


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

Timothy G Townsend, Lena Ma (Investigators)

Justin Roessler, Weizhi Cheng , Vicharana Intrakamhaeng, Michael Hofmeister, Nawaf Blasai (EES Graduate Research Assistants)

Evandro da Silva, Xiaoling Dong, and Ky Gress (SWS Graduate Research Assistants)

University of Florida

October 14, 2014 TAG Meeting

Presentation Objectives

- Review the objectives and methodology of the project
- Provide TAG with an overview of LEAF methods and questions that have been raised in our work
- Give examples of recent research
- Gather feedback from the TAG

- Michael Hoffmeister
  - Project objectives and tasks
- Justin Roessler, Dr. Ma
  - Examples of recent applications of LEAF as part of Florida beneficial use assessments
- B Intrakamhaeng, Weizhi Cheng
  - Observations from some recent work comparing LEAF with other leaching procedures

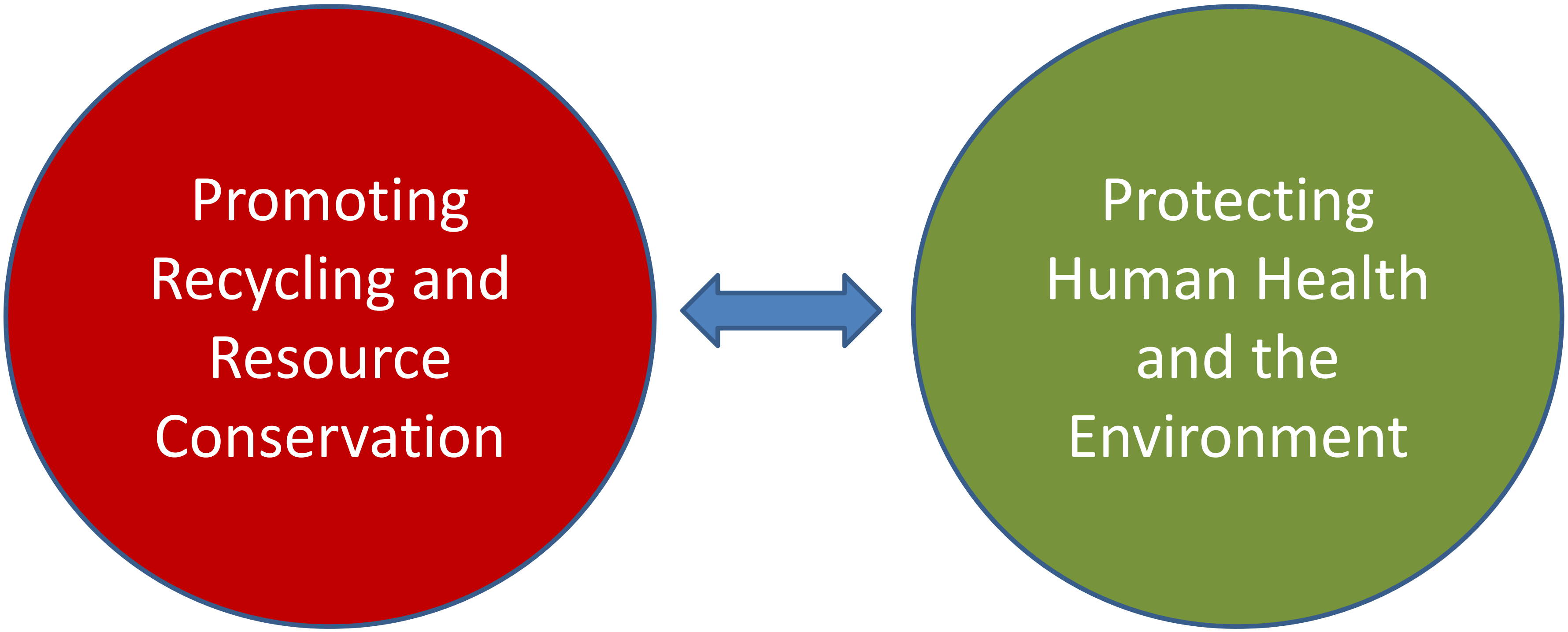
Uses of Leaching Tests

- Hazardous waste determination
  - TCLP is used to determine whether a solid waste is a toxicity characteristic hazardous waste (40CFR261)
- Waste treatment
  - TCLP is used to determine whether hazardous waste is sufficiently treated prior to land disposal (40CFR268)
- Beneficial use
  - SPLP is commonly used by regulatory agencies to assess leaching risk from beneficially used waste materials
- Other

Hinkley Center Evaluations of Beneficial Use

Hinkley Center Evaluations of Beneficial Use

Challenge


Promoting Recycling and Resource Conservation
Protecting Human Health and the Environment

Leaching Tests for Beneficial Use

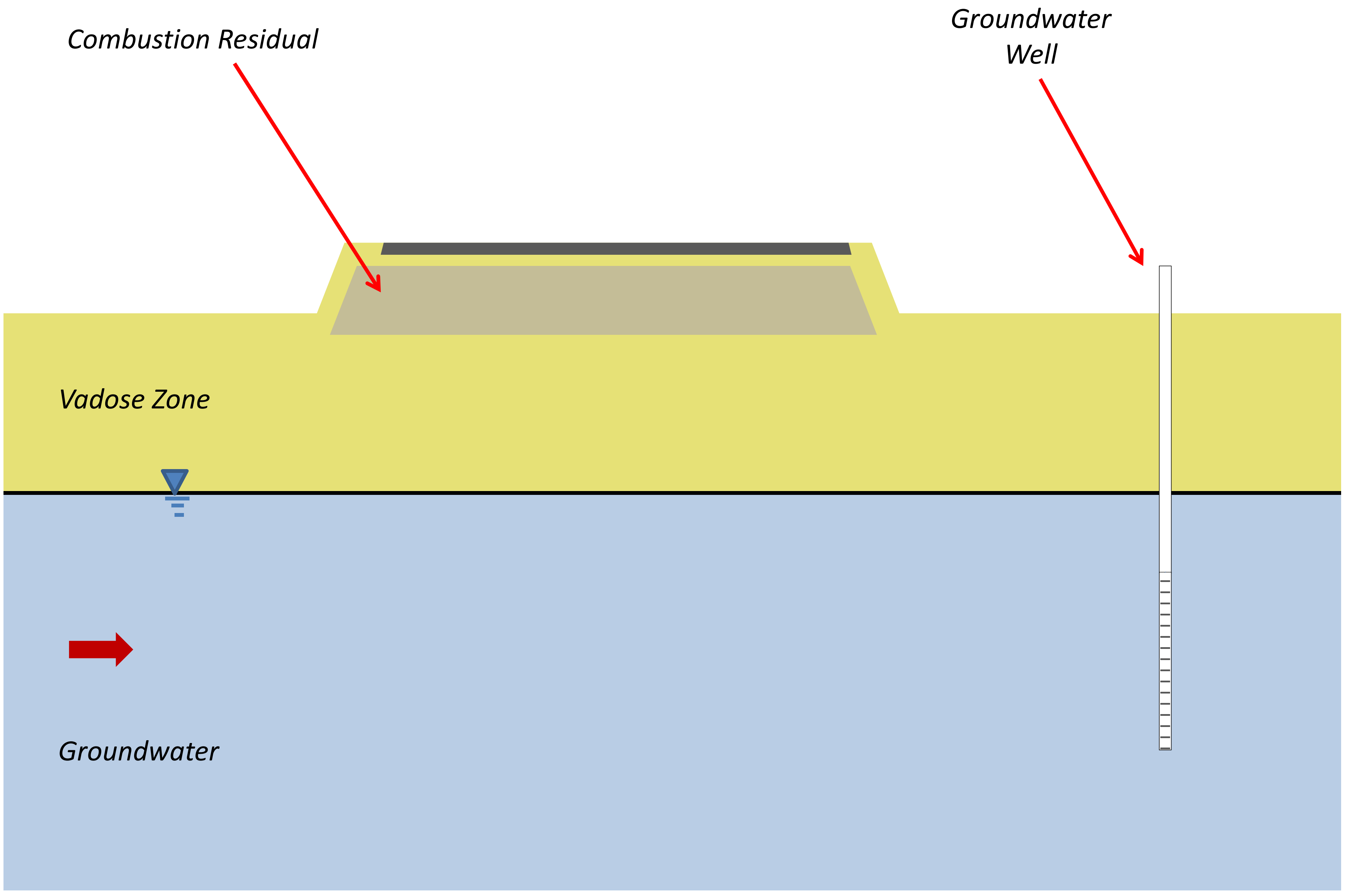
- The TCLP may not be a good predictor since it is designed to simulate a landfill environment
- The SPLP is similar to the TCLP but it uses a simulated rainwater as the leaching solution.
- New EPA leaching tests in SW-846:
  - Leaching Environmental Assessment Framework (LEAF)
  - Provides a framework to characterize the waste under a larger scope of release conditions

Example FL GCTLs

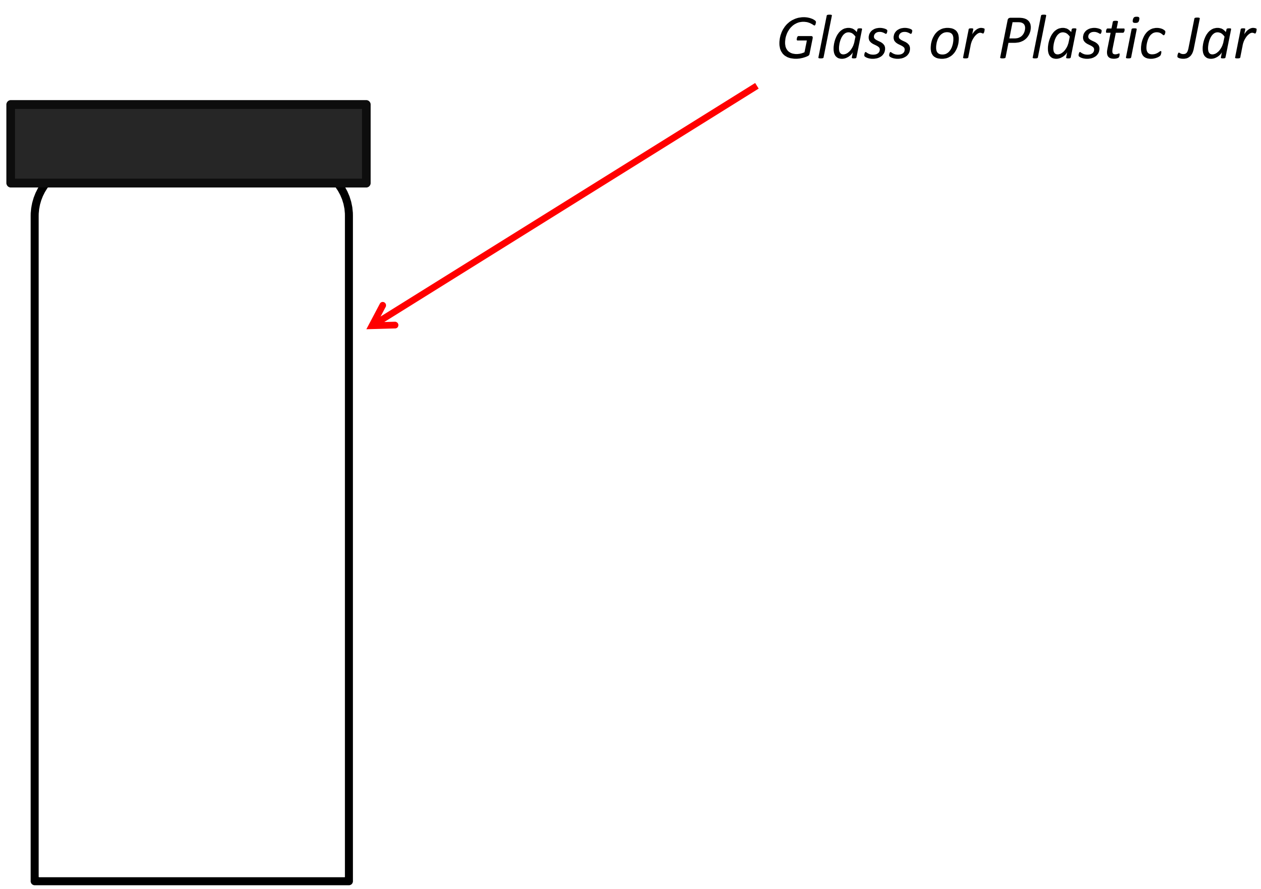
Element	GCTL (mg/L)
Aluminum (Al	0.2
Arsenic (As)	0.01
Barium (Ba)	2
Cadmium (Cd)	0.005
Chromium (total)	0.1
Cobalt (Co)	140
Copper (Cu)	1
Iron (Fe)	0.3
Lead (Pb)	0.015
Manganese (Mn)	50
Mercury (Hg)	0.002
Selenium (Se)	0.05
Silver (Ag)	0.1
Vanadium (V)	49

Typical practice is to compare leaching test results to GCTL or similar threshold

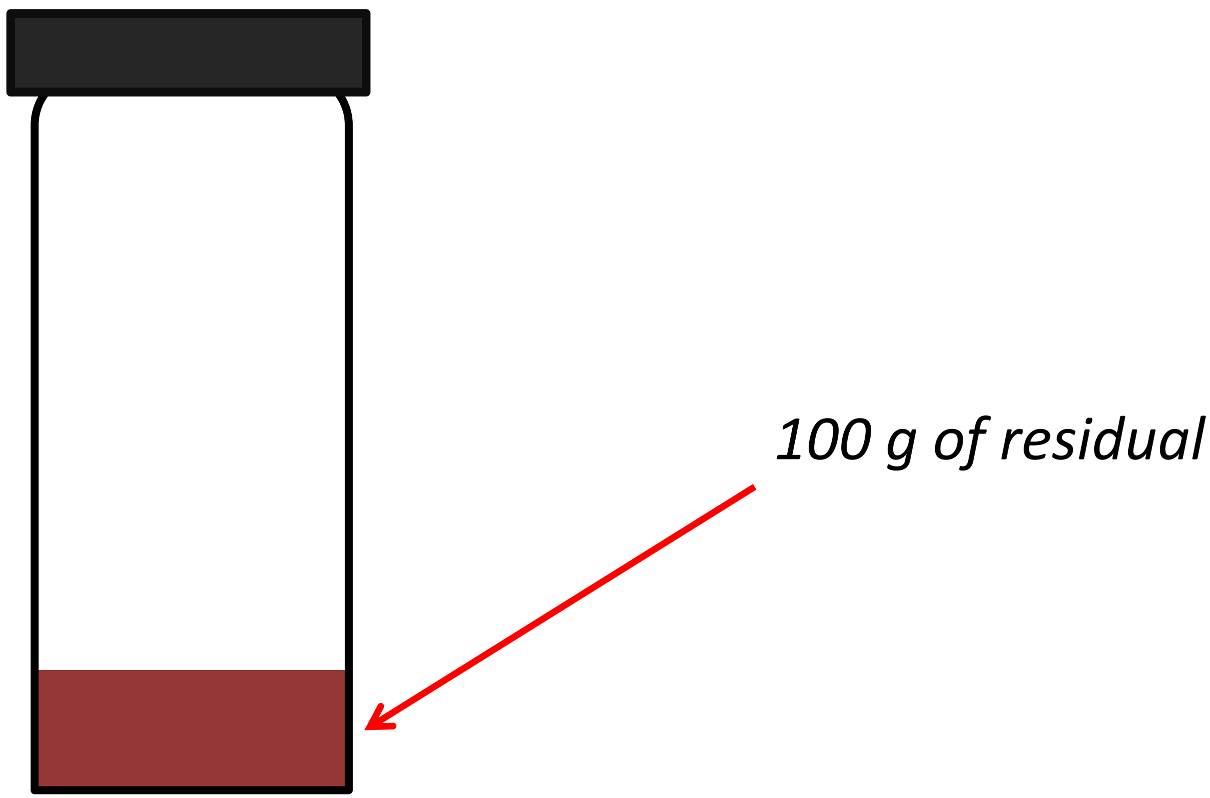
What we are trying to assess?



