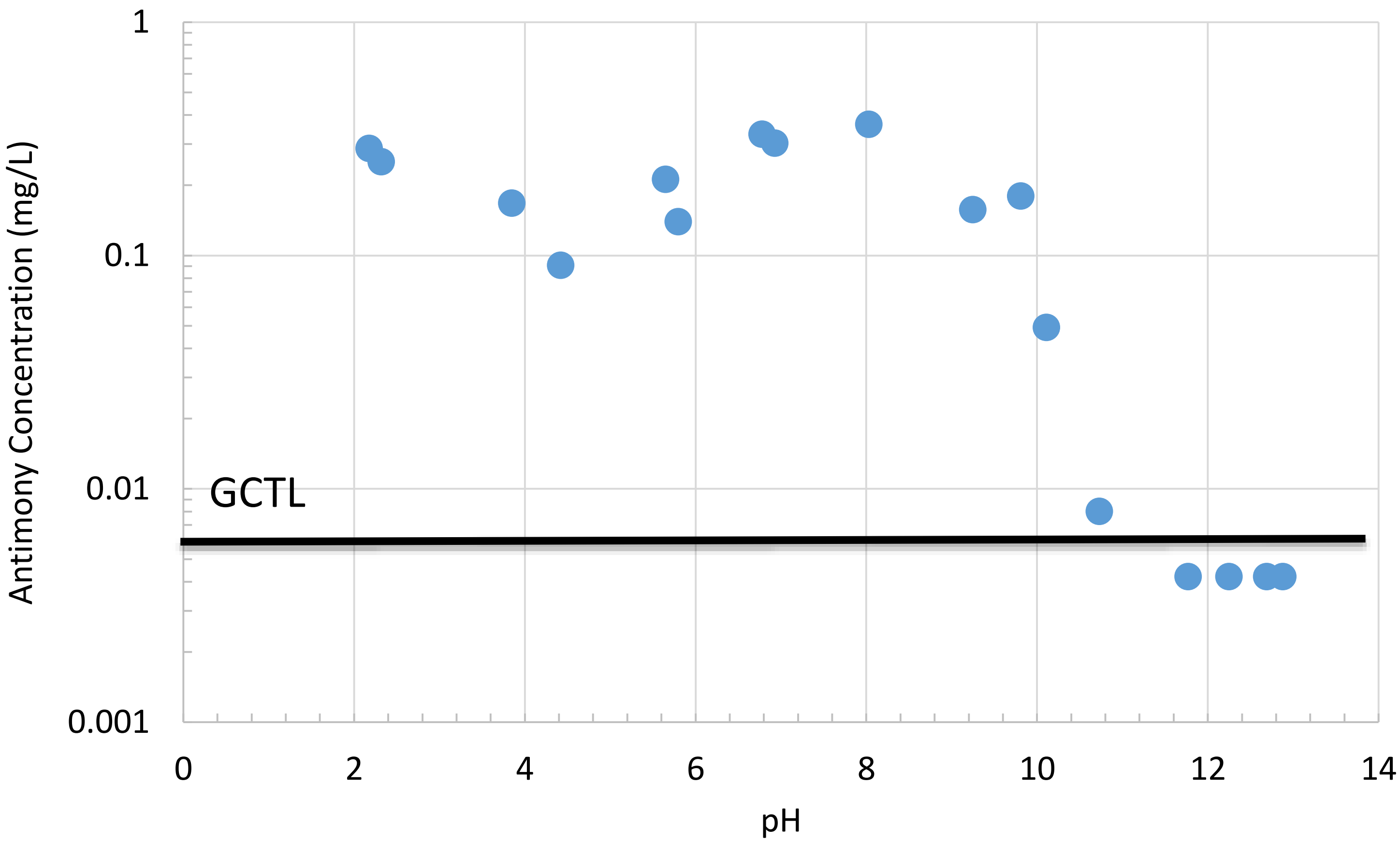
Leaching as a Function of pH
Strontium



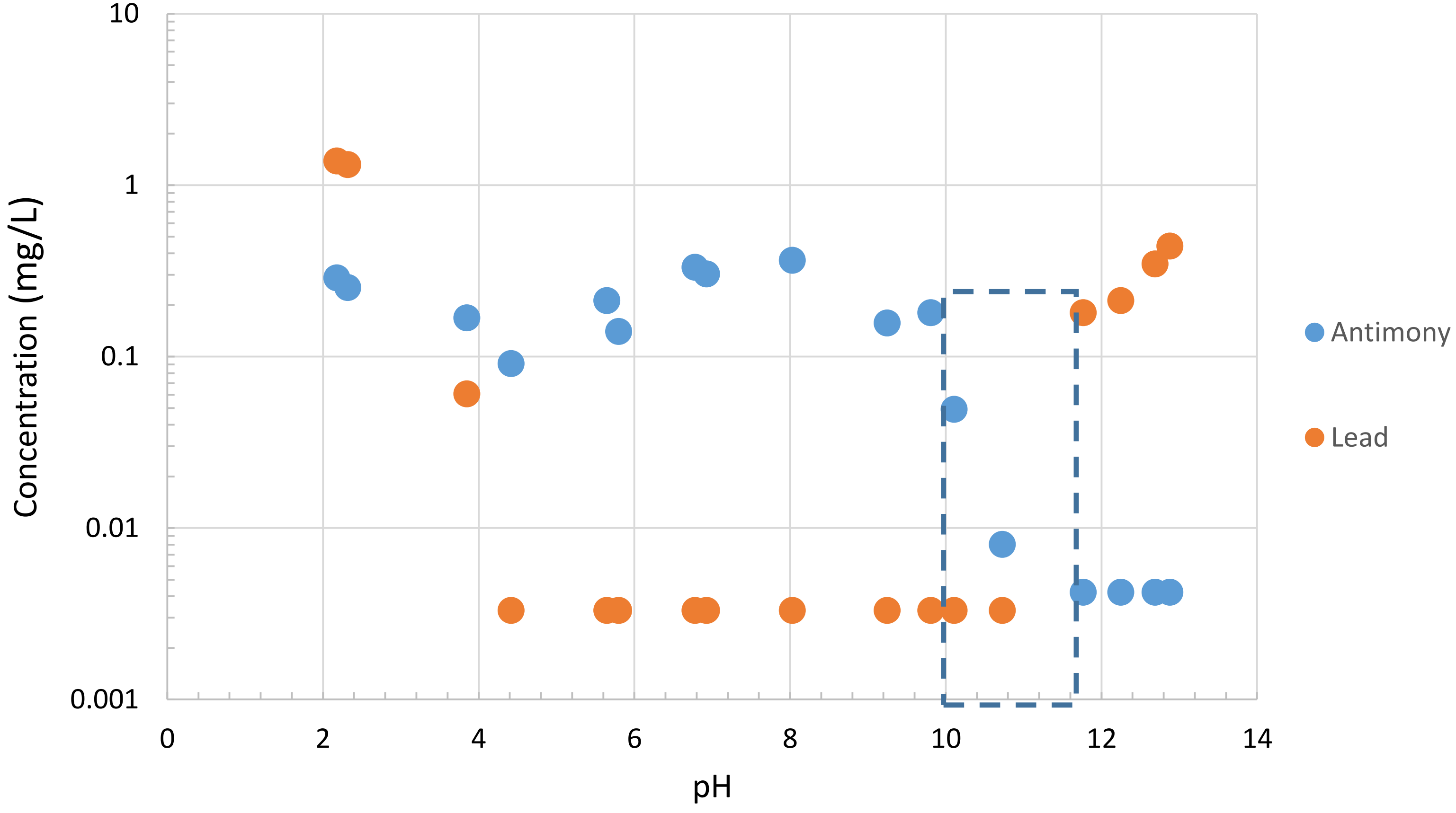
Leaching as a Function of pH
Arsenic



Leaching as a Function of pH
Antimony



Leaching as a Function of pH
Antimony and Lead



pH Dependent Leaching

- Here we see that arsenic and antimony increase with a decrease in pH
- Strontium leaching also increased although it was not as dramatic as arsenic or antimony
- Therefore although blending could decrease concerns with respect to lead, but other elements could potentially pose problems
- This would be missed if only SPLP was conducted on the wood and tire ash

Lessons Learned

- Leaching of lead was seen in the SPLP and supported by the results of the LEAF tests
- Although leaching of lead was lower in column testing with respect to SPLP, a consistent release was seen indicating that lead leaching was caused by lead diffusing from the material over time
  - This was additionally supported by results from the monolith test
- The pH of the material also remained constant during the column test indicating that it is relatively buffered at a high pH

Lessons Learned

- Blending of the material at with soil at a 25% ratio did not reduce the pH of the solution to a value where lead leaching would be reduced, suggesting a lower amended percentage would probably be needed
- However the results of 1313 indicate that if the pH were to decrease too dramatically other elements (particularly arsenic and antimony) could become mobilized

Laboratory Leaching Demonstrations and Lunch

Thanks to Jones Edmunds and Associates for Sponsoring Lunch

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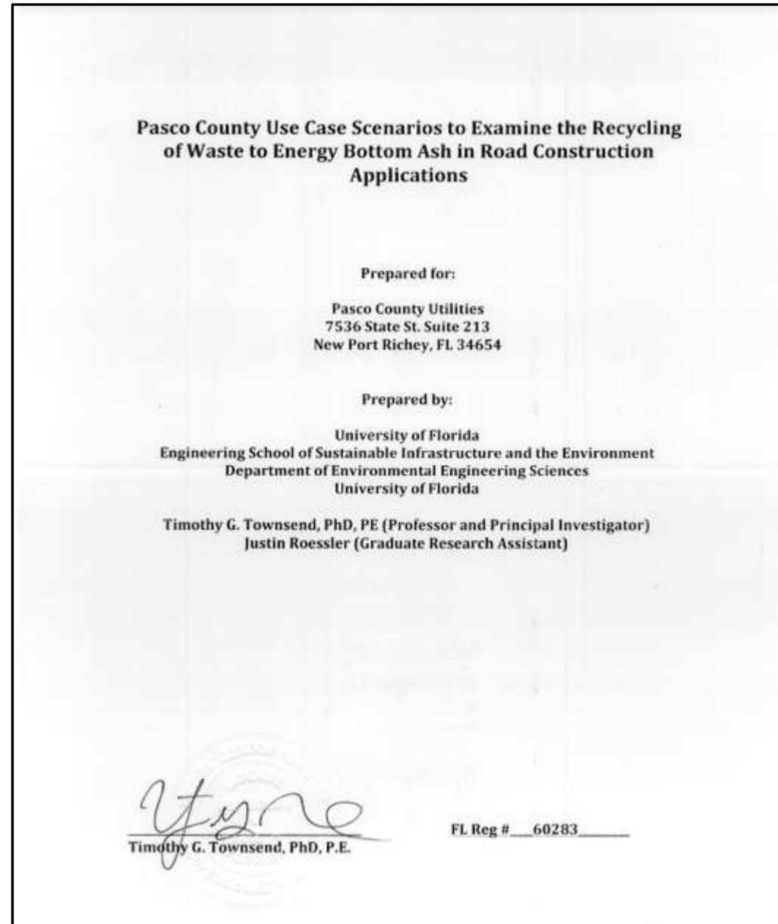
Application of LEAF for Beneficial Use Decision Making

- Now that we understand how LEAF results can be applied we want to provide everyone with a “homework assignment” where they use LEAF in beneficial use decision making
    - Handouts have been provided with mock test results
- How would these results be used an interpreted to make a decision on a beneficial use assessment



Pasco County Use Case Scenarios to Examine the Recycling of Waste to Energy Bottom Ash in Road Construction Applications

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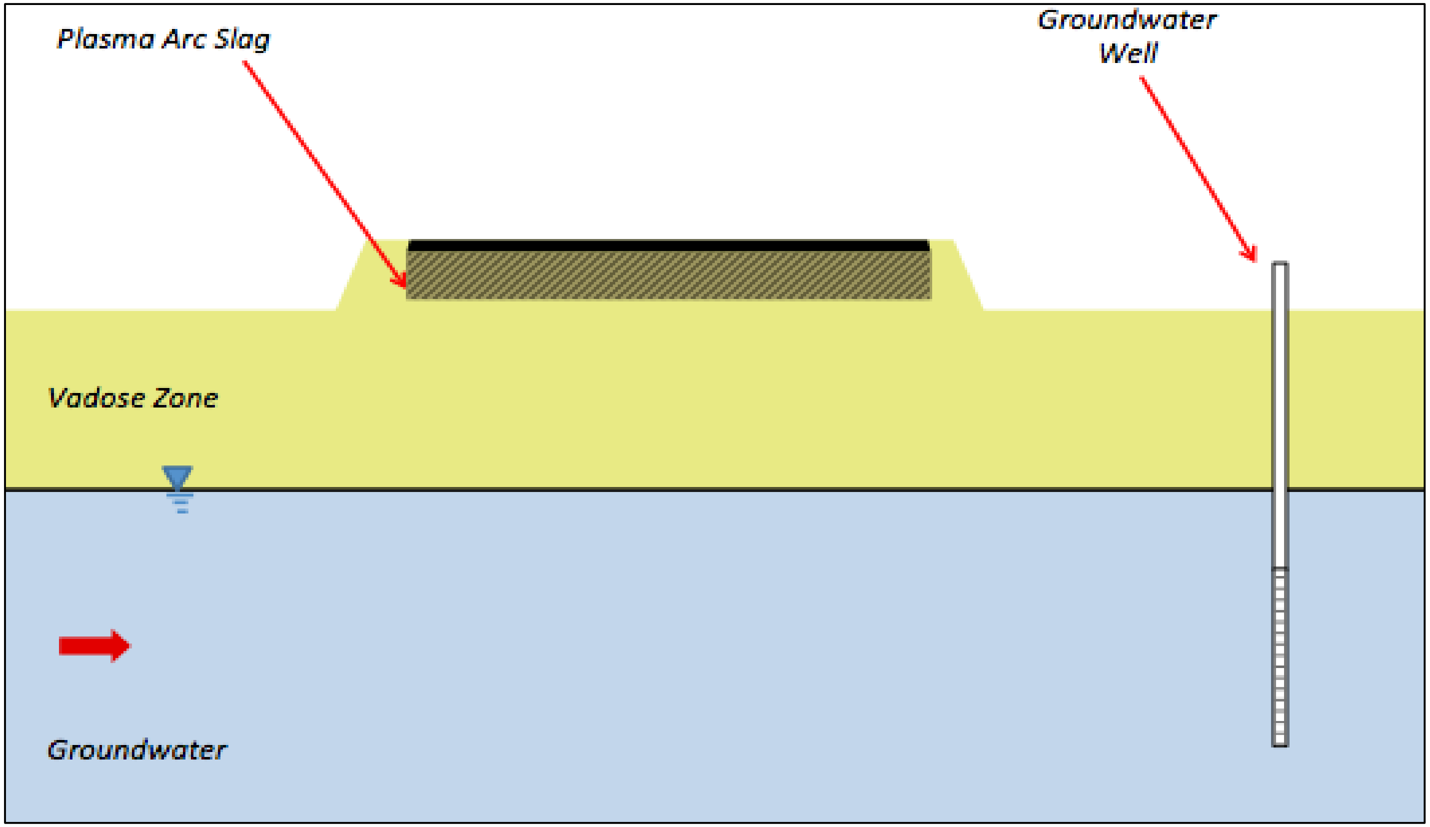
Timothy G. Townsend, PhD, P.E.

FL Reg #___60283______

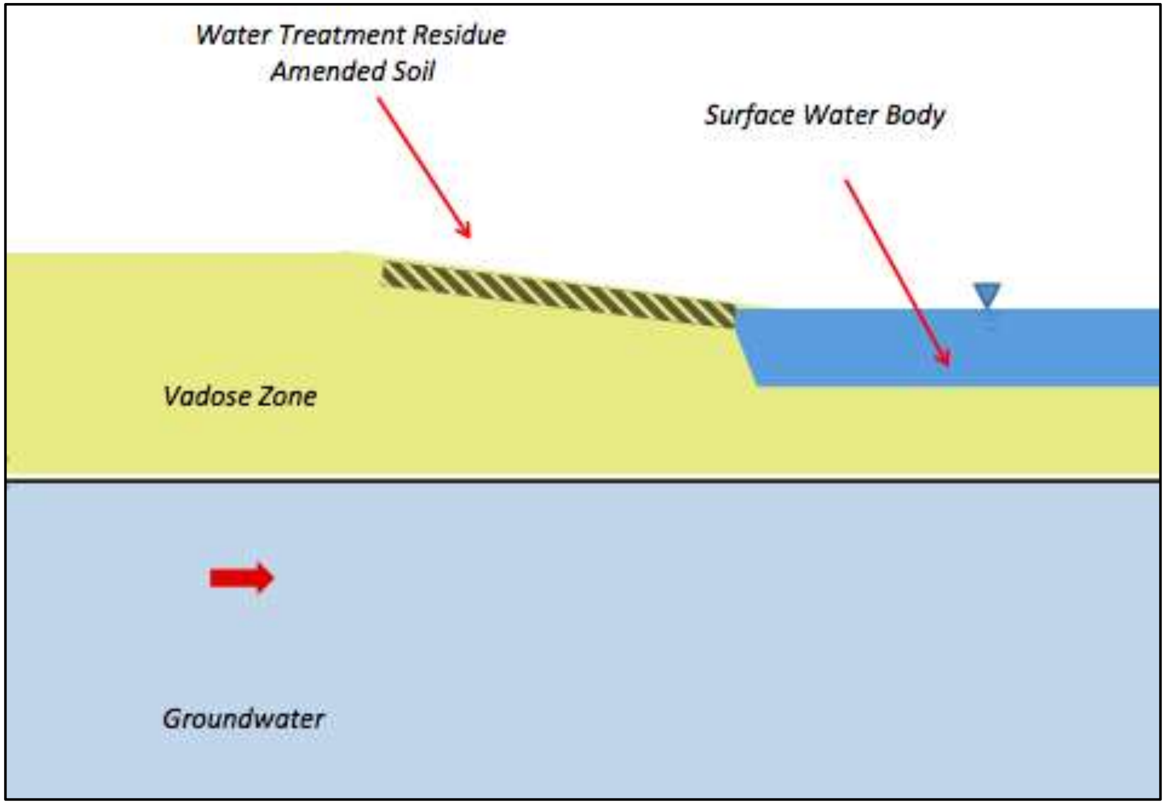
Scenario One

You want to apply a plasma arc slag as a sub-base course under a roadway. SPLP, total metals, and LEAF testing were conducted (see data below). How do you use the available data to make a decision on its appropriateness for use?