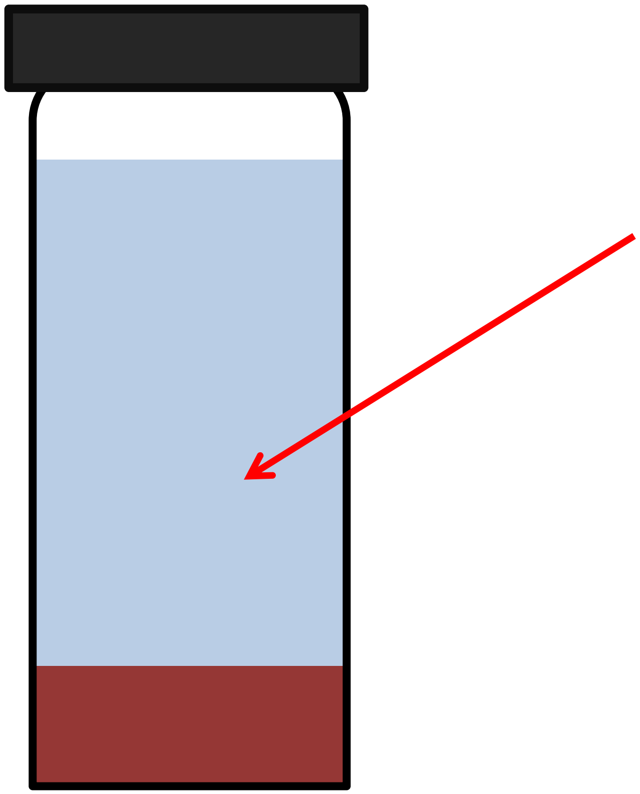
Consider a Typical Leaching Test



Consider a Typical Leaching Test



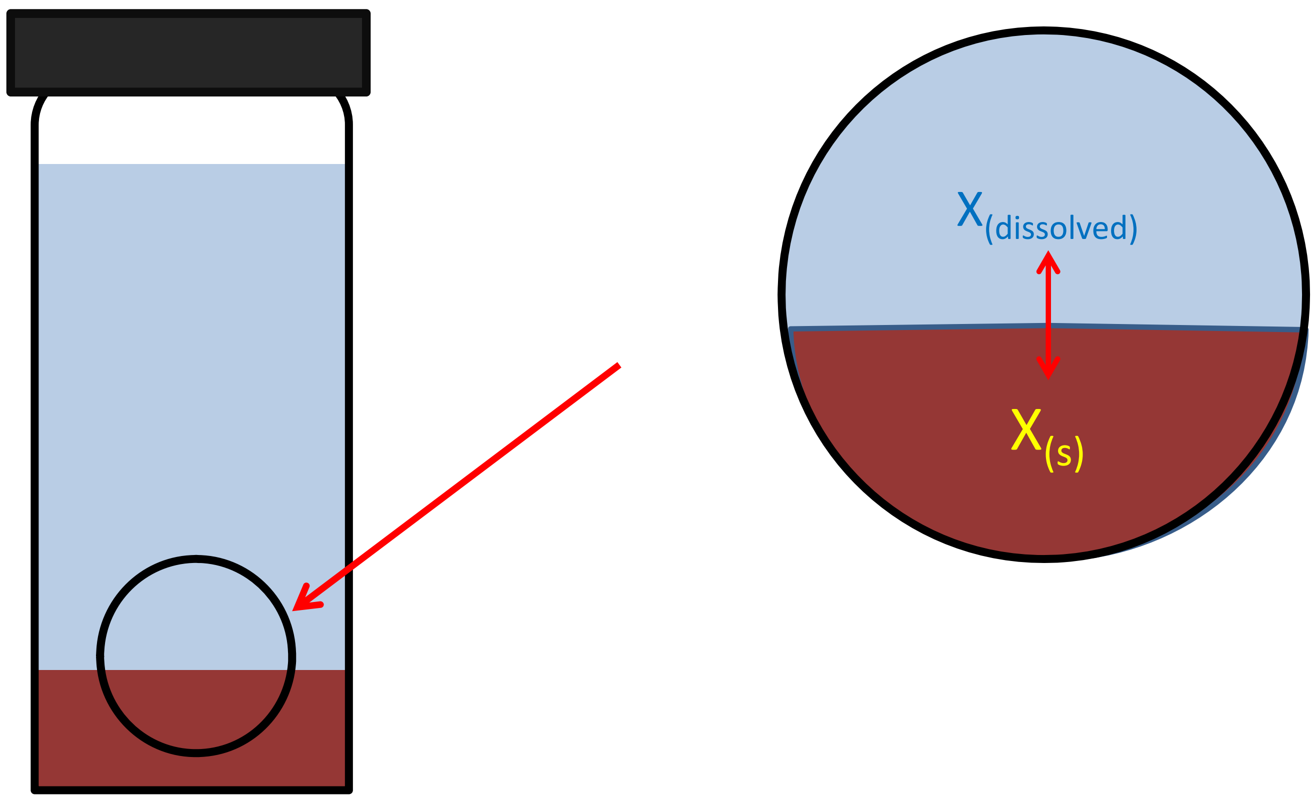
Consider a Typical Leaching Test



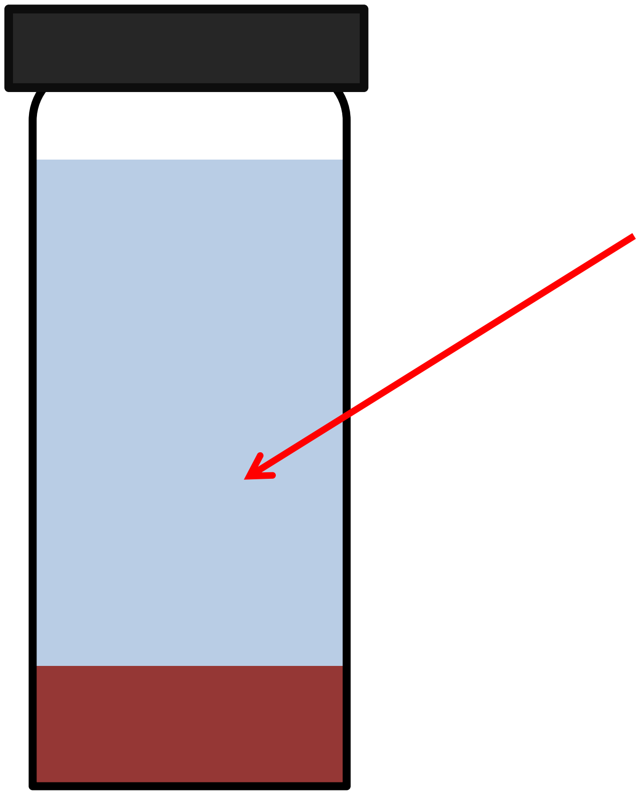
2 L of leaching solution

This is a batch test.
Other types of leaching tests include dynamic batch tests and flow-through column tests.

Consider a Typical Leaching Test



What Impacts Leaching?

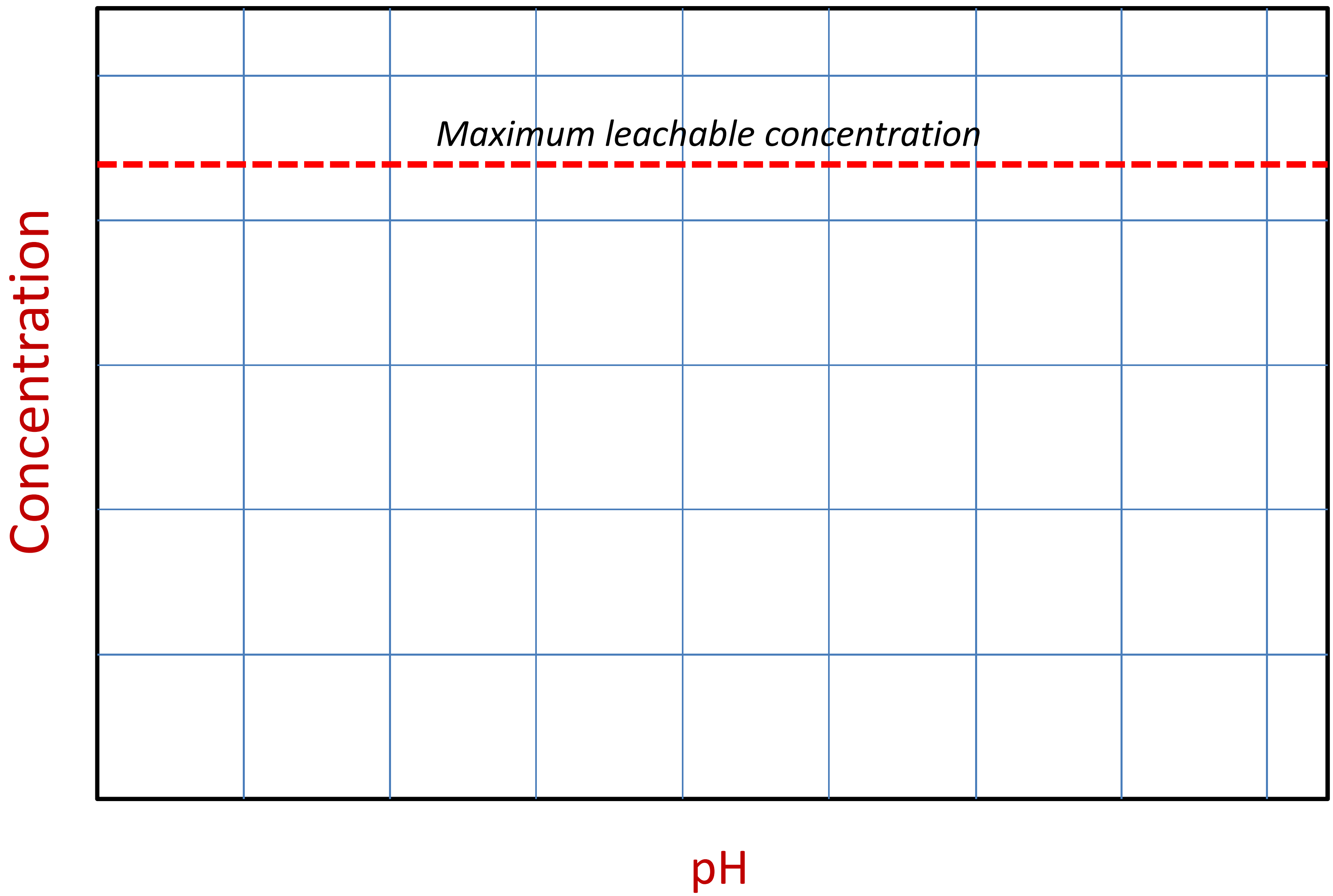


Leaching Solution Chemistry

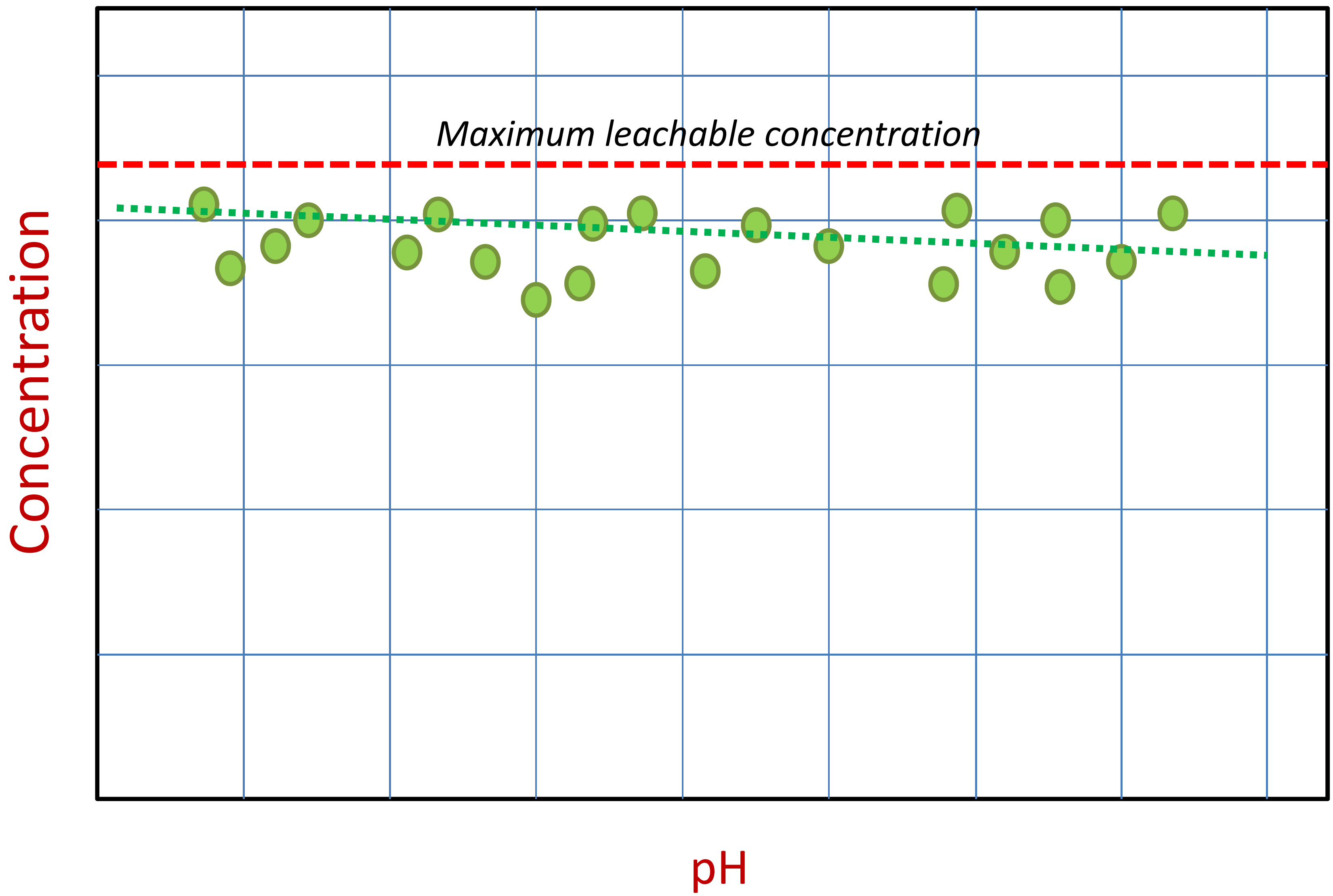
→ TCLP: Buffered acetic acid solution with pH = 4.8 or 2.3