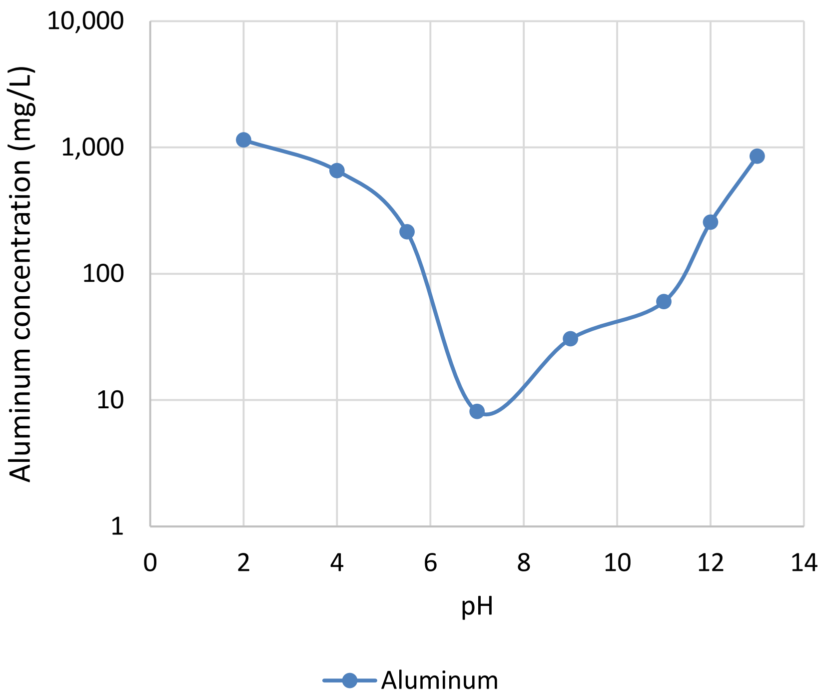
Scenario Two

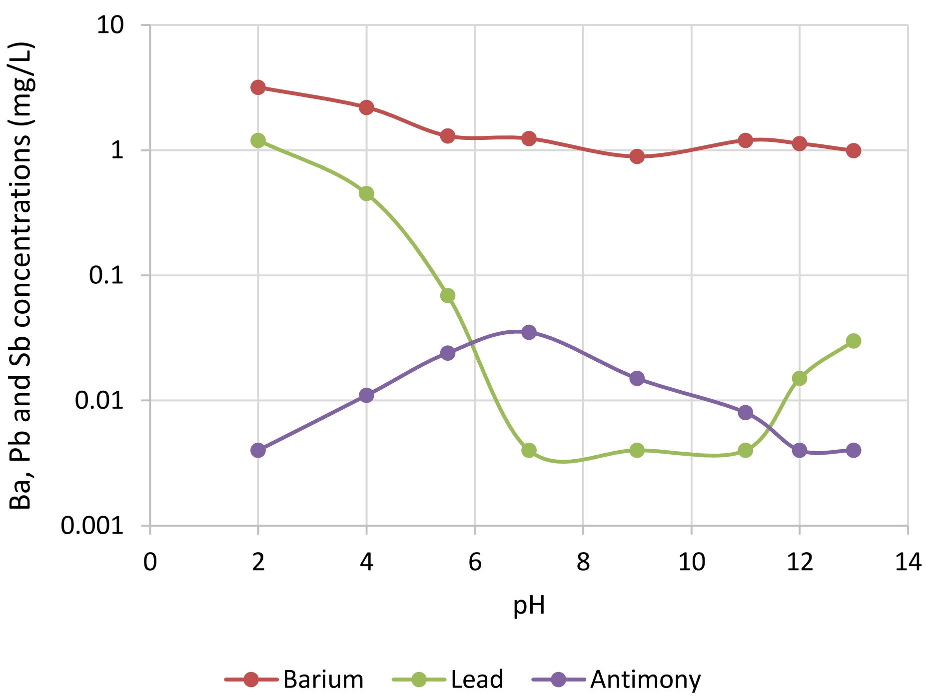
Drinking water sludge is being proposed as a soil amendment in and around the edges of surface water bodies to reduce nutrient load. SPLP, total metals and LEAF testing were conducted (see data below). How do you use the available data to make a decision on its appropriateness for use?



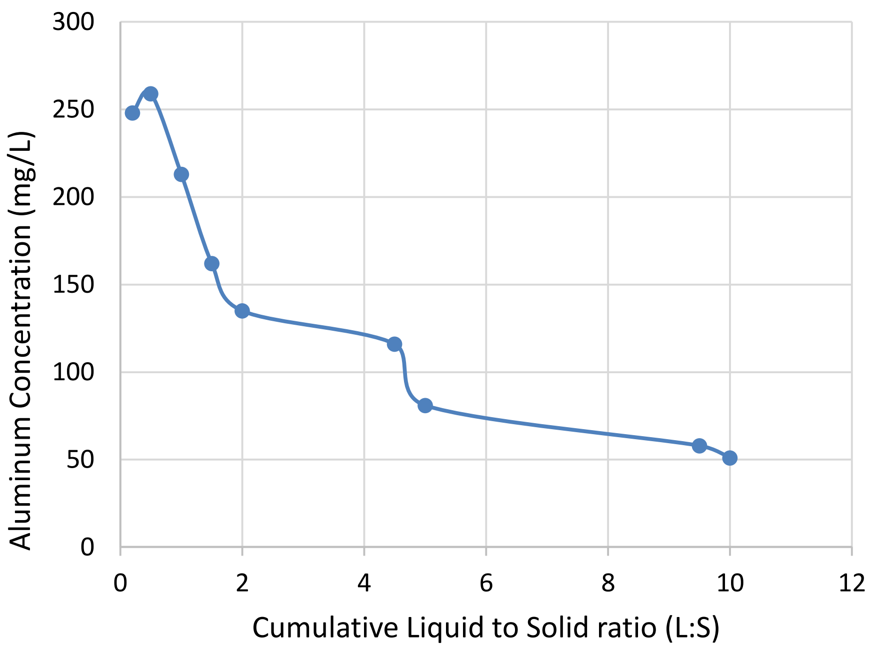
Scenario 1 – Plots and Evaluation

Method 1313

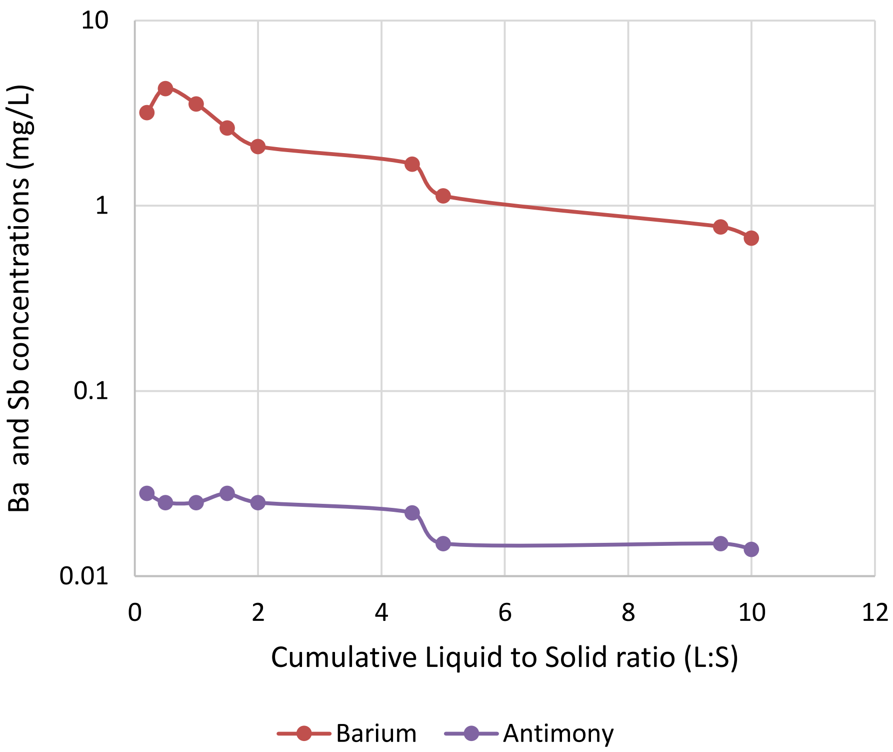

10,000
1,000
100
10
1
Aluminum concentration (mg/L)
0
2
4
6
8
10
12
14
pH
Aluminum


10
1
0.1
0.01
0.001
Ba, Pb and Sb concentrations (mg/L)
0
2
4
6
8
10
12
14
pH
Barium
Lead
Antimony