→ SPLP: Unbuffered solution of nitric and sulfuric acid with pH = 4.2 or

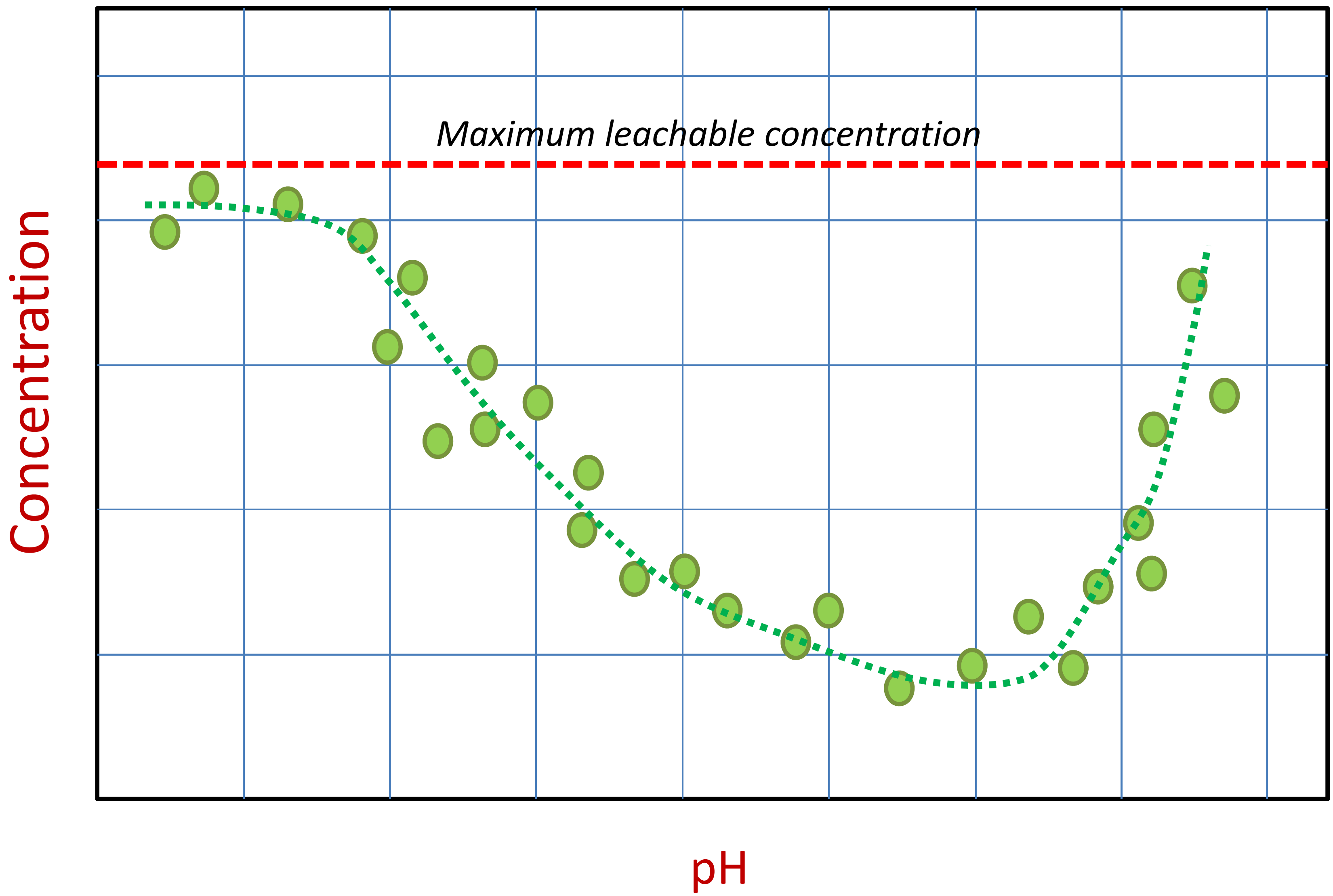
Impact of pH



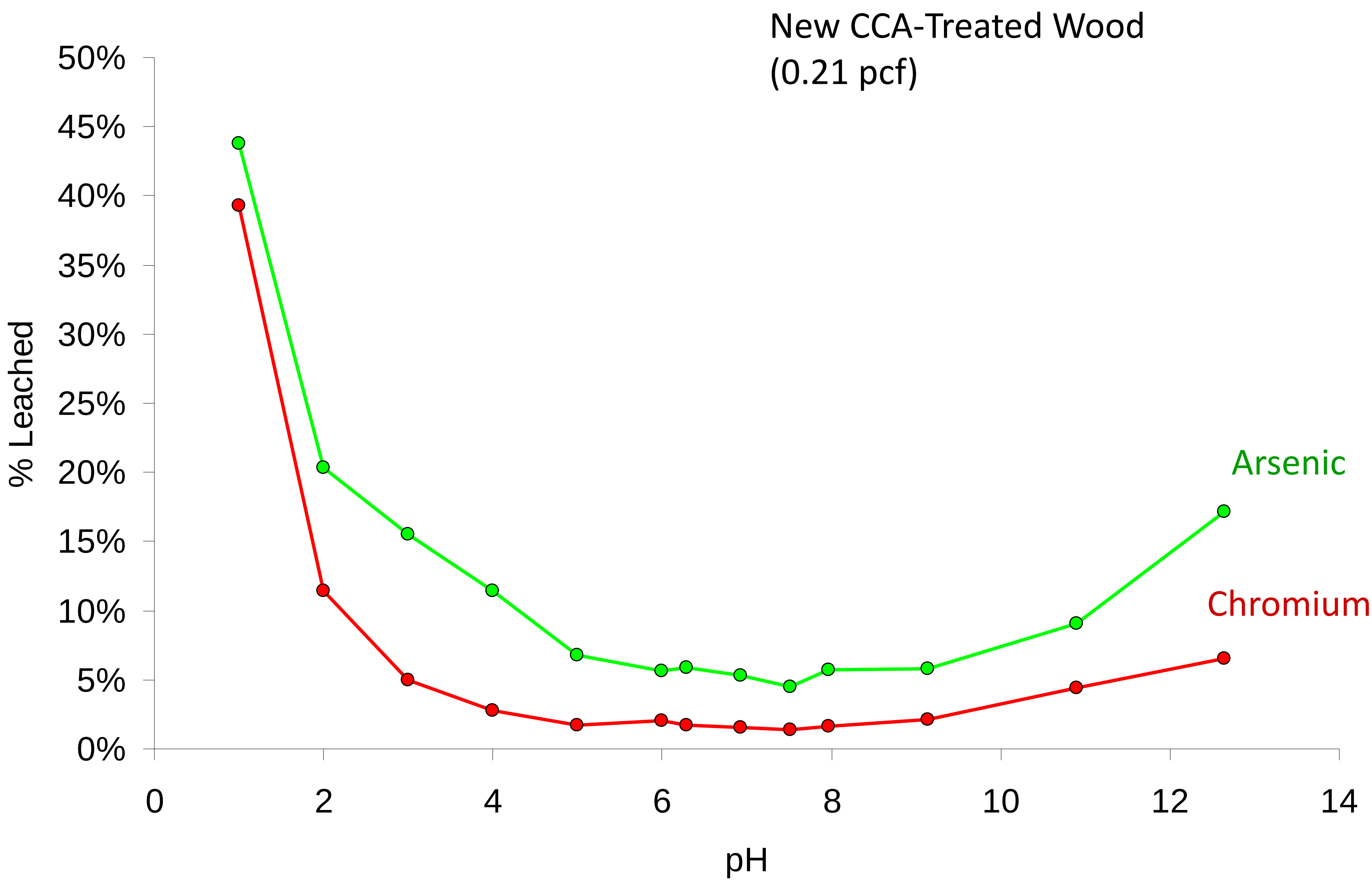
Impact of pH: Soluble Salt



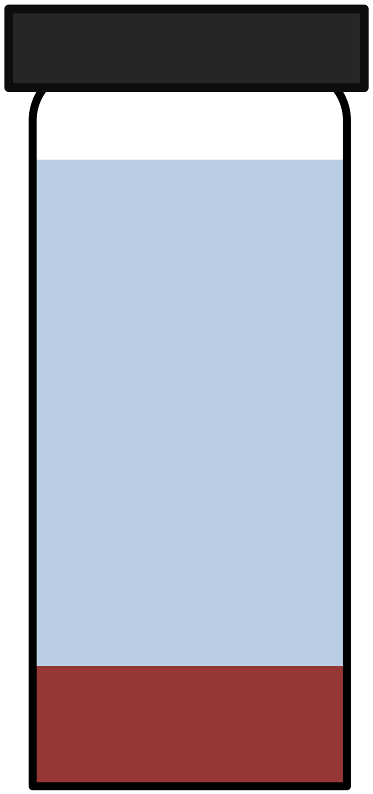
Impact of pH: Amphoteric



Impact of pH


New CCA-Treated Wood
(0.21 pcf)
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
% Leached
0
2
4
6
8
10
12
14
pH
Arsenic
Chromium

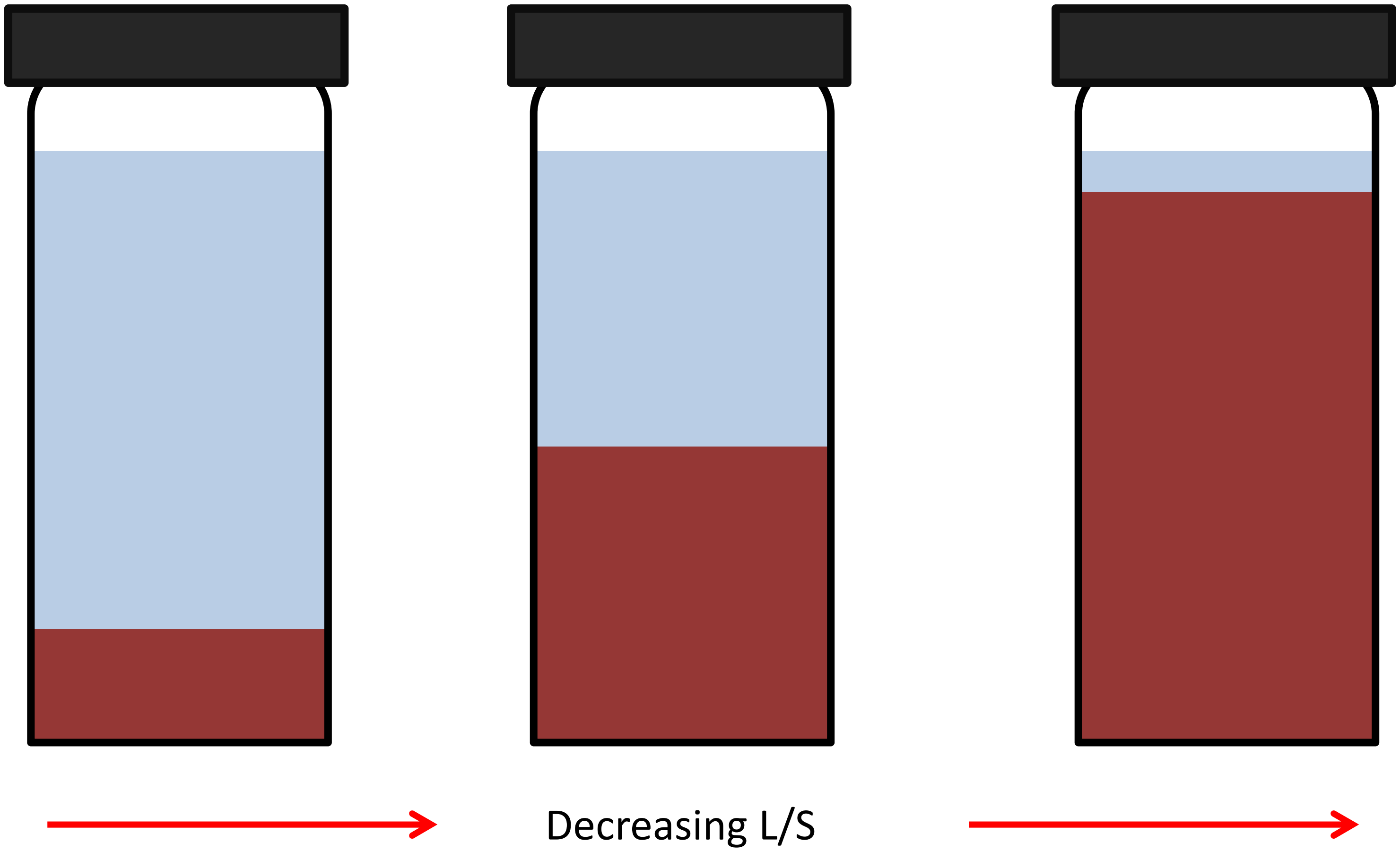
What Impacts Leaching?



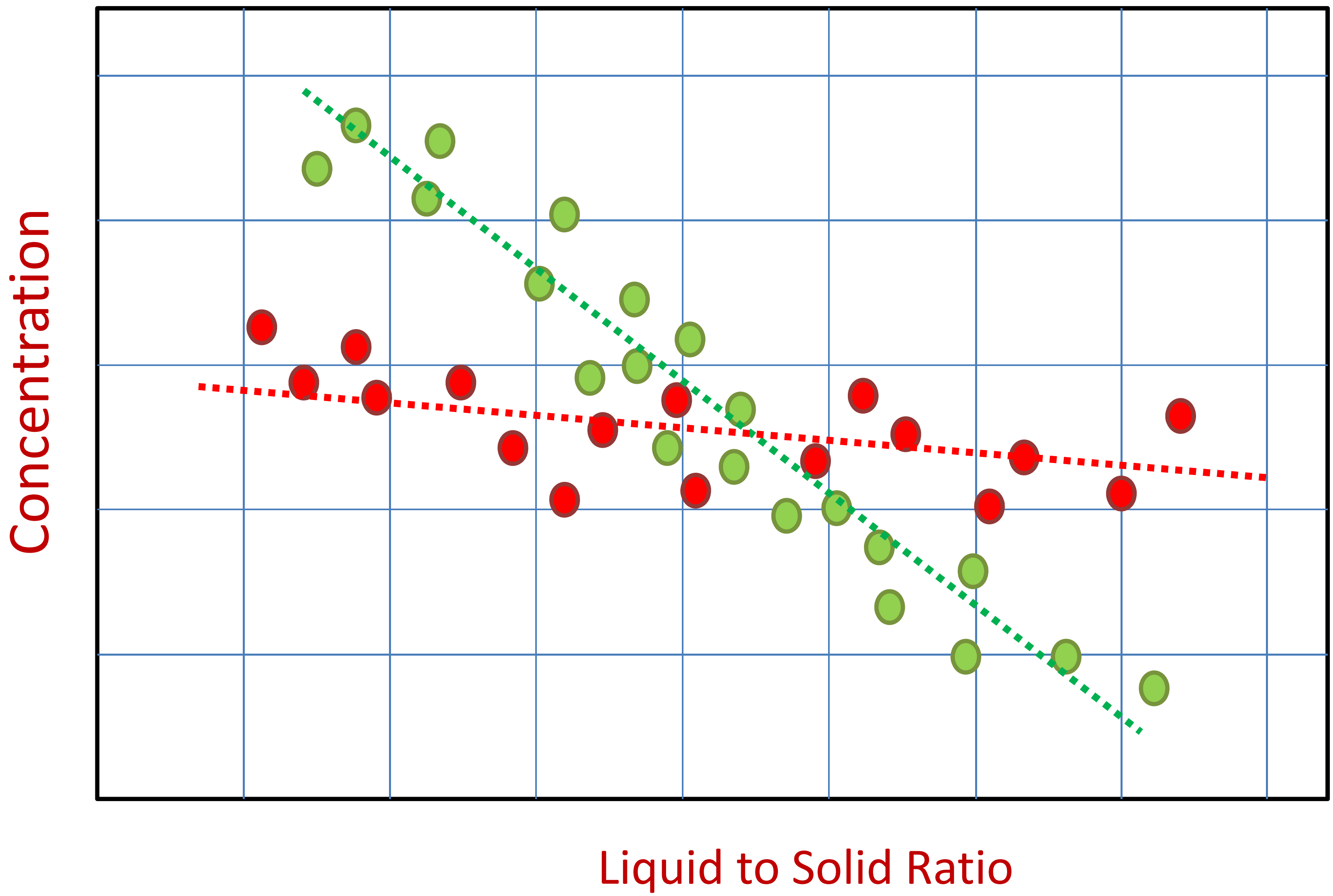
Liquid to Solid Ratio

→ TCLP and SPLP: 20 to 1

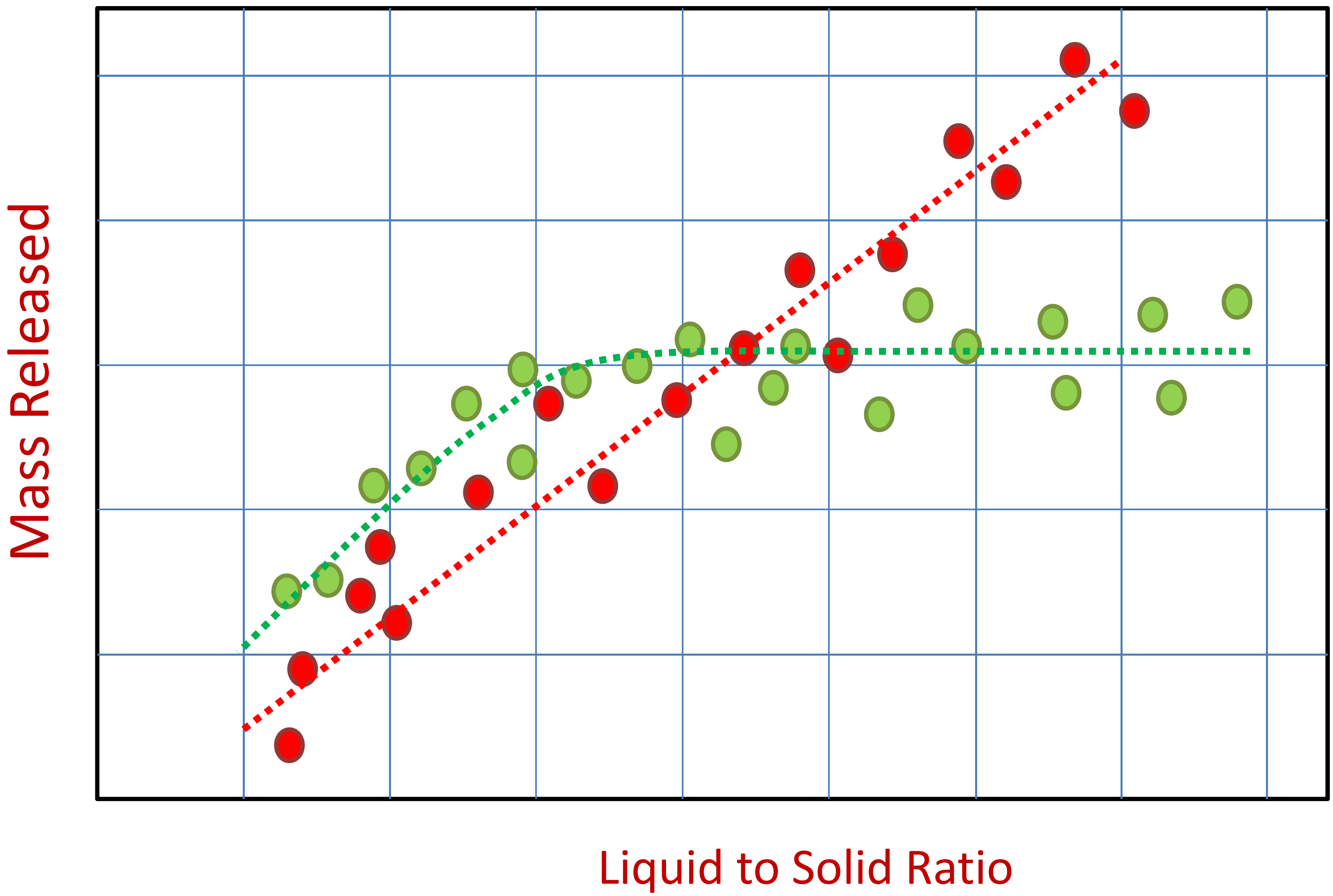
What Impacts Leaching?



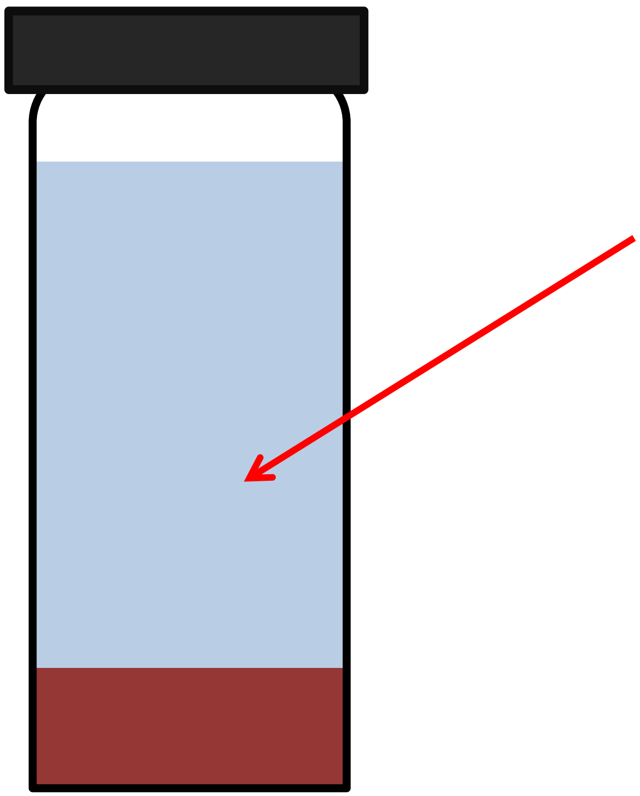
Impact of Liquid to Solid Ratio



Impact of Liquid to Solid Ratio



What Impacts Leaching?

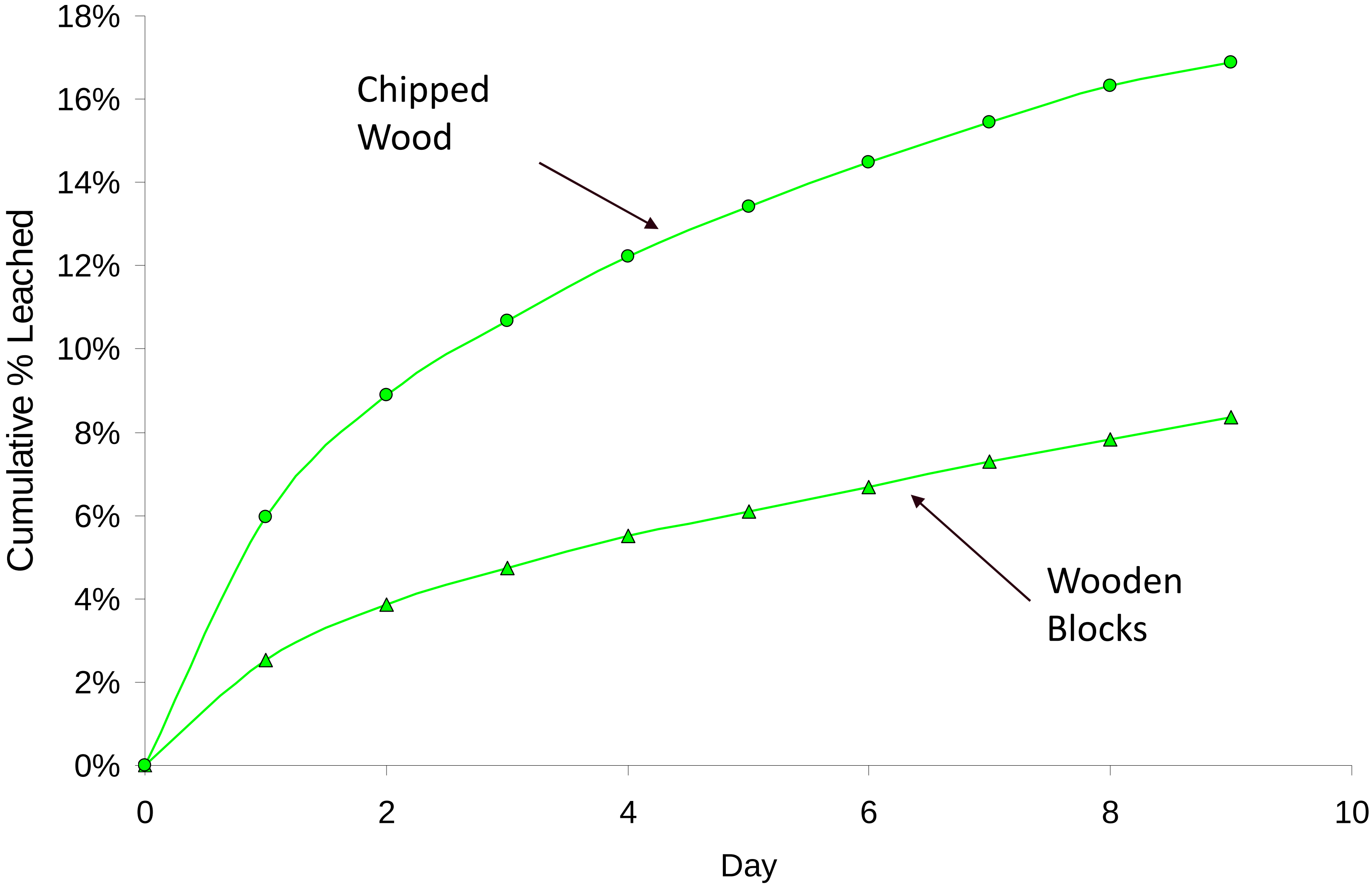


Leaching Time

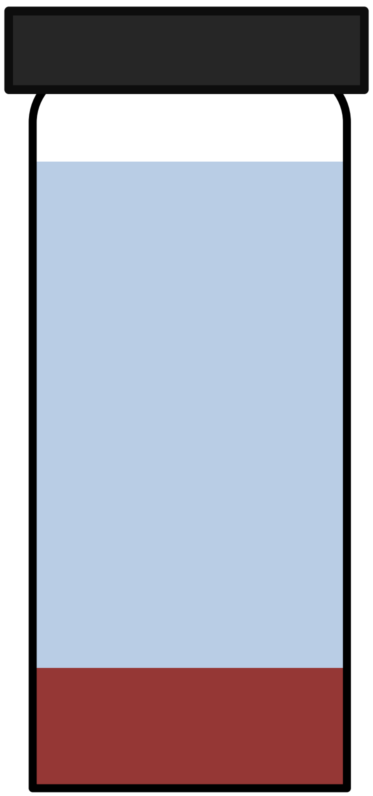
→ TCLP and SPLP: 18 +/- 2 hours

Impact of Time

Multiple Extraction Procedure (Arsenic)



What Impacts Leaching?



Redox Potential?

Oxidizing or reducing environment

EPA Leaching Tests

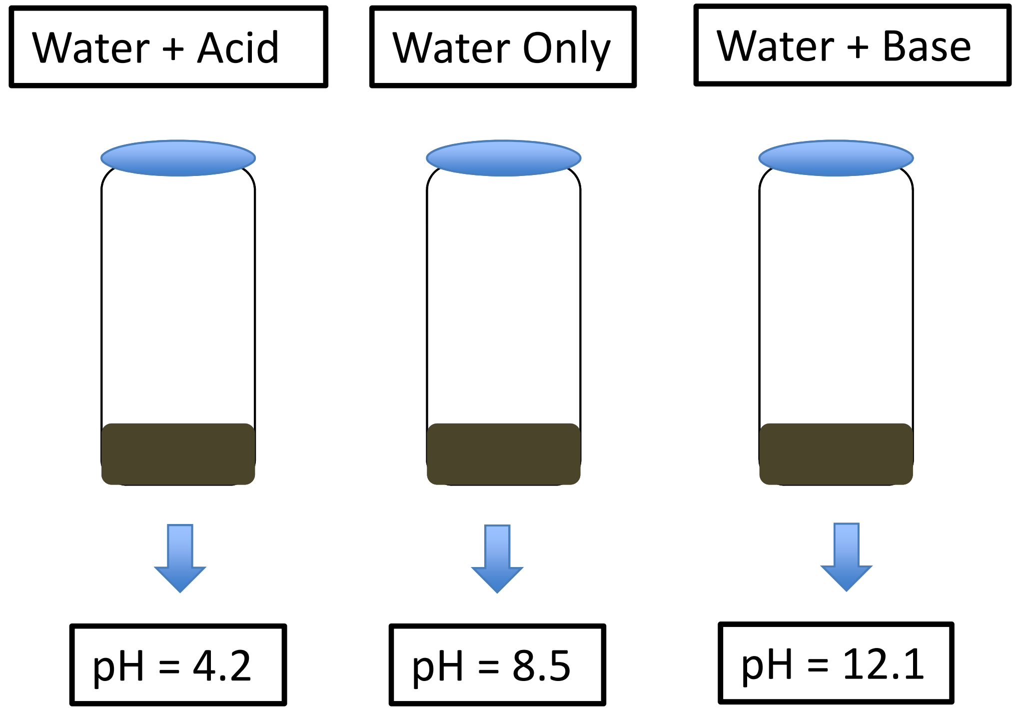
- *Method 1311* "Toxicity Characteristic Leaching Procedure"
- *Method 1312* "Synthetic Precipitation Leaching Procedure"
- *Method 1313* "Liquid-Solid Partitioning as a Function of Extract pH for Constituents in Solid Materials using a Parallel Batch Extraction Procedure"
- *Method 1314* "Liquid-Solid Partitioning as a Function of Liquid-Solid Ratio for Constituents in Solid Materials using an Up-flow Percolation Column Procedure"
- *Method 1315* "Mass Transfer Rates of Constituents in Monolithic or Compacted Granular Materials using a Semi-dynamic Tank Leaching Procedure"
- *Method 1316* "Liquid-Solid Partitioning as a Function of Liquid-Solid Ratio for Constituents in Solid Materials using a Parallel Batch Extraction Procedure"

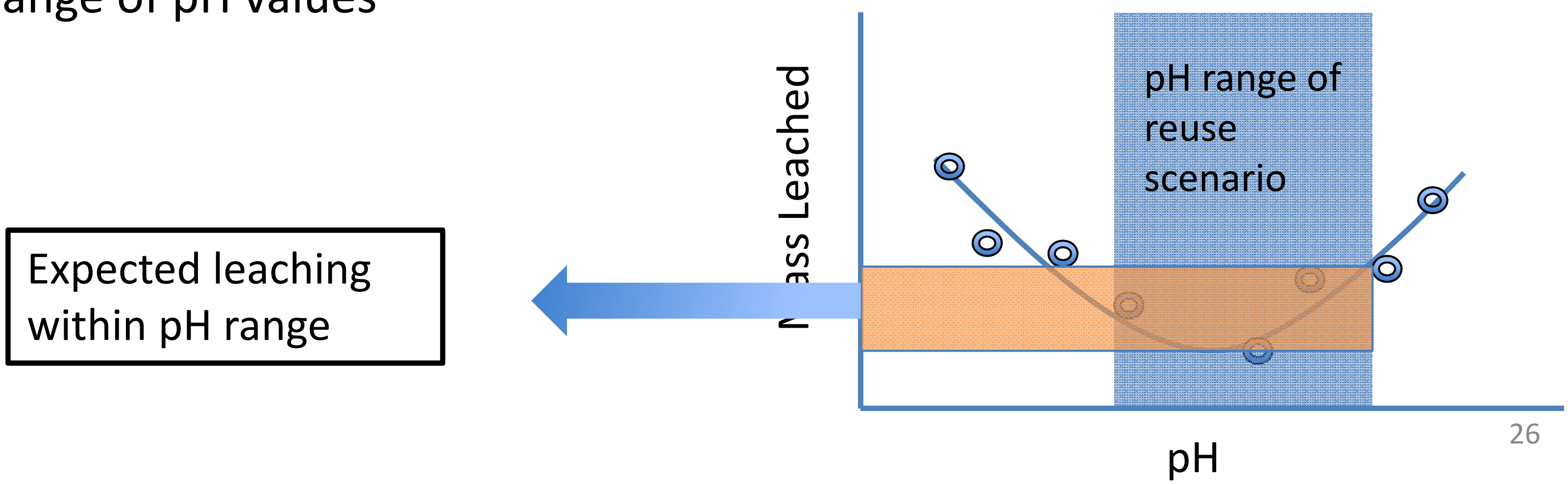
Method 1313

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

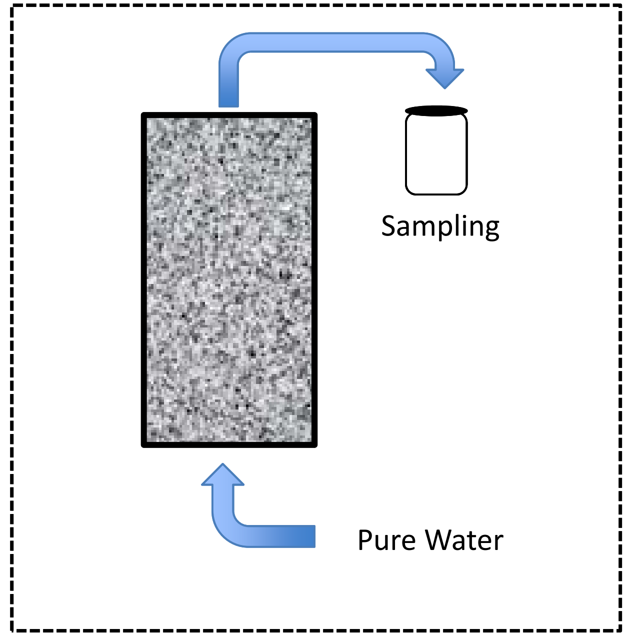


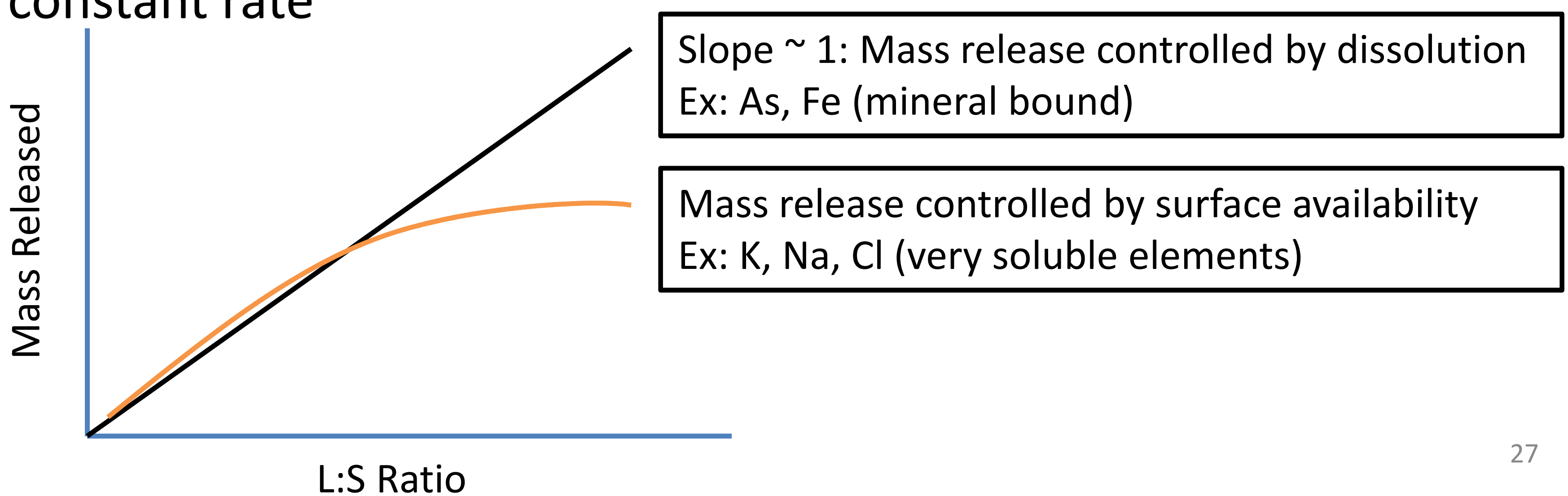


Method 1314

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

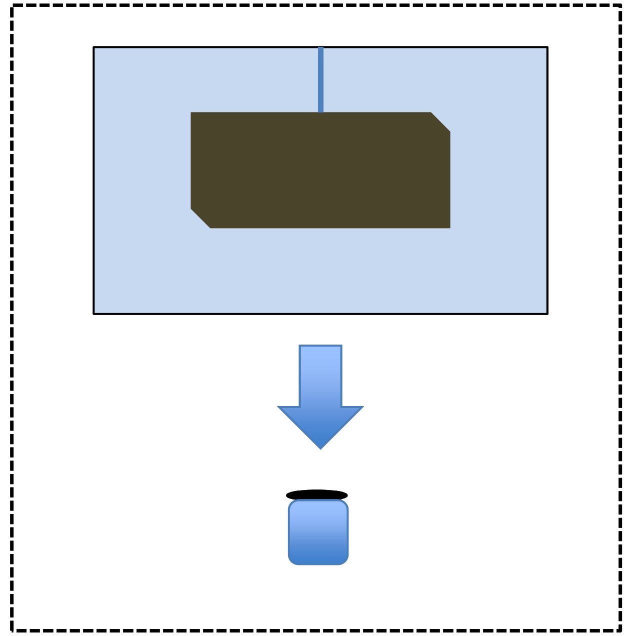
Goal: Determine which constituents wash out quickly and which dissolve into the water at a constant rate