Method 1314

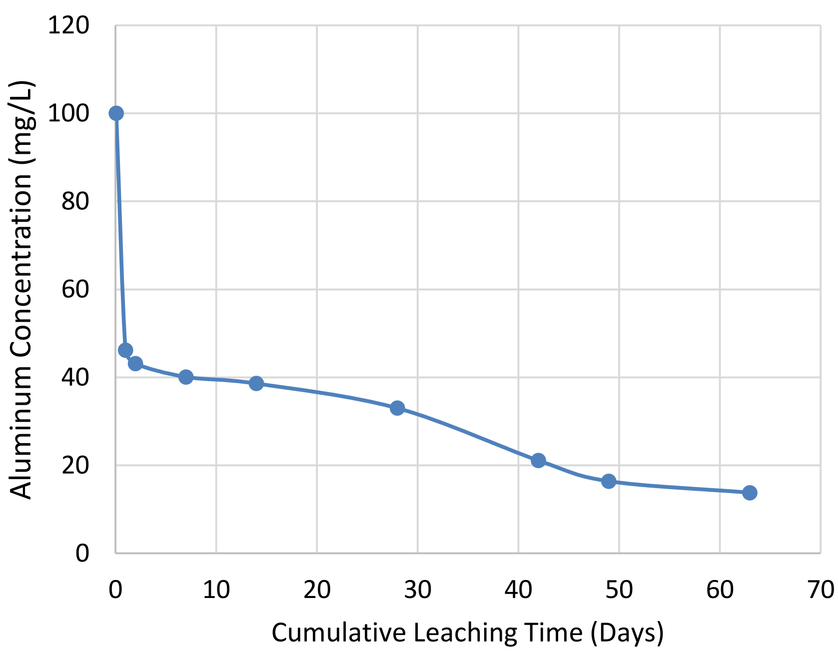


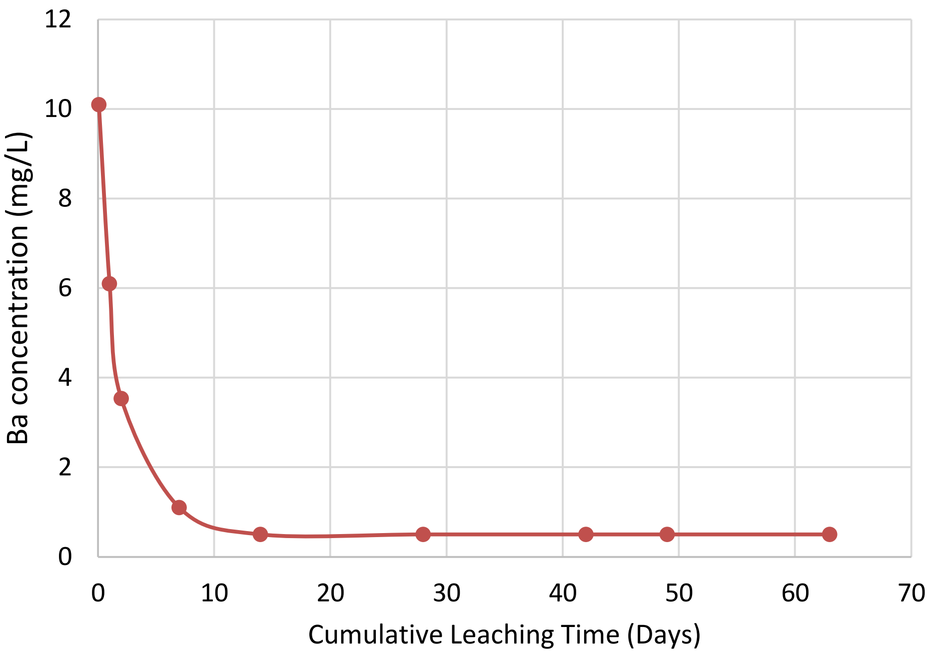
Aluminum Concentration (mg/L)
300
250
200
150
100
50
0
0
2
4
6
8
10
12
Cumulative Liquid to Solid ratio (L:S)



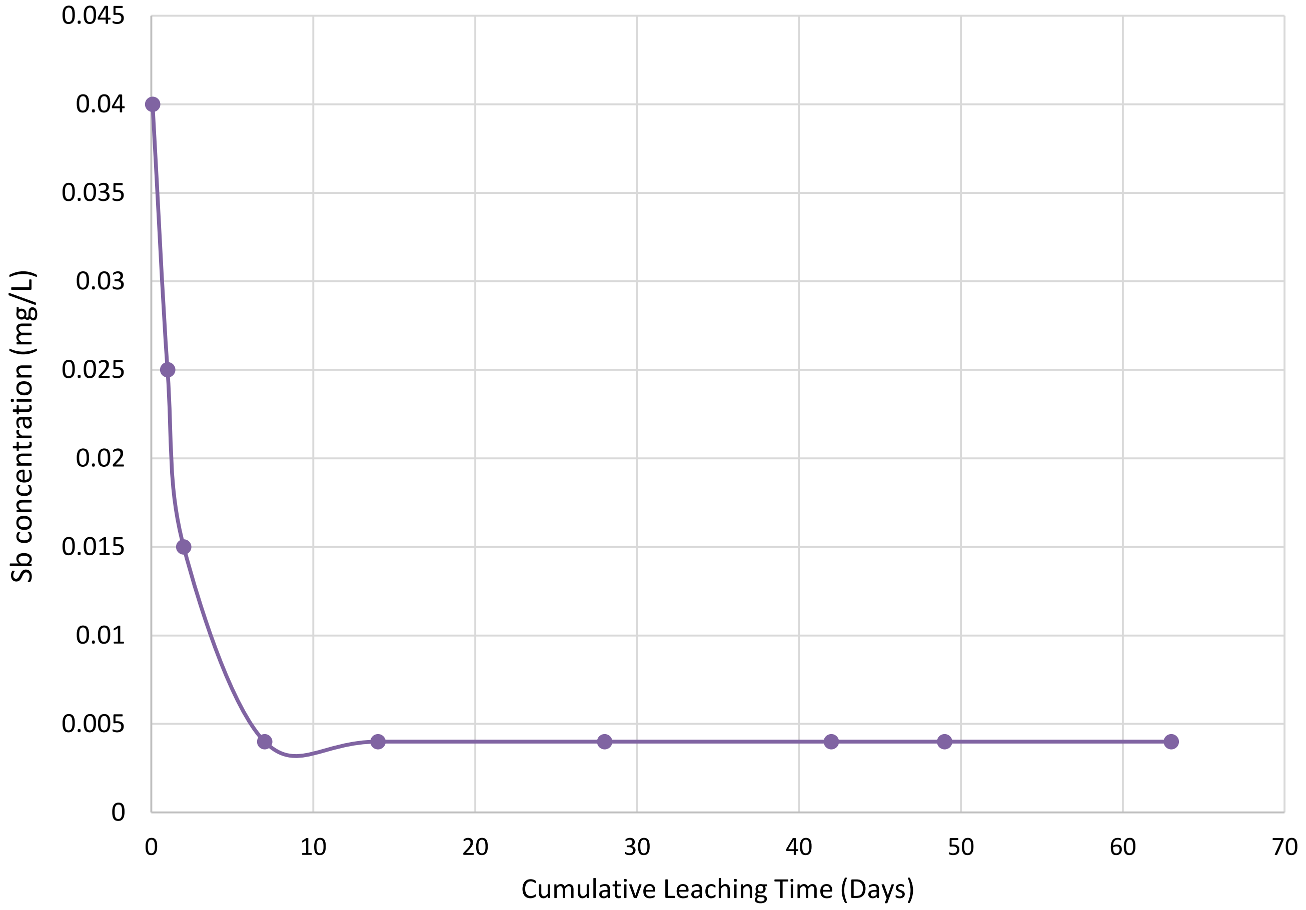
Ba and Sb concentrations (mg/L)
10
1
0.1
0.01
0
2
4
6
8
10
12
Cumulative Liquid to Solid ratio (L:S)
Barium
Antimony

Method 1315


Aluminum Concentration (mg/L)
120
100
80
60
40
20
0
0
10
20
30
40
50
60
70
Cumulative Leaching Time (Days)