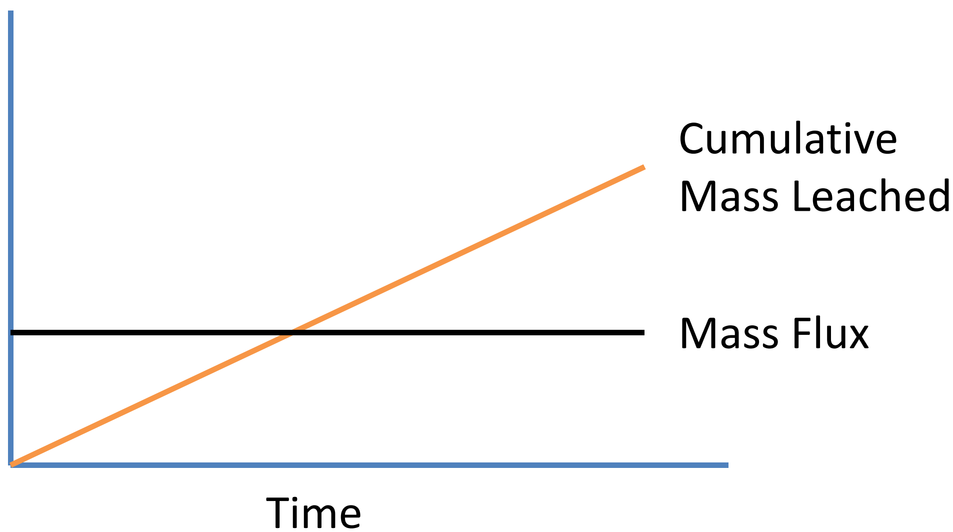


Method 1315

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



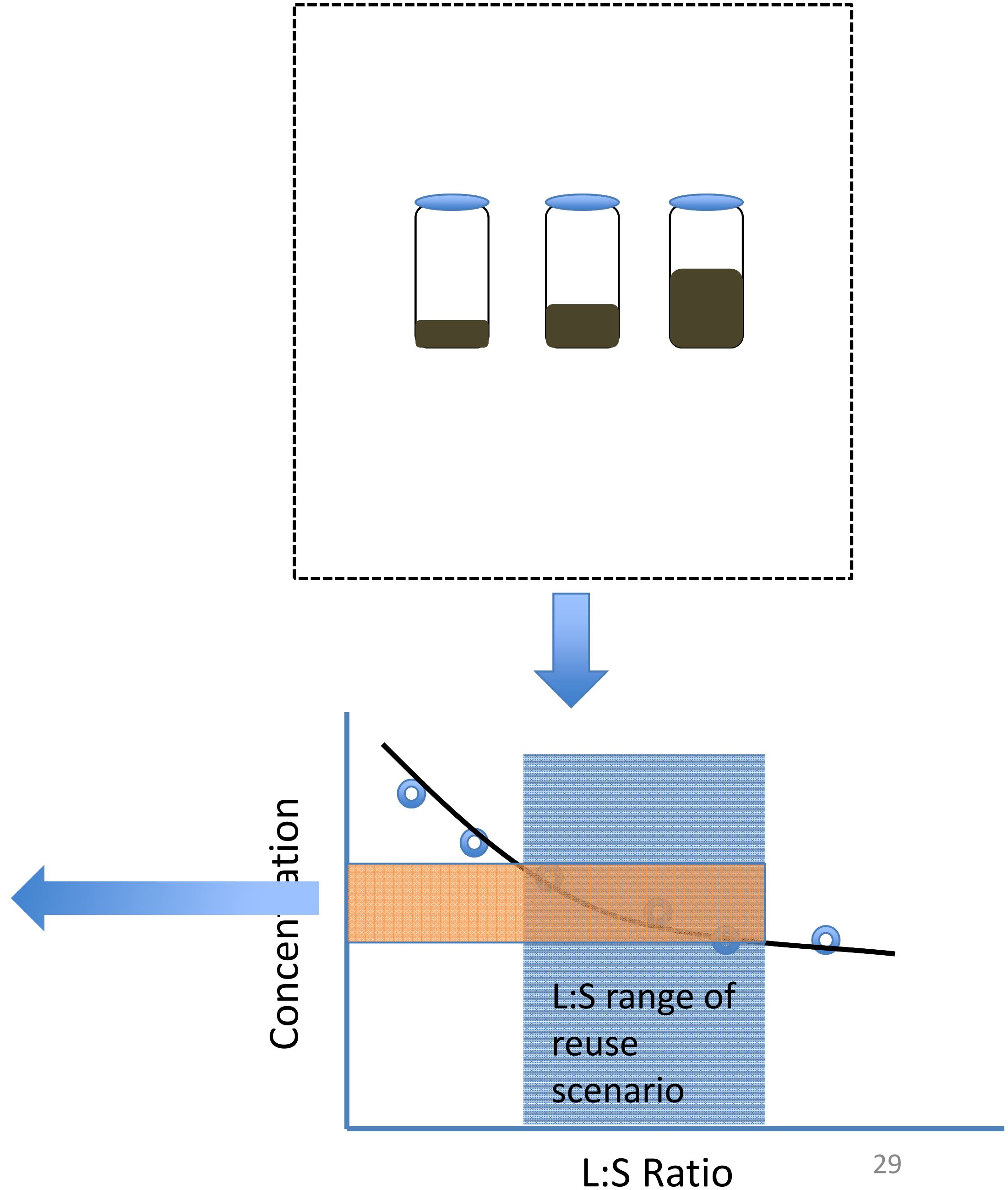
This information can help in predicting mass release in the long run

Method 1316

Interpreting Results

Parallel batch performed at five different liquid to solid ratios.

Similar to 1313 but more rapid.



Expected leaching within L:S range

Example Questions

Analytical

- How do new tests compare to SPLP?
- What particle size is appropriate to use?
- How do the different filters impact the results?

Application

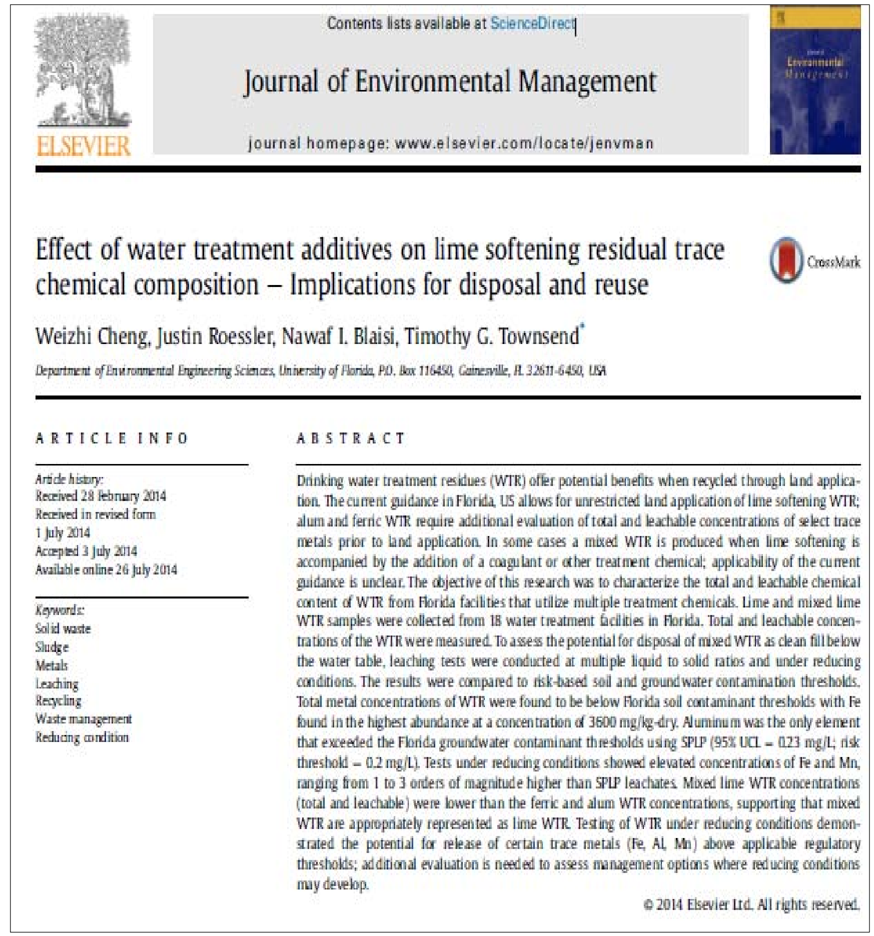
- Which pH regime should be the target regime?
- How do you evaluate leachate concentrations that change over time?
- For different reuse scenarios, what is the most appropriate test to use and how?

Project Objectives

- Document LEAF Methods
  - Testing procedures
- Guidance for practitioners
  - Intent
  - Differences
  - Application

Literature Review

- Application of leaching protocols
  - Refereed literature
  - Industry and government
  - International experience
- Identify candidate waste streams



Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Effect of water treatment additives on lime softening residual trace chemical composition – Implications for disposal and reuse

Weizhi Cheng, Justin Roessler, Nawaf I. Blaisi, Timothy G. Townsend*

Department of Environmental Engineering Sciences, University of Florida, P.O. Box 116450, Gainesville, FL 32611-6450, USA

ARTICLE INFO

Article history:
Received 28 February 2014
Received in revised form
1 July 2014
Accepted 3 July 2014
Available online 26 July 2014

Keywords:
Solid waste
Sludge
Metals
Leaching
Recycling
Waste management
Reducing condition

ABSTRACT

Drinking water treatment residues (WTR) offer potential benefits when recycled through land application. The current guidance in Florida, US allows for unrestricted land application of lime softening WTR; alum and ferric WTR require additional evaluation of total and leachable concentrations of select trace metals prior to land application. In some cases a mixed WTR is produced when lime softening is accompanied by the addition of a coagulant or other treatment chemical; applicability of the current guidance is unclear. The objective of this research was to characterize the total and leachable chemical content of WTR from Florida facilities that utilize multiple treatment chemicals. Lime and mixed lime WTR samples were collected from 18 water treatment facilities in Florida. Total and leachable concentrations of the WTR were measured. To assess the potential for disposal of mixed WTR as clean fill below the water table, leaching tests were conducted at multiple liquid to solid ratios and under reducing conditions. The results were compared to risk-based soil and groundwater contamination thresholds. Total metal concentrations of WTR were found to be below Florida soil contaminant thresholds with Fe found in the highest abundance at a concentration of 3600 mg/kg-dry. Aluminum was the only element that exceeded the Florida groundwater contaminant thresholds using SPLP (95% UCL = 0.23 mg/L; risk threshold = 0.2 mg/L). Tests under reducing conditions showed elevated concentrations of Fe and Mn, ranging from 1 to 3 orders of magnitude higher than SPLP leachates. Mixed lime WTR concentrations (total and leachable) were lower than the ferric and alum WTR concentrations, supporting that mixed WTR are appropriately represented as lime WTR. Testing of WTR under reducing conditions demonstrated the potential for release of certain trace metals (Fe, Al, Mn) above applicable regulatory thresholds; additional evaluation is needed to assess management options where reducing conditions may develop.

© 2014 Elsevier Ltd. All rights reserved.

Project Objectives

- Examine previous beneficial use assessments in Florida

Florida Beneficial Use Leaching Assessment

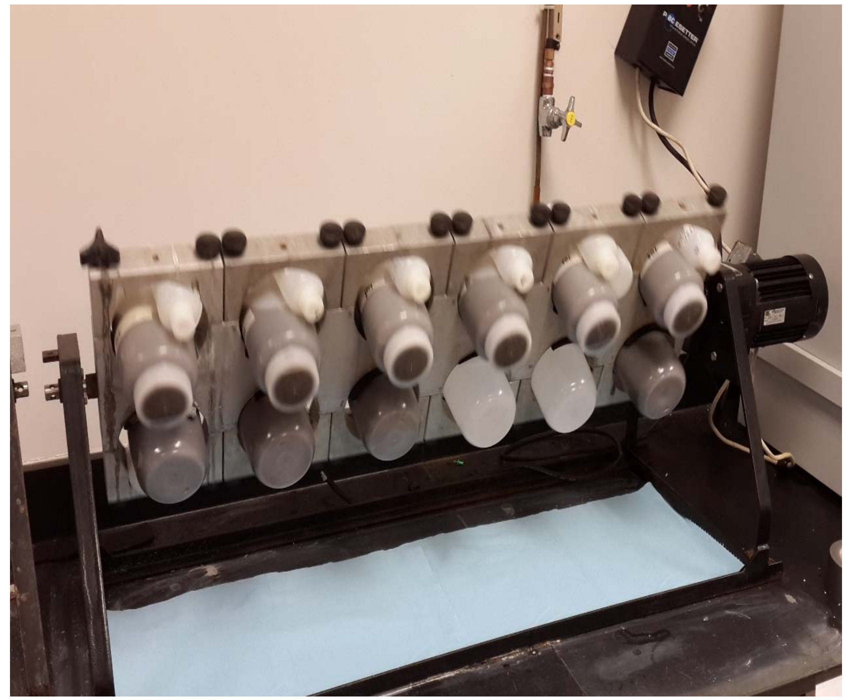
- Street sweepings
- Catch basin/SW sediments
- Waste-to-energy ash
- Milled asphalt pavement
- Coal combustion residuals
- Recovered waste-amended concrete

How may have LEAF impacted decision?

Project Objectives

- Perform leaching tests on three specific waste streams

- Selected from:
  - Previous assessments in FL
  - Feedback from project TAG

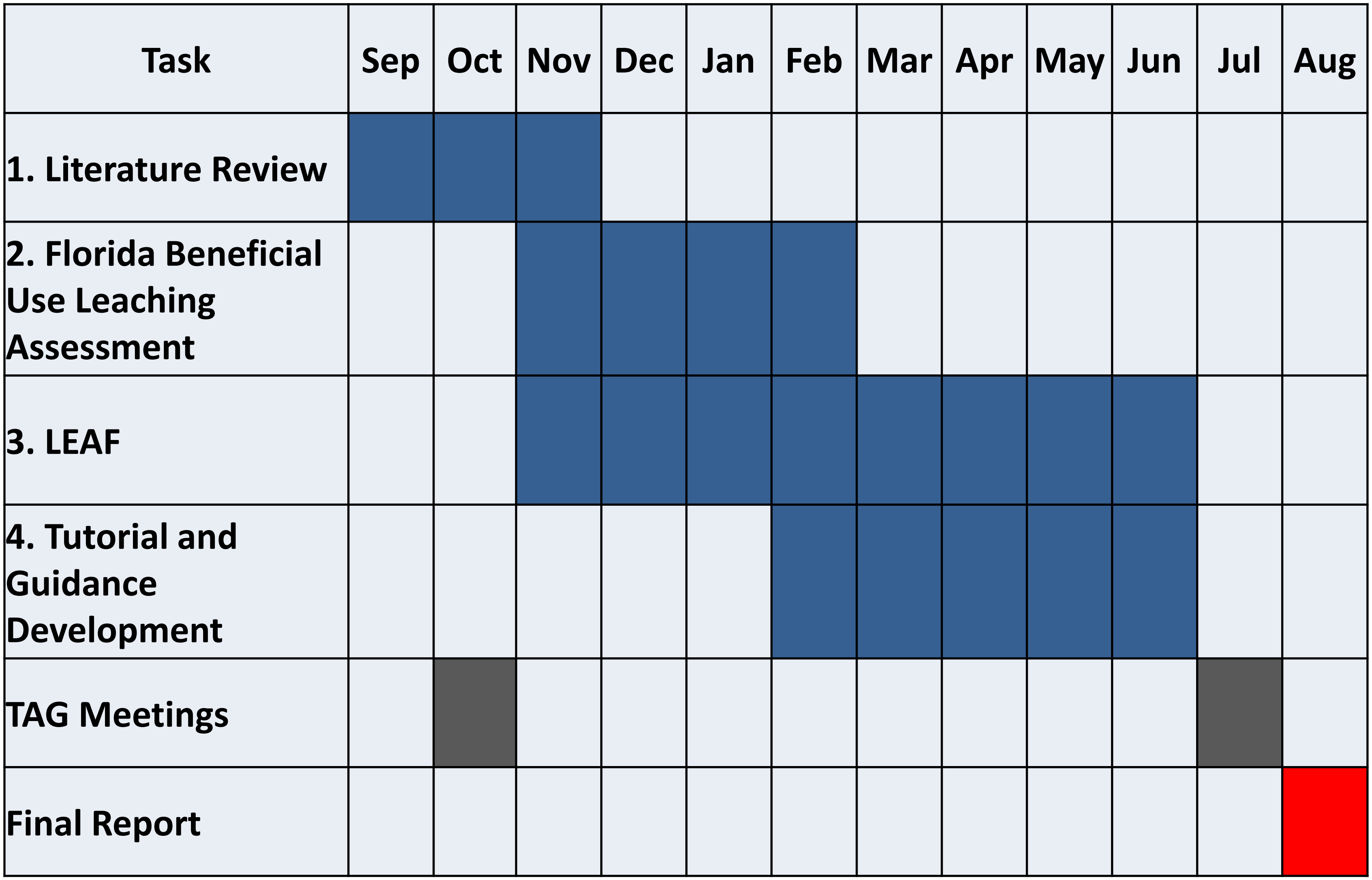


LEAF Testing

- LEAF tests
- SPLP and total concentration
- Answer questions from previous tasks:
  - How LEAF methods are applied
  - Added insight

Guidance Document

- Final Report
  - Utility of LEAF methods for beneficial use decisions
- Tutorial on LEAF methods
  - Differences from existing procedures
  - How they may be applied
- Potential ideas for guidance document


Task
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
1. Literature Review
2. Florida Beneficial Use Leaching Assessment
3. LEAF
4. Tutorial and Guidance Development
TAG Meetings
Final Report

How have we used LEAF?

- Several examples where LEAF has been used by our research team to help with a beneficial use assessment
  - Sludge from water treatment
  - Waste to energy ash
- We have also evaluated other wastes
  - Coal ash
  - Mining Waste
  - Electronic Waste

Our Approach

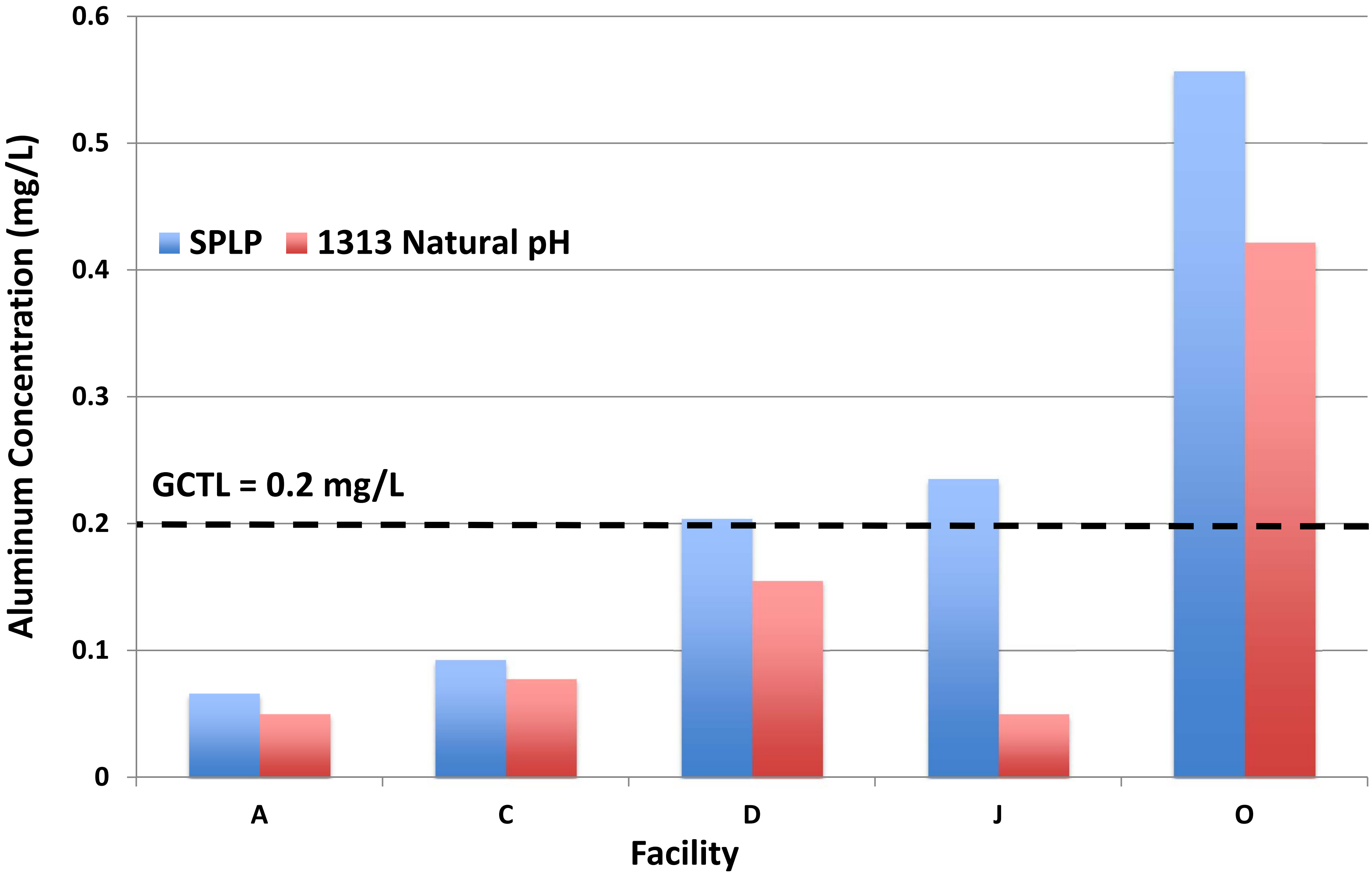
- SPLP testing still conducted
  - Screening tool
  - Needed for a comparison
- LEAF testing conducted to better assess contaminant release under specific reuse conditions
- LEAF testing conducted to examine waste treatment options
  - What can be done to make material leach less

Drinking Water Sludge

Drinking Water Sludge

- Assess the effect of additional treatment additives and possibility for use as a "clean fill" in water bodies
- Aluminum a potential concern with respect to leaching
- Consider the scenario where values are compared directly to target levels

Method Natural pH and SPLP



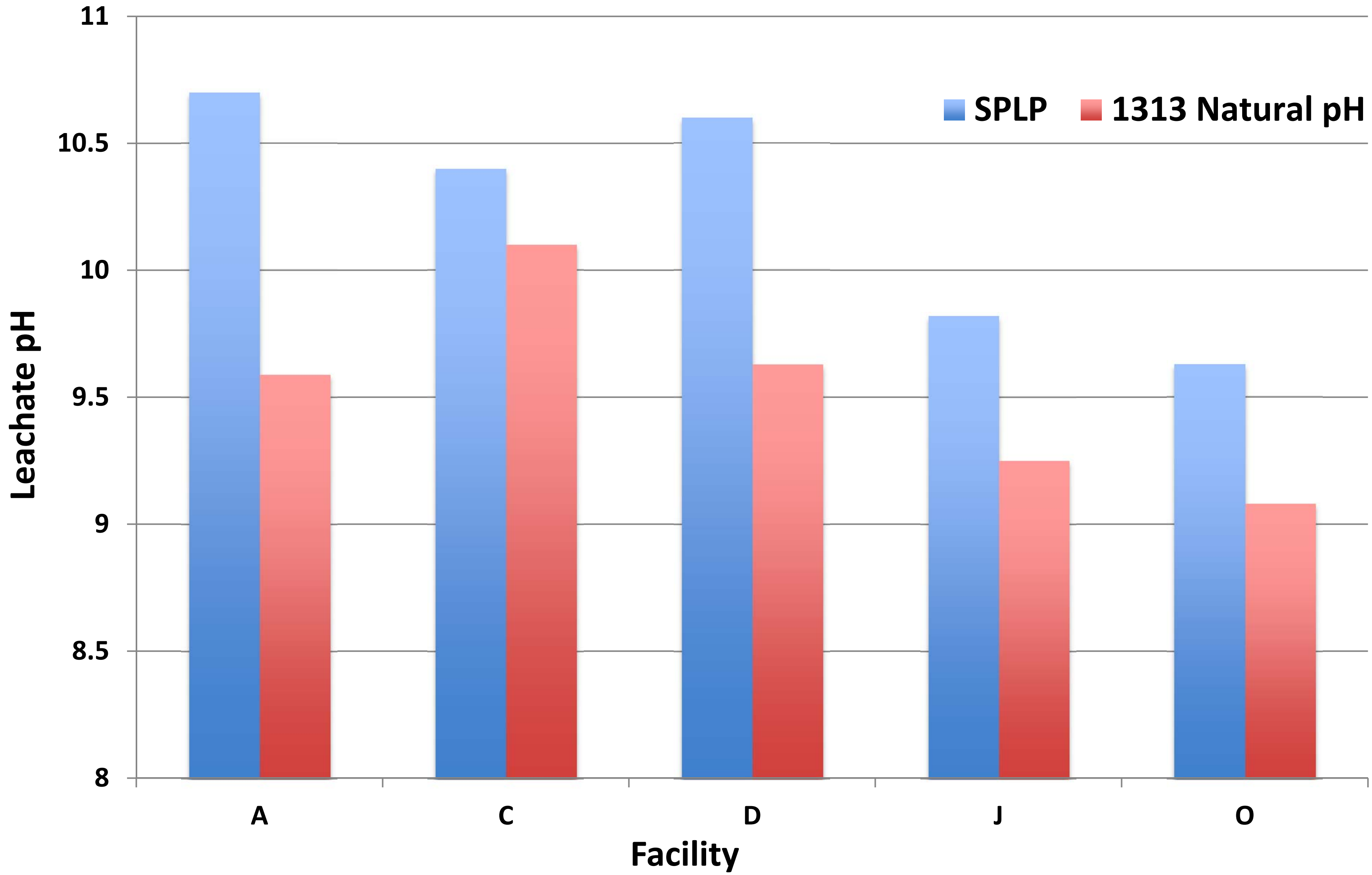
Leaching Results

Natural pH – pH when immersed in water at a liquid to solid ratio of 10

Method 1313 (Natural pH), Method 1316 (L/S – 10)

- Some would argue this is a more representative batch test than SPLP
- For some of the facilities tested SPLP concentrations were elevated when compared values at the natural pH
- In one instance method 1313 values were on different side of GCTL than SPLP
  - Mean and 95% UCL

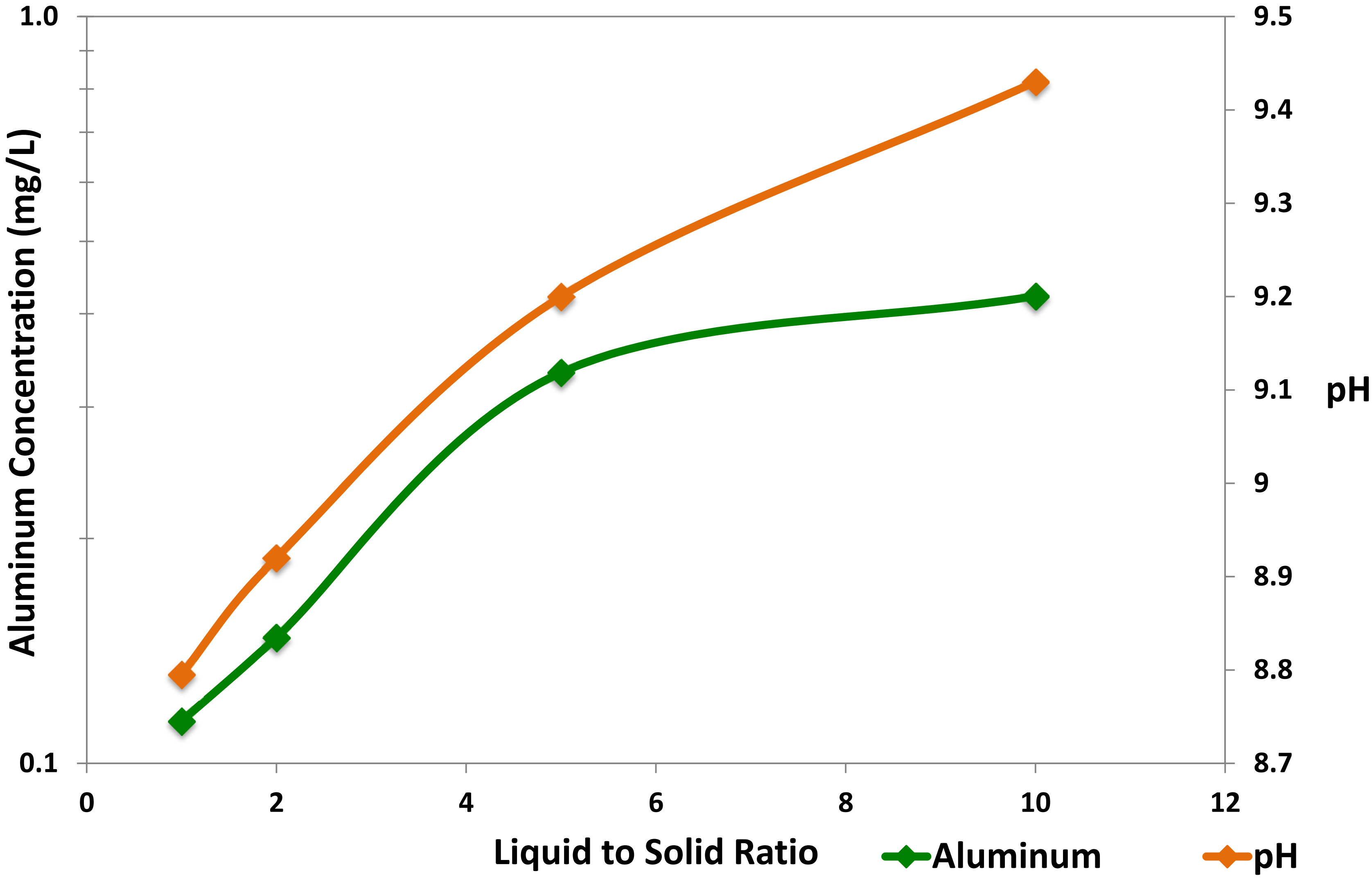
pH - Method 1313 and SPLP



Explaining Differences

- Differences in leachate pH between SPLP could explain discrepancy in concentrations
- SPLP test is conducted at a higher liquid to solid ratio and you would expect that pH would be lower
- Conduct Method 1316 – Batch Leaching as a function of liquid to solid ratio
  - Large number of facilities
  - Speed of testing, cost

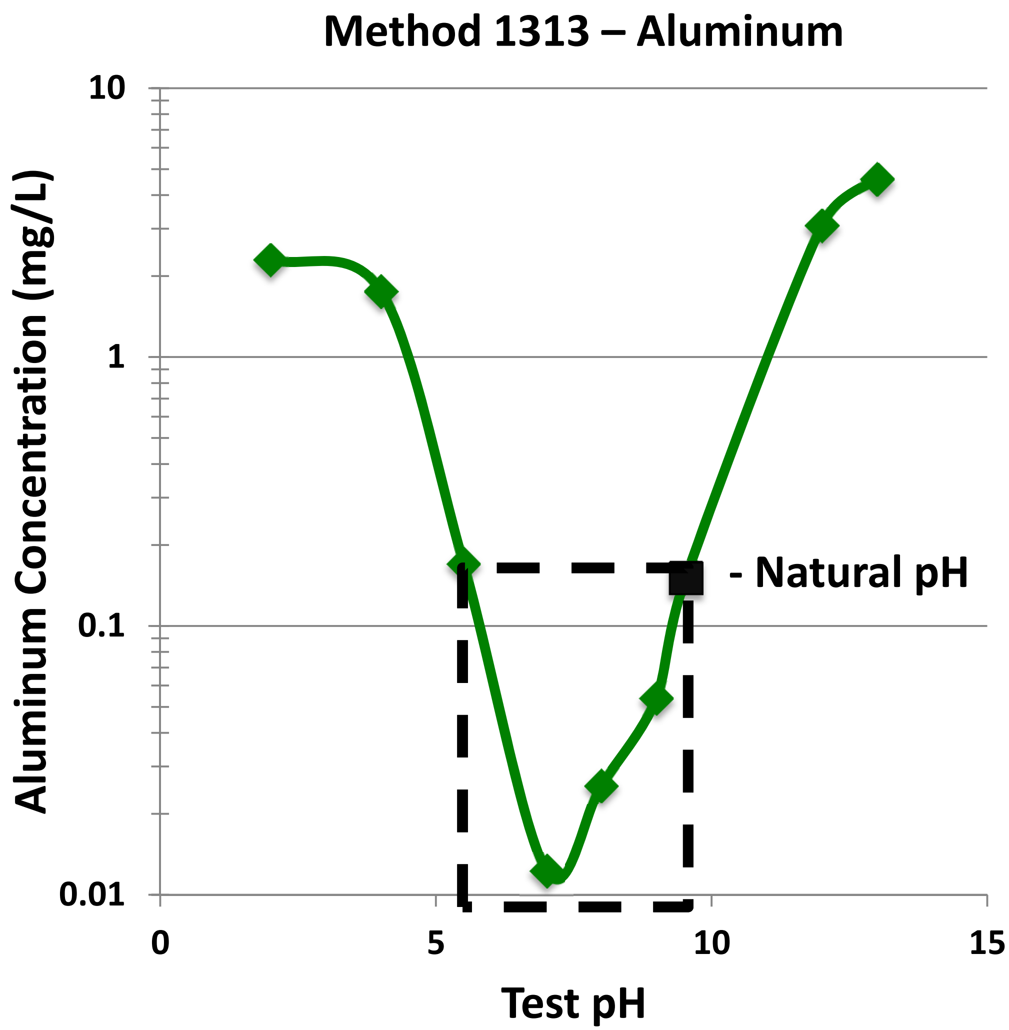
Method 1316



1.0
0.1
Aluminum Concentration (mg/L)
9.5
9.4
9.3
9.2
9.1
9
8.9
8.8
8.7
pH
0
2
4
6
8
10
12
Liquid to Solid Ratio
Aluminum
pH

Drinking Water Sludge Summary

- SPLP and natural pH leaching can differ significantly
  - Implications for risk assessment
  - Which test is more representative?
- LEAF helps to demonstrate leaching of Al in pH range of water bodies below GCTL