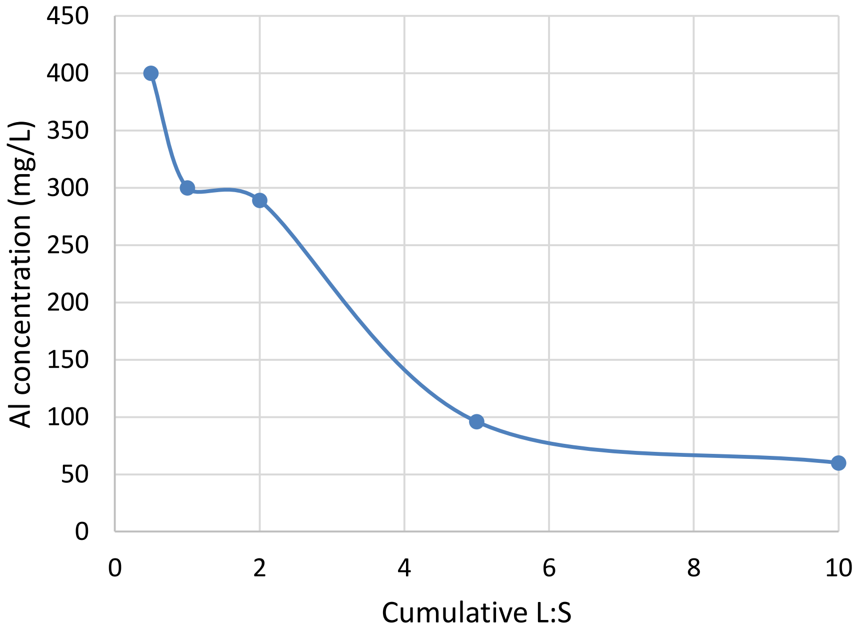

Ba concentration (mg/L)
12
10
8
6
4
2
0
0
10
20
30
40
50
60
70
Cumulative Leaching Time (Days)

Method 1315

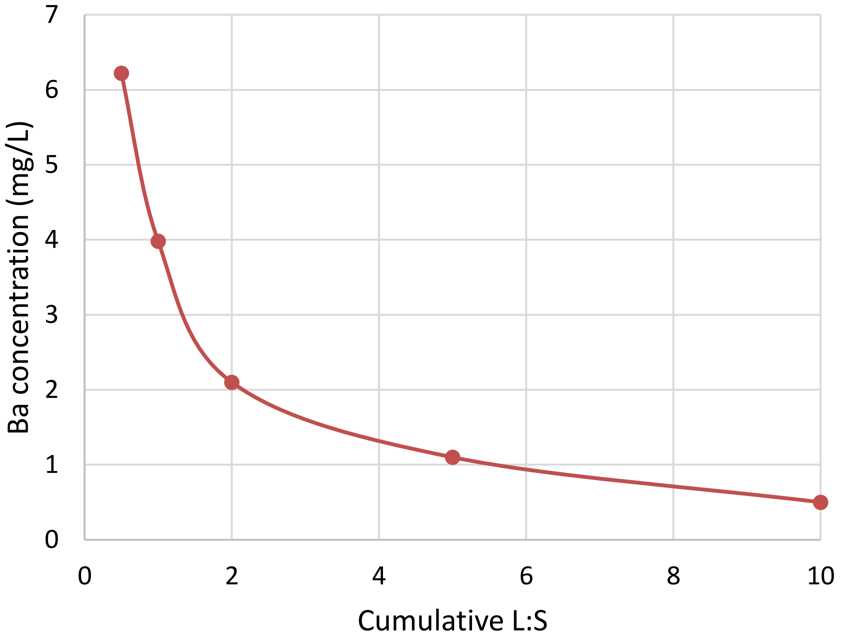


0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0
10
20
30
40
50
60
70
Sb concentration (mg/L)
Cumulative Leaching Time (Days)

Method 1316

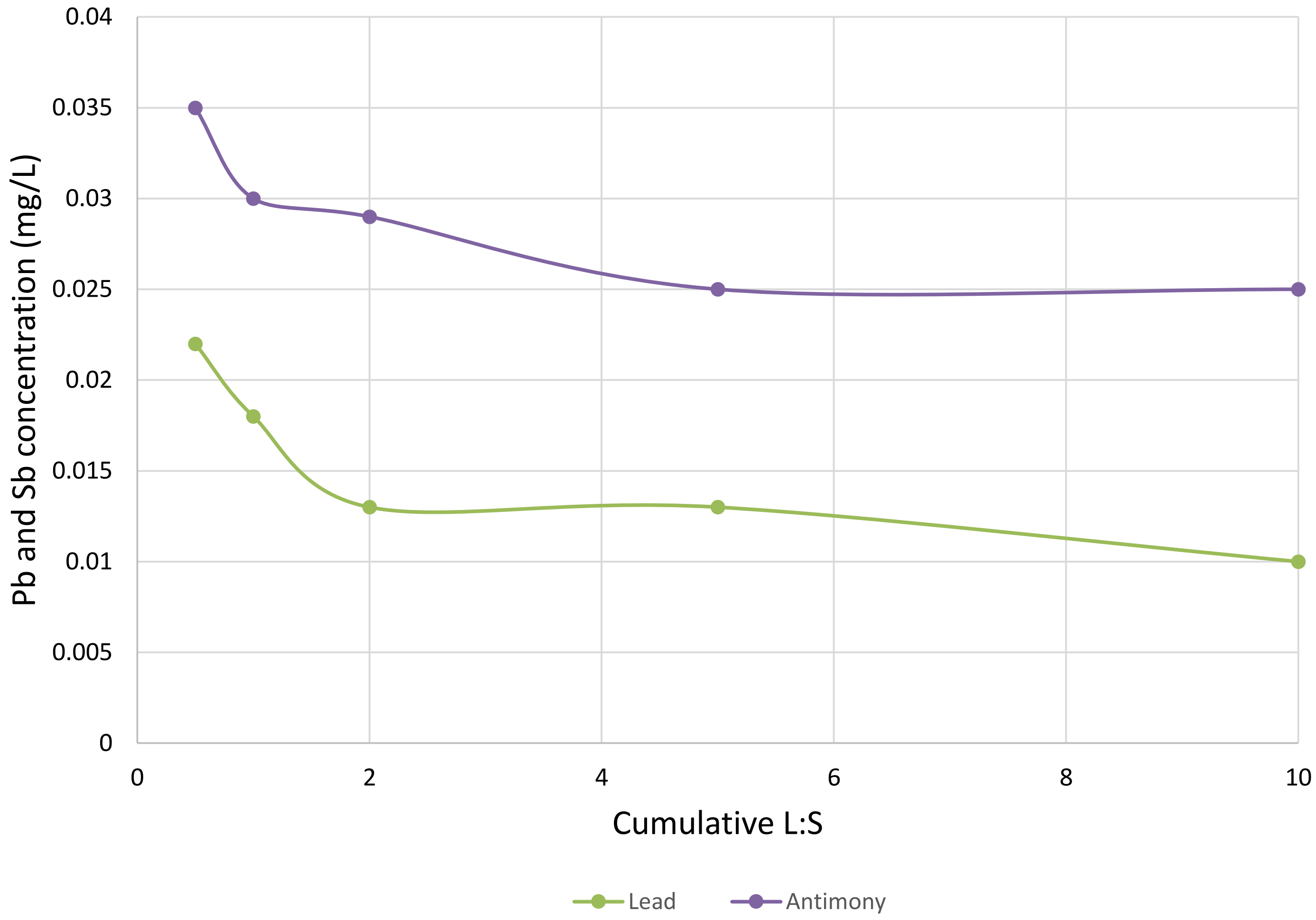


450
400
350
300
250
200
150
100
50
0
Al concentration (mg/L)
0
2
4
6
8
10
Cumulative L:S



7
6
5
4
3
2
1
0
Ba concentration (mg/L)
0
2
4
6
8
10
Cumulative L:S

Method 1316

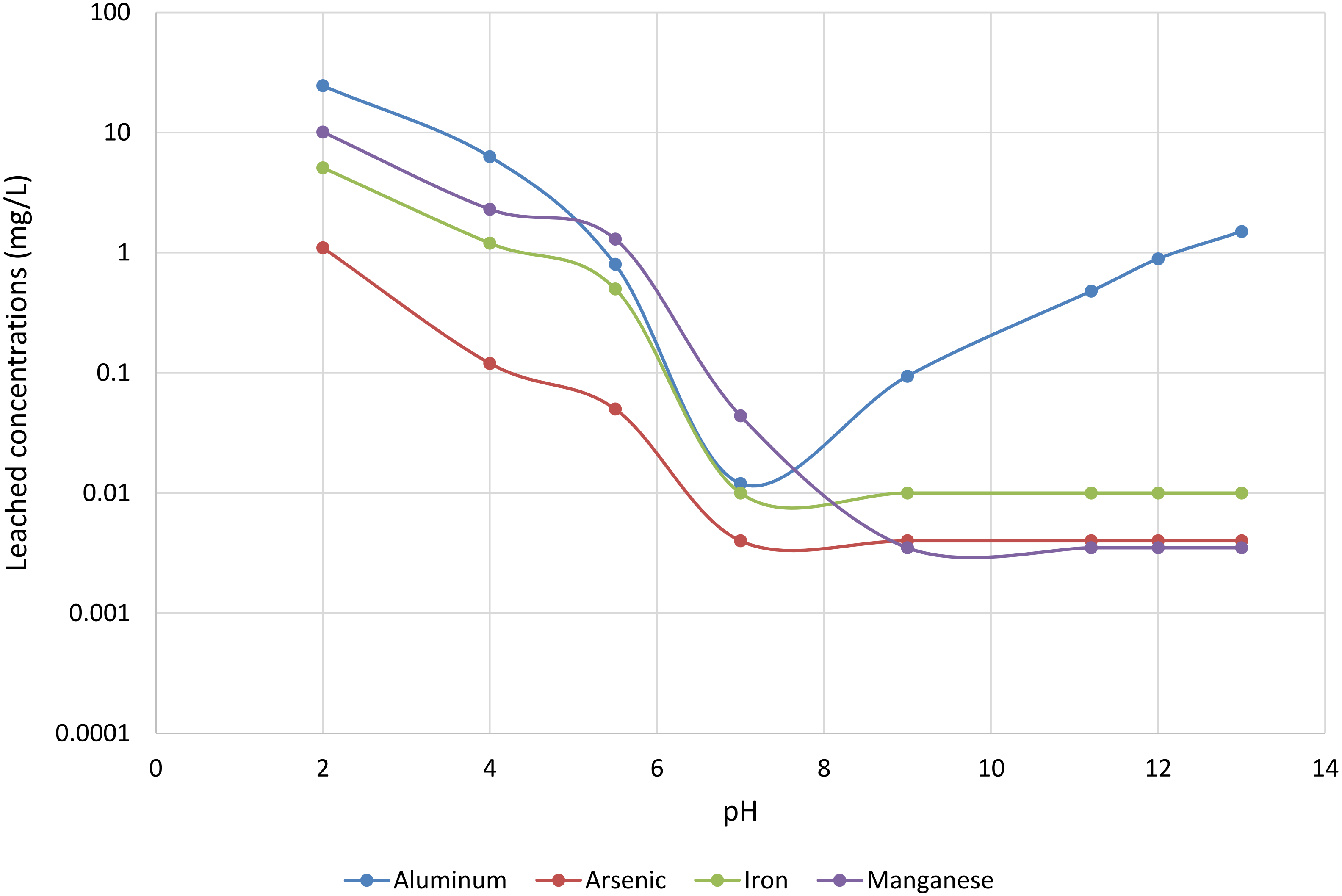

0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
Pb and Sb concentration (mg/L)
0
2
4
6
8
10
Cumulative L:S
Lead
Antimony

Evaluation

- Initial SPLP test results for Al significantly above GCTL
  - Sb and Pb also slightly elevated
- Al and Sb concentrations found to decrease in column test
  - Pb was below detection limit
- Method 1313 test supports decreased Al leaching at lower pH
- Also shows the potential for Sb concentrations to increase slightly in the neutral pH range
- Compacted granular leaching shows a decrease in concentrations in comparison to batch/column tests
- These results would allow you to determine a series of appropriate concentration inputs that could be used in a fate and transport modeling evaluation

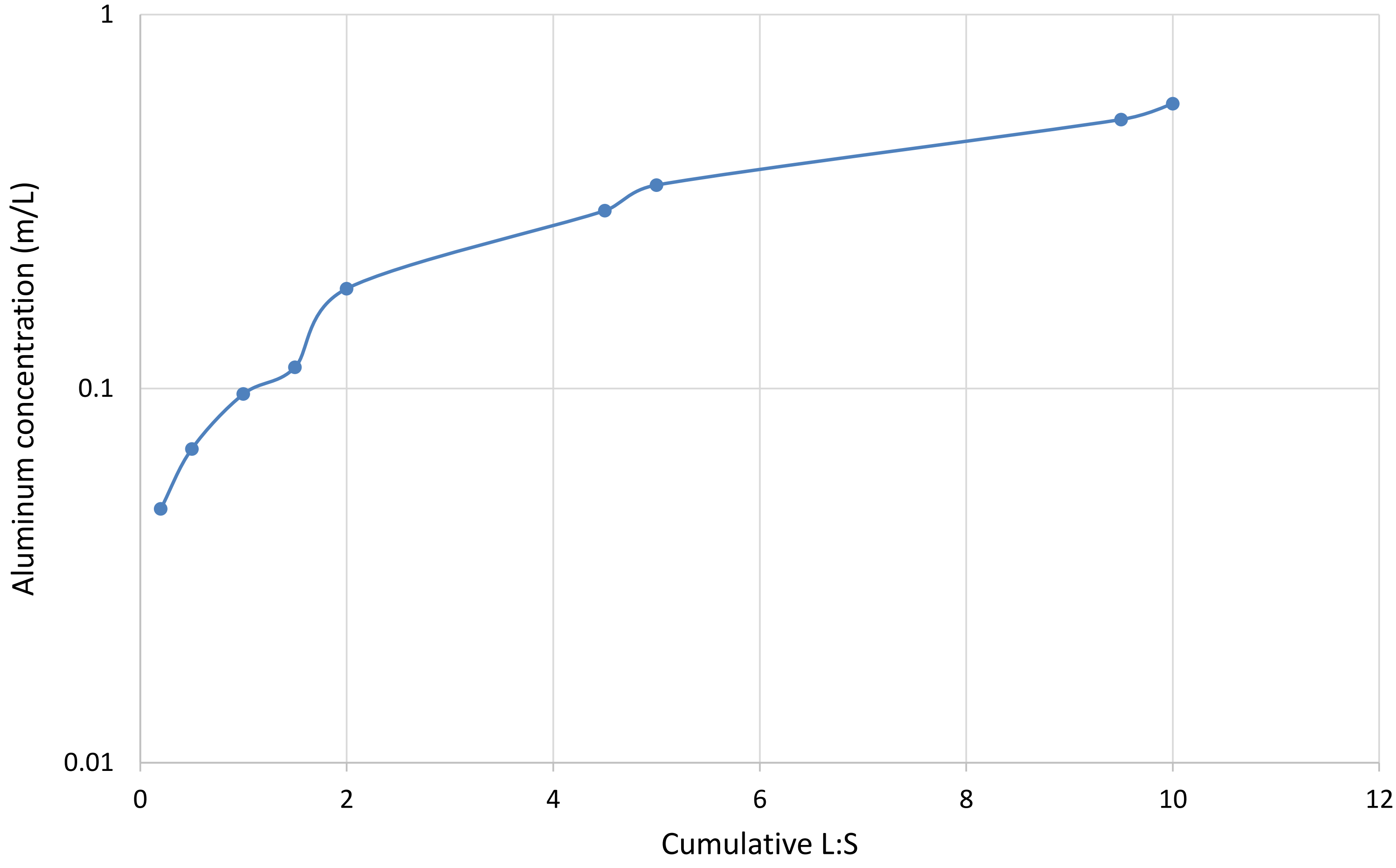
Scenario 2 – Plots and Evaluation

Method 1313



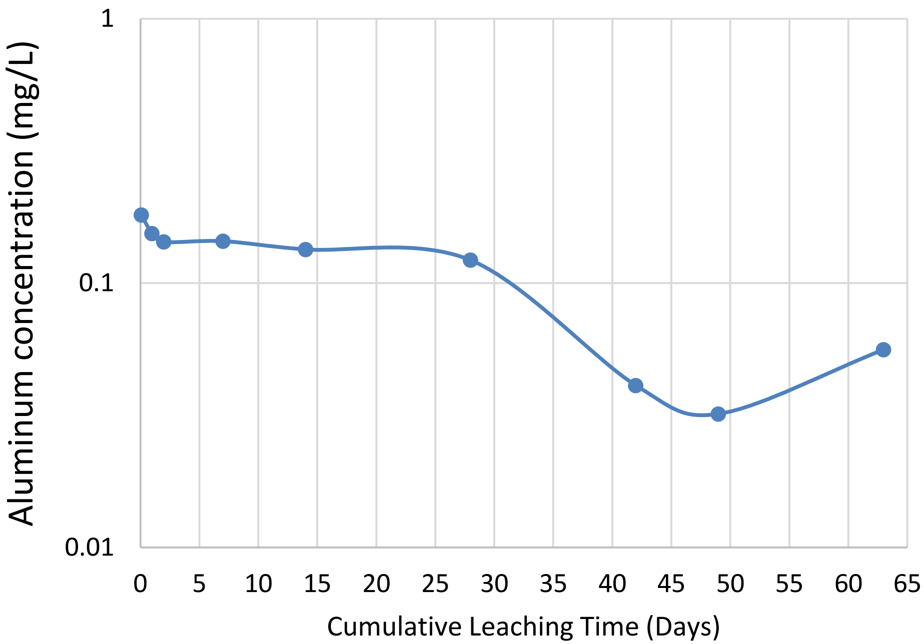
100
10
1
0.1
0.01
0.001
0.0001
Leached concentrations (mg/L)
0
2
4
6
8
10
12
14
pH
Aluminum
Arsenic
Iron
Manganese