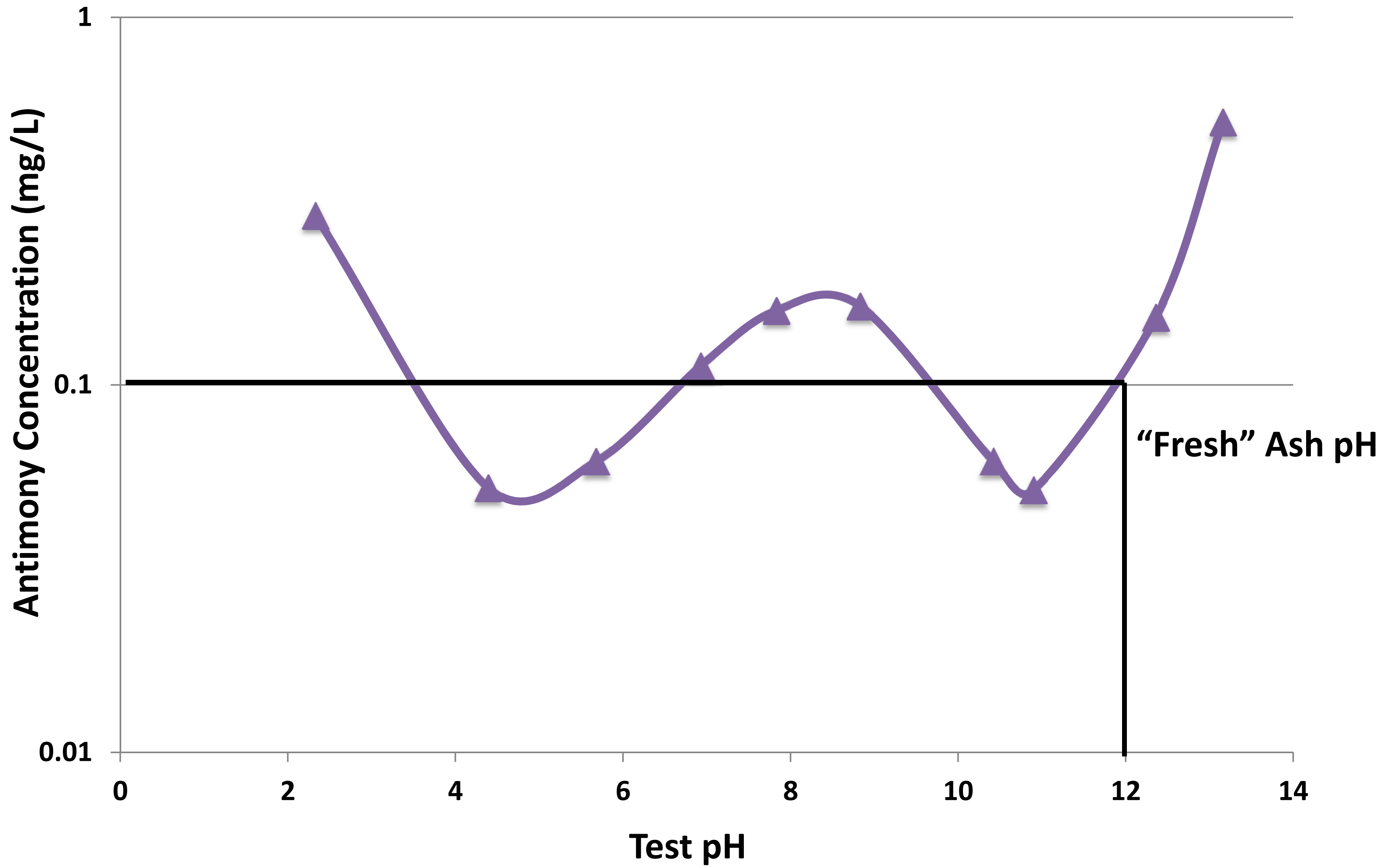
Beneficial Use Assessment Pasco County – WTE Bottom Ash

- Conduct standard batch test SPLP
- Identify COPCs
  - GCTLs
- Which elements elevated above GCTLS?
  - Lead, Antimony, Molybdenum

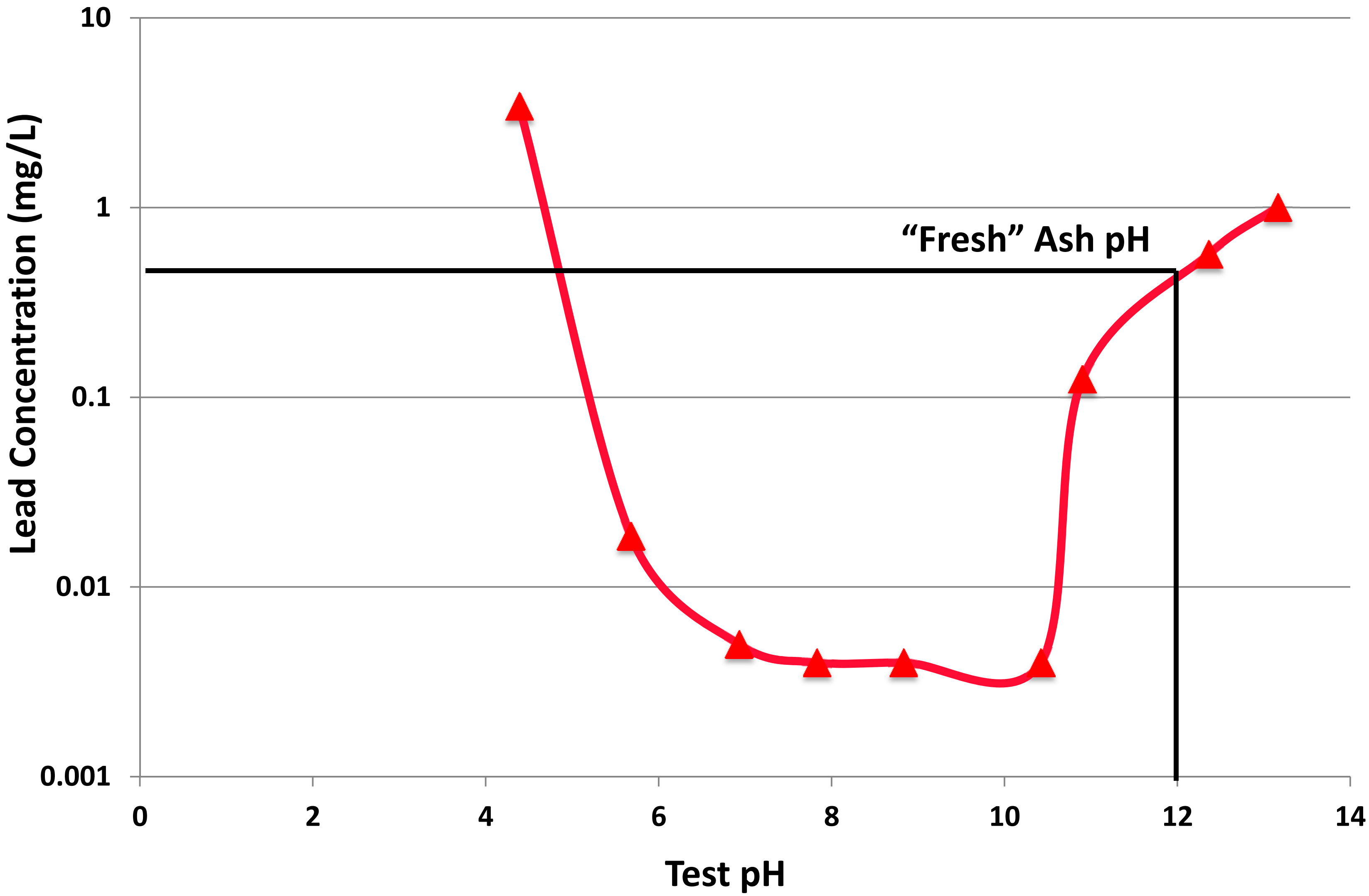
What Can We Do to Decrease Leaching?

- Aging has been demonstrated to reduce leaching of WTE ash
- Use LEAF to examine leaching of aged material
- pH changes due to carbonation
- Wash-off of elements due to precipitation

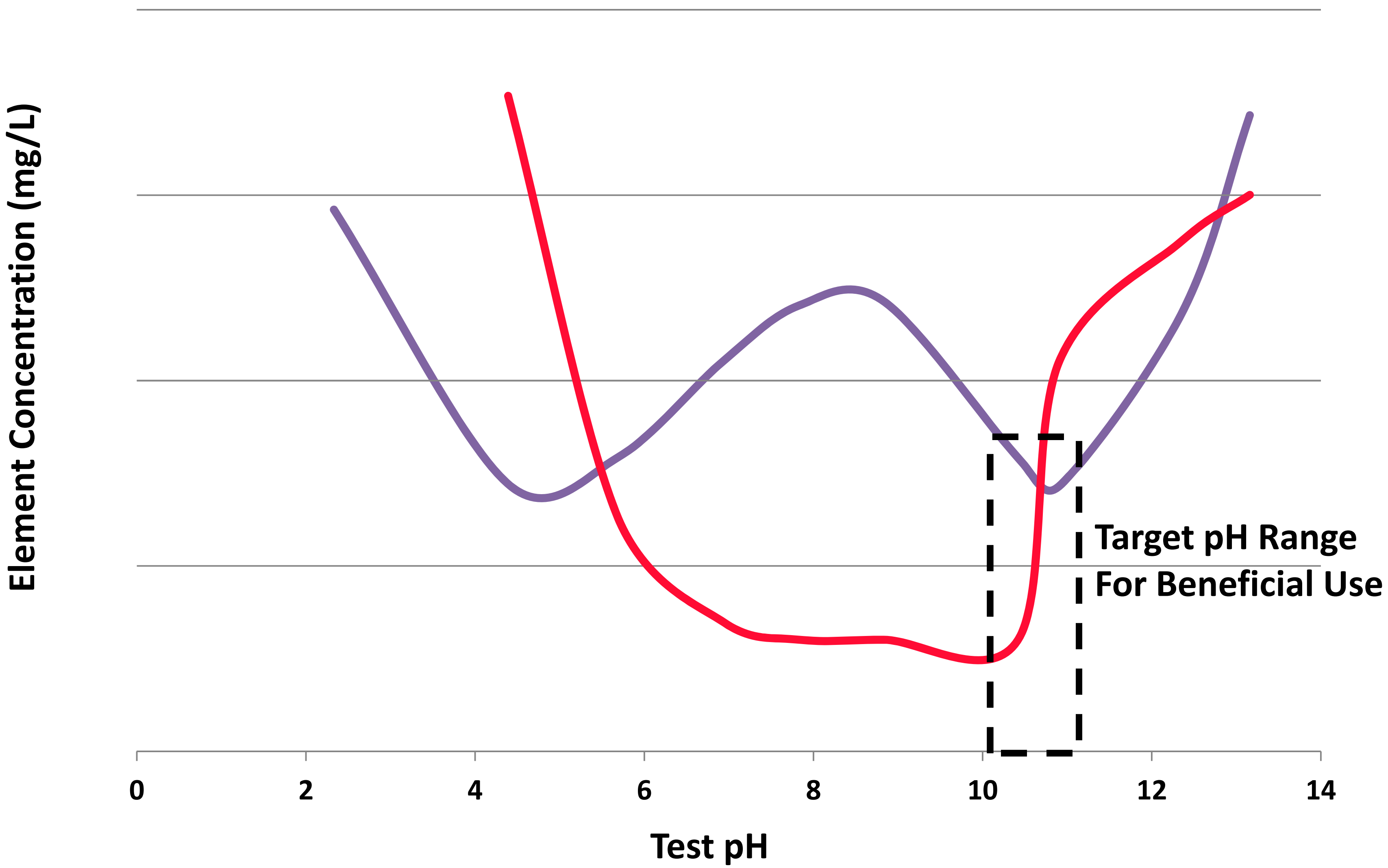
Method 1313 - Antimony



Method 1313 - Lead



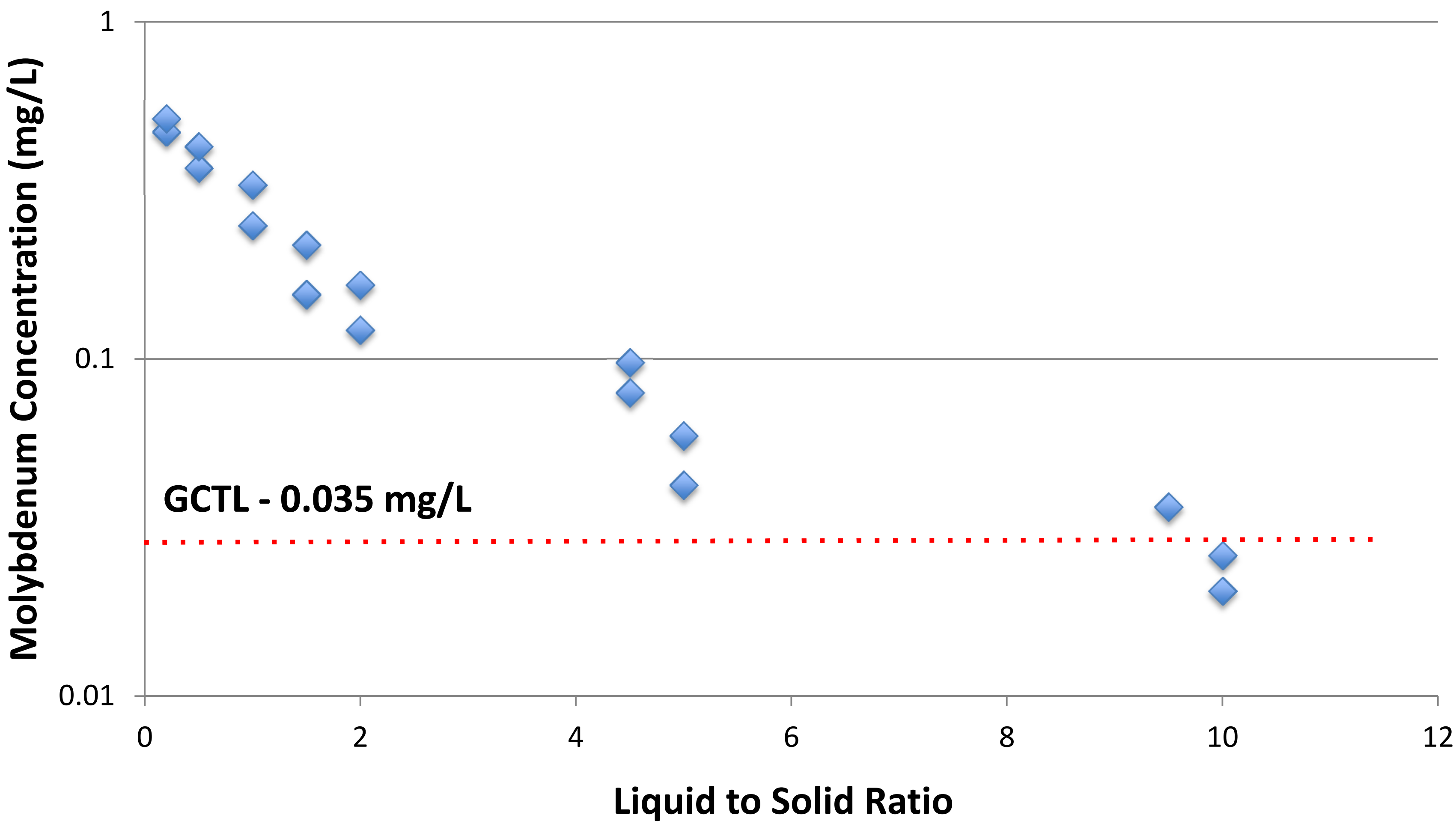
Optimum Final pH



Molybdenum Concentrations

- Initially elevated with respect to a direct comparison to GCTLs
- Concentration decreased throughout duration of column test
- Based on method 1313 data this is not expected to be related to pH changes
- "Surface Wash-Off" release mechanism

Method 1314- Molybdenum Leaching



What Did We Learn?