Method 1314

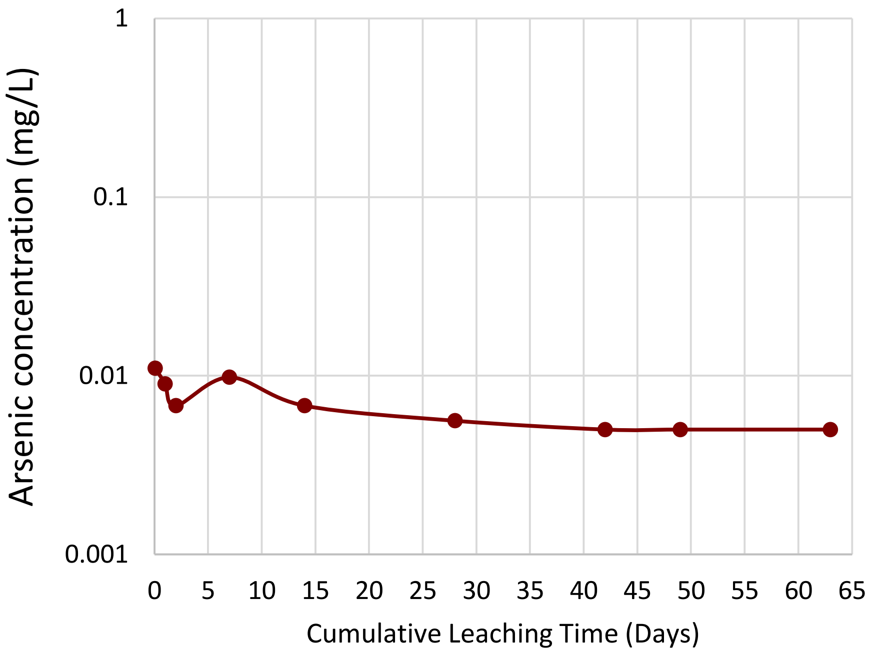


1
0.1
0.01
Aluminum concentration (m/L)
0
2
4
6
8
10
12
Cumulative L:S

Method 1315

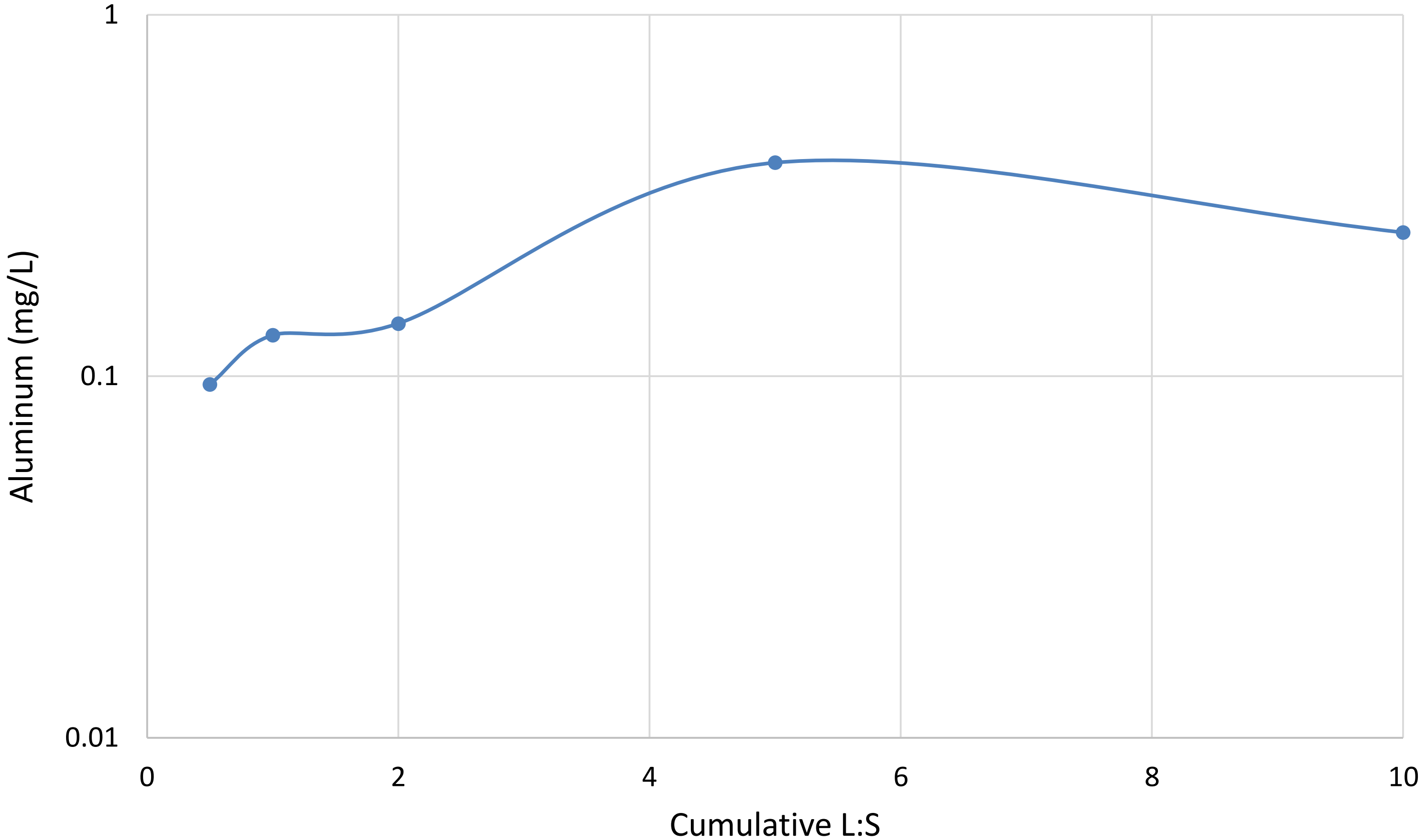


Aluminum concentration (mg/L)
1
0.1
0.01
0
5
10
15
20
25
30
35
40
45
50
55
60
65
Cumulative Leaching Time (Days)



Arsenic concentration (mg/L)
1
0.1
0.01
0.001
0
5
10
15
20
25
30
35
40
45
50
55
60
65
Cumulative Leaching Time (Days)

Method 1316



Evaluation

- Aluminum leaching slightly elevated initially in SPLP
- Again method 1313 supports decreased leaching of Al in neutral pH range
- Arsenic see in first flush of compacted granular test but not observed in any other test points except at extremely low pH
- Iron seen in first set of column and tank tests, washed away quickly
- These results would allow you to determine a series of appropriate concentration inputs that could be used in a fate and transport modeling evaluation

How Would You Conduct This Type of Assessment?

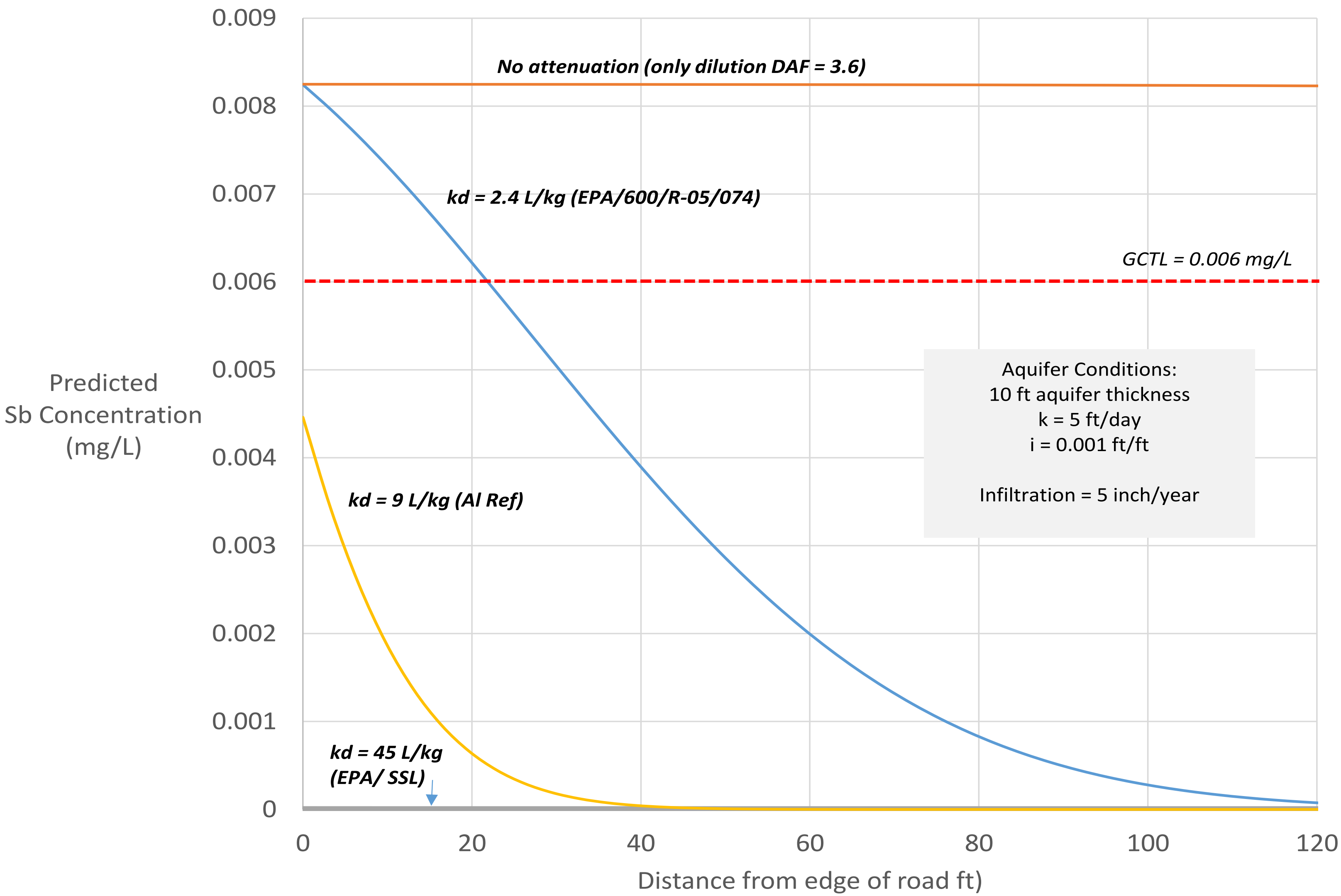
- You would need to determine a series of inputs for a fate and transport modeling evaluation
- These would typically include:
  - C_0 - input concentration
  - q – infiltration rate
  - Subsurface hydrogeologic conditions
    - Vadose zone depth
    - Aquifer thickness
  - Soil partitioning coefficients (K_d)