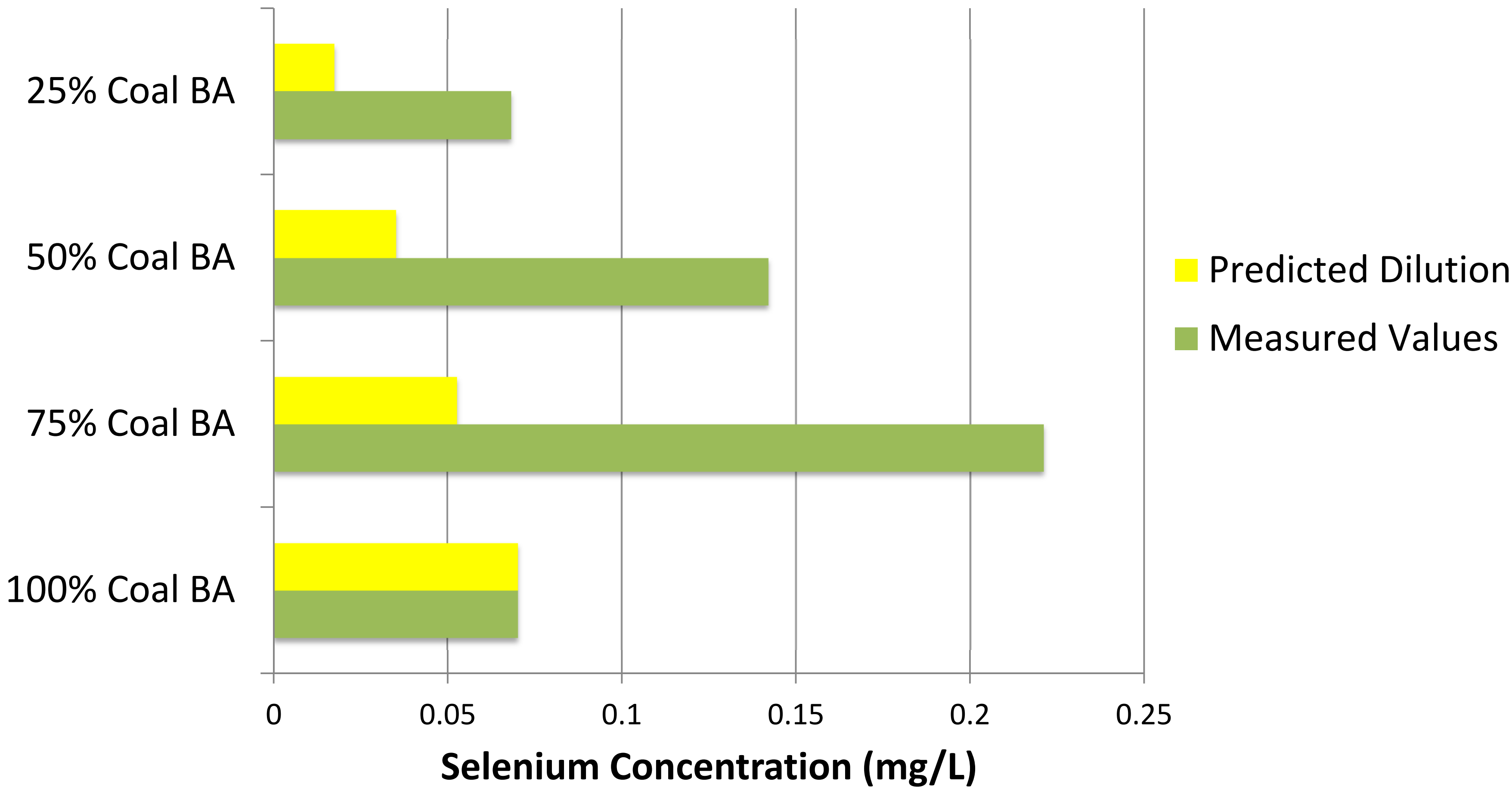
- LEAF allows us to better understand leaching of WTE ash
- pH changes influencing leaching
  - Lead, Antimony
  - Helped to select optimal pH range, ageing time
- Decrease in Molybdenum concentrations over time
  - Loss of Mo while "Aging"
  - Expected decrease over time

LEAF Assessment - Blending Coal Bottom Ash

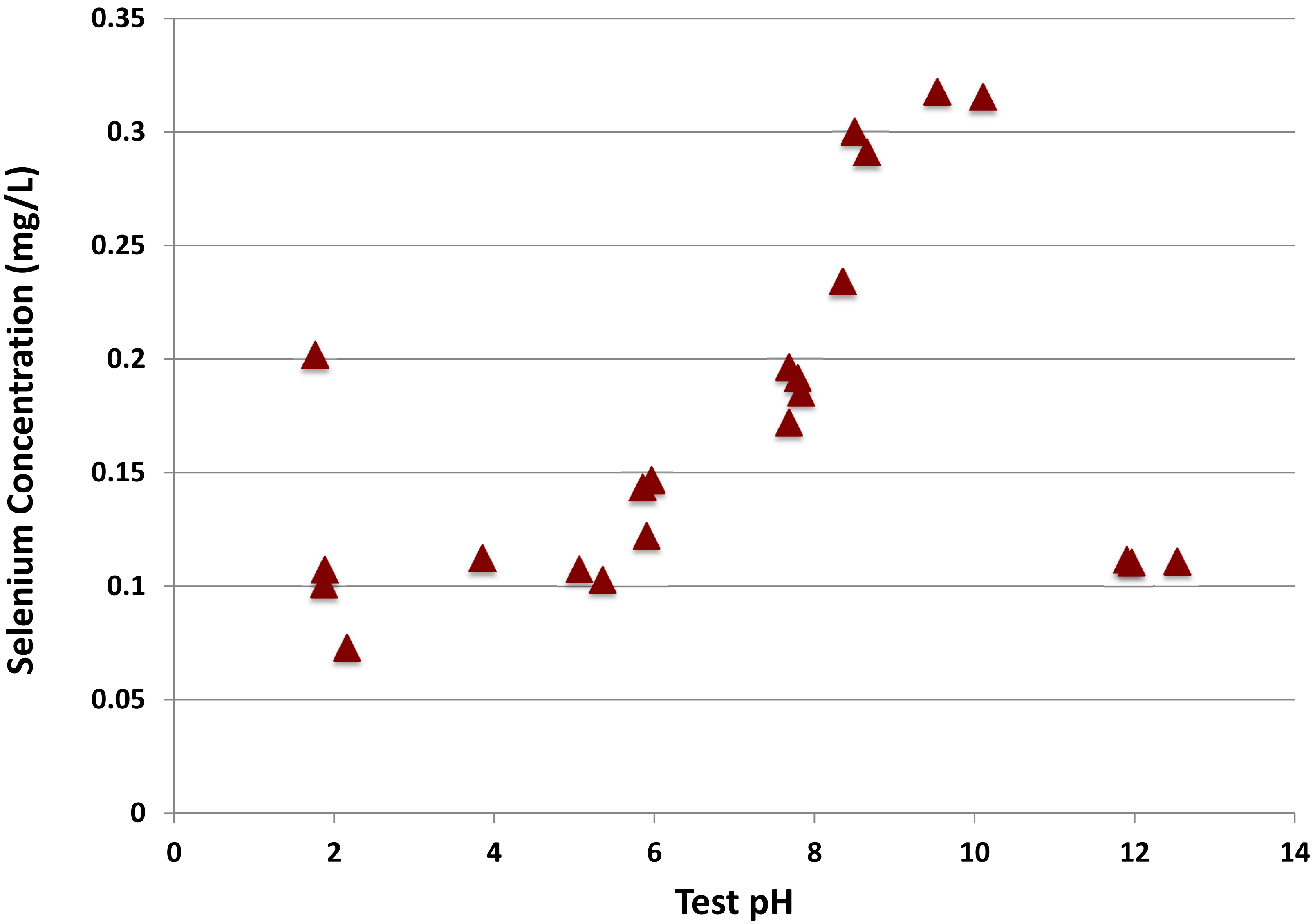
Coal Bottom Ash

- Relatively inert material
- SPLP test results produced majority of leachate concentrations below GCLTs
  - Exception was Se within 10% of threshold
- Materials testing values (LBR) low
  - Experimented by blending bottom ash with lime rock to increase strength
- 50/50 blend able to achieve x2 strength
  - How would blending effect leaching?

Coal Bottom Ash-Lime Rock Blends



Selenium



Selenium Concentration (mg/L)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
2
4
6
8
10
12
14
Test pH

Blending

- Trying to improve the structural characteristics of the material had unintended consequences
- Differences between SPLP and natural pH
  - SPLP pH – 5.3 "Natural" pH - 7.7
  - Natural pH selenium leaching:
    0.184 mg/L (3 x SPLP values)
  - 50:50 ash/lime rock blends: pH- 8.0
- By mass you would expect the concentrations of blends to be diluted
  - Better understanding because of LEAF testing and proper interpretation of results

Which Batch Leaching Test Best Represents Monofill Disposal Conditions?

Methodology

- Samples

Bottom Ash Greater 3/8”

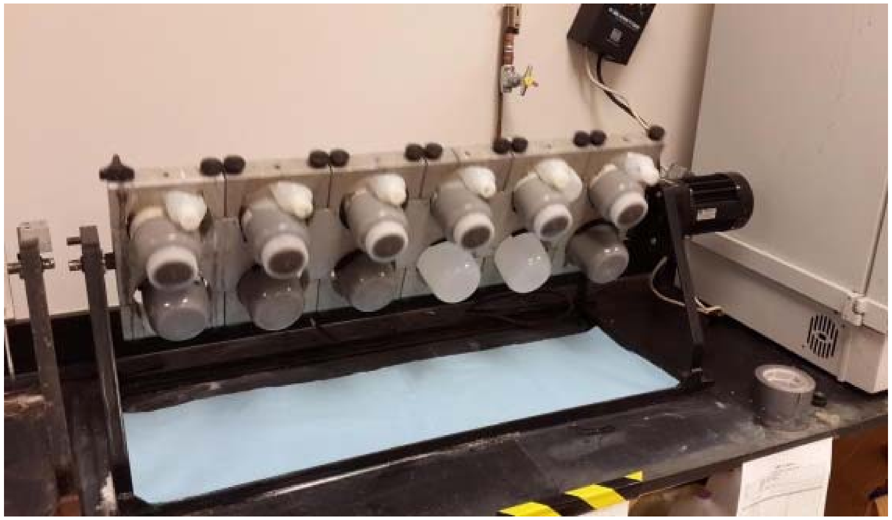
Bottom Ash Less 3/8”

Mixed Ash

Fly Ash

Methodology

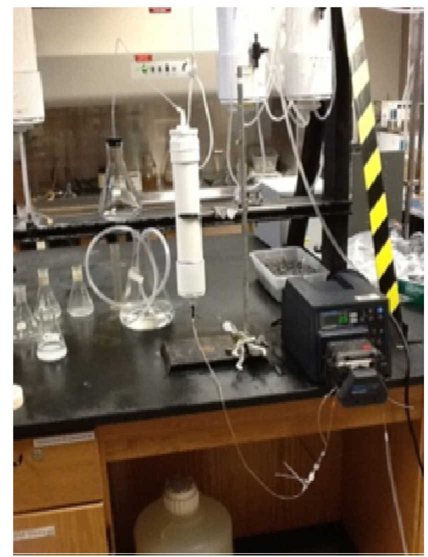
- Leaching method
  - Batch Tests
    - TCLP (EPA method 1311)
      - TCLP#1; (pH = 4.93±0.05)
      - TCLP#2; (pH = 2.88±0.05)
    - SPLP (EPA method 1312); (pH = 4.2)



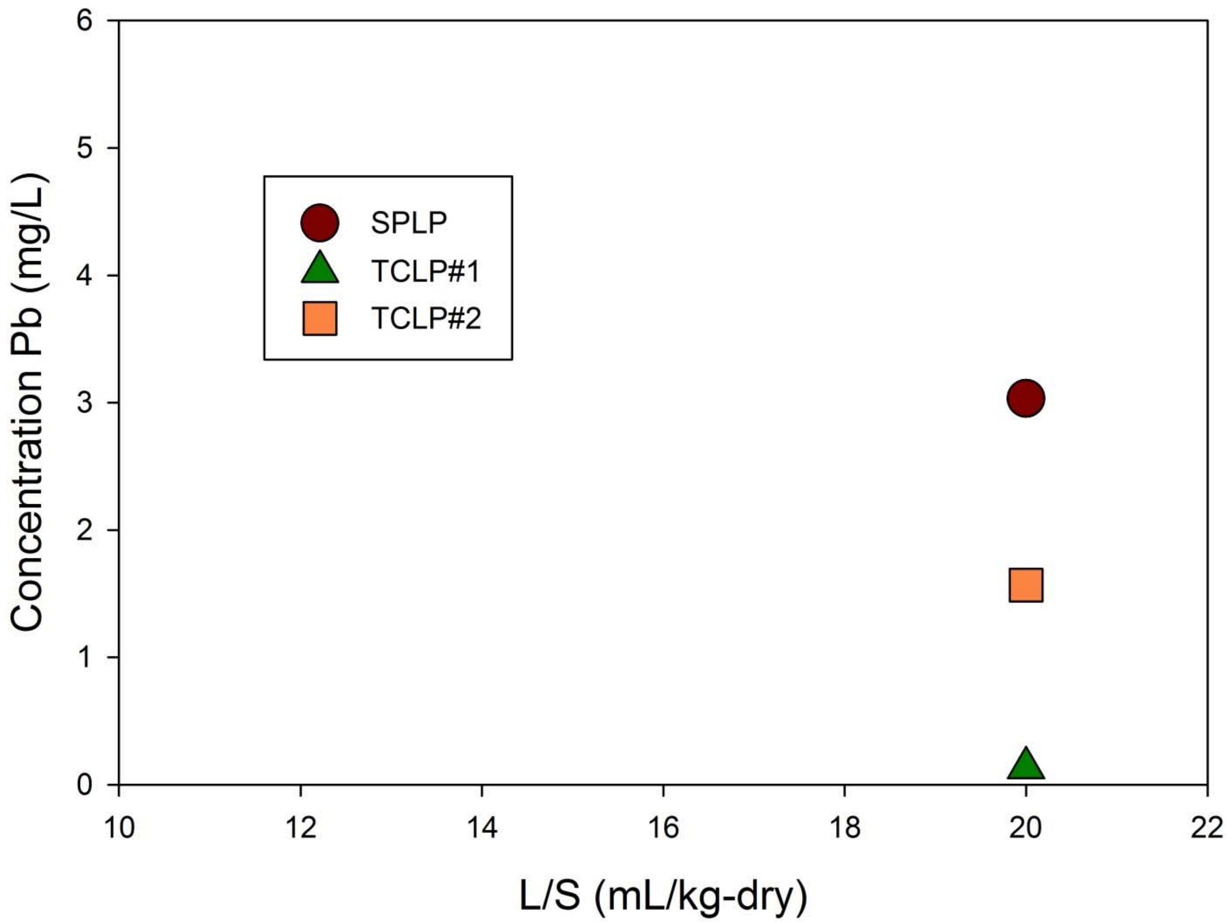
Methodology

- Column test (EPA Method 1314)

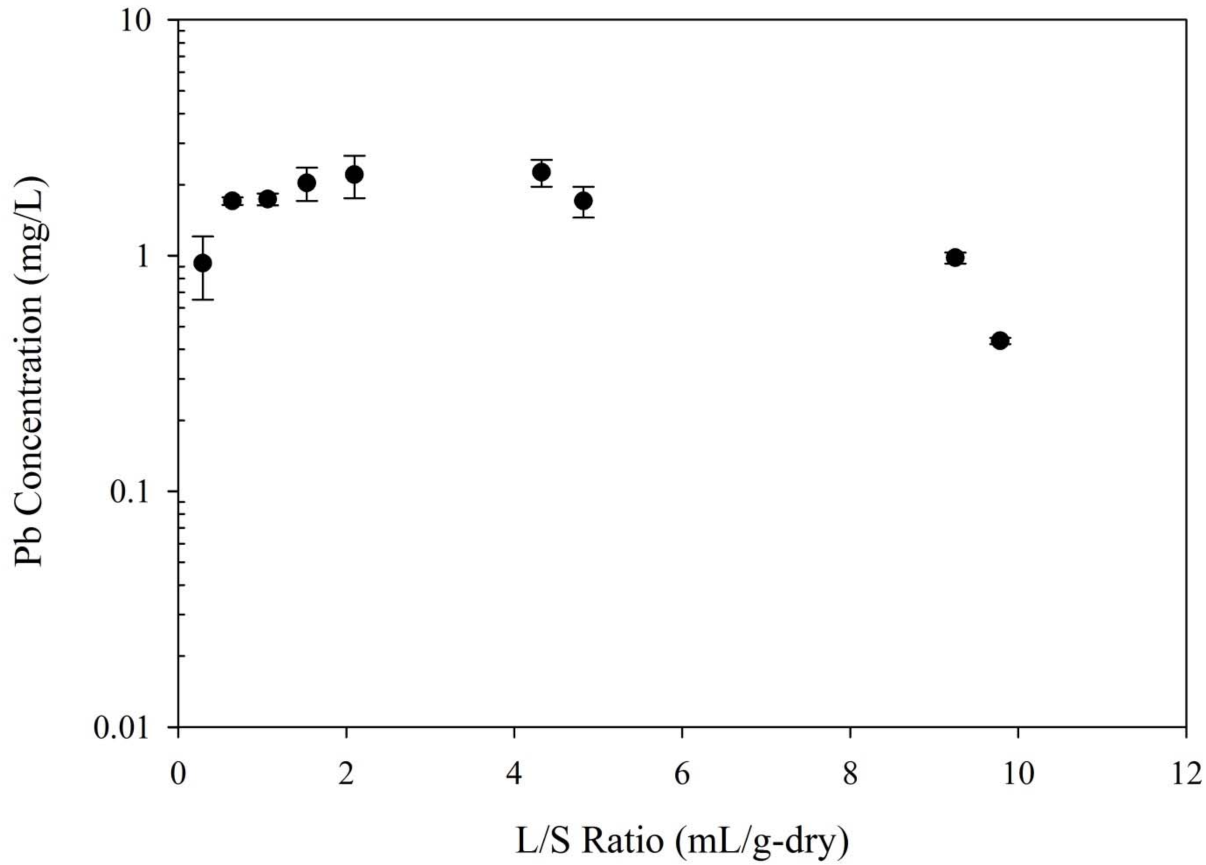