Selected Constituents

CAS Number	Constituent Name	Leachate Concentration (mg/L)
7440-38-2	Arsenic	0.01
7440-36-0	Antimony	0.05
7440-39-3	Barium	1.4
7440-62-2	Vanadium	0.07
7440-66-6	Zinc	0.501
7440-22-4	Silver	0.004
7782-49-2	Selenium	0.053
7440-02-0	Nickel	0.001
7439-98-7	Molybdenum	0.02

Example C_0 selection in EPA's Industrial Waste Management Evaluation Model

Impact of Soil Partitioning Coefficient



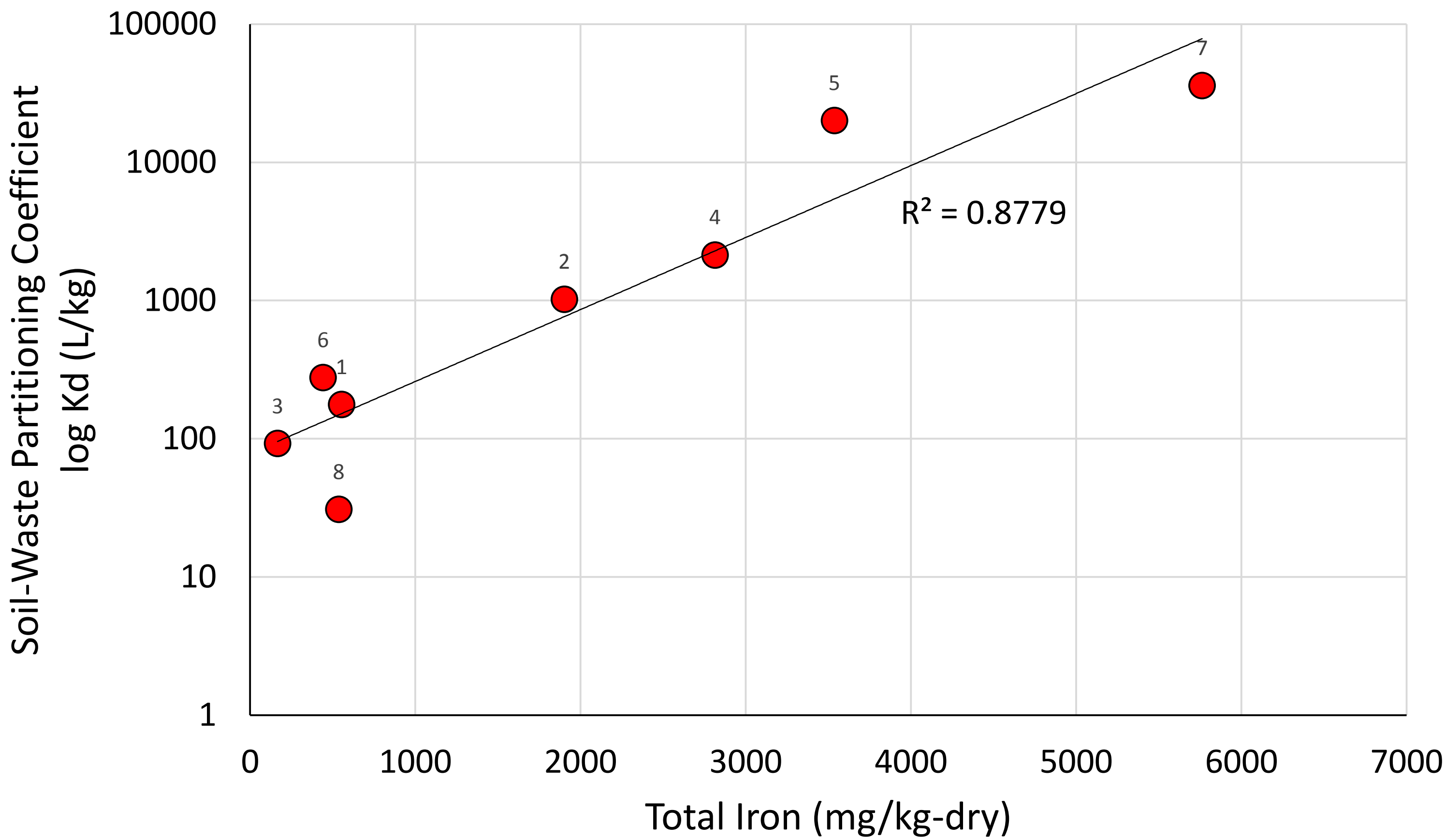
Waste/Site Specific Partitioning

- Leachates generated from different candidate waste materials for beneficial use (WTE bottom ash, coal fly ash)
- Introduced to different soil samples in a series of batch extraction tests (ASTM D4646)
- Concentrations of metals in aqueous phase measured before and after test
- Allows for the calculation of metals sorbed to soil (partitioning coefficient - L/kg)

	As (L/kg)	Cr(L/kg)
Soil#1	176±40.1	1.83±0.214
Site#2	1,020±400	3.73±0.561
Site#3	92.1±2.84	1.11±0.230
Site#4	2,129±300	7.07±0.140
Site#5	19,980±1,640	2.73±0.0416
Site#6	276±5.01	1.06±0.150
Site#7	35,880±169	7.46±1.50
Site#8	30.7±5.30	8,120±423
Min	*30.7±5.30*	*1.06±0.150*
Max	*35,880±169*	*8,120±423*

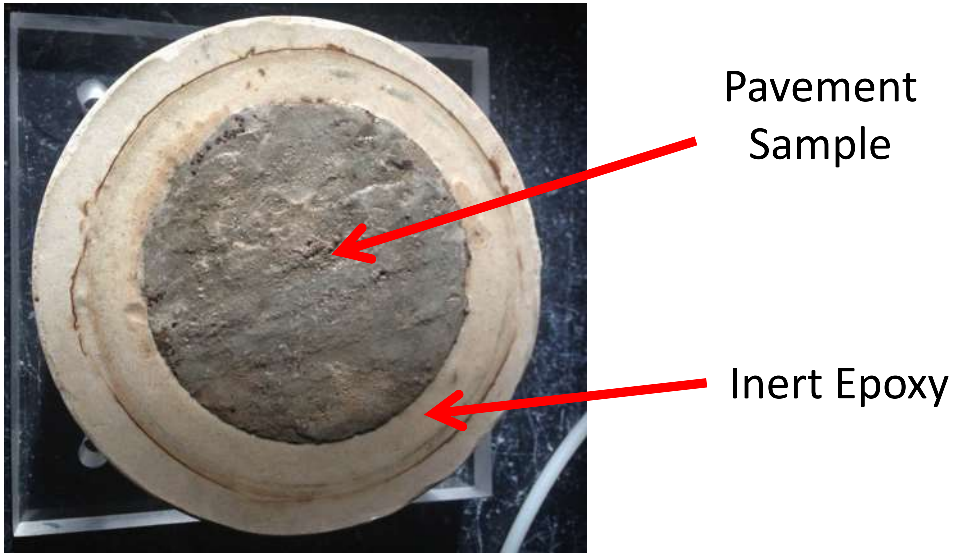
Example calculated K_d with coal fly ash leachates and 9 Florida soils

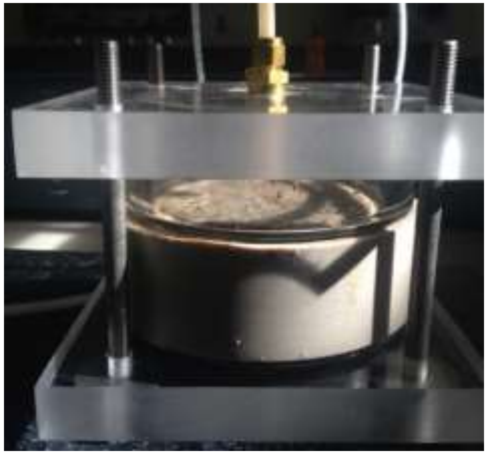
Impact of Soil Iron Content on Partitioning Coefficient



Selection of Infiltration Rate

- How to best choose the appropriate infiltration rate for scenarios such as use as a road base course?
- Subject of next years Hinkley Center Project
- Evaluation of asphalt and concrete permeability and cracking





Thank You

Questions / Open Discussion

UNIVERSITY of FLORIDA

Hinkley Center for Solid and Hazardous Waste Management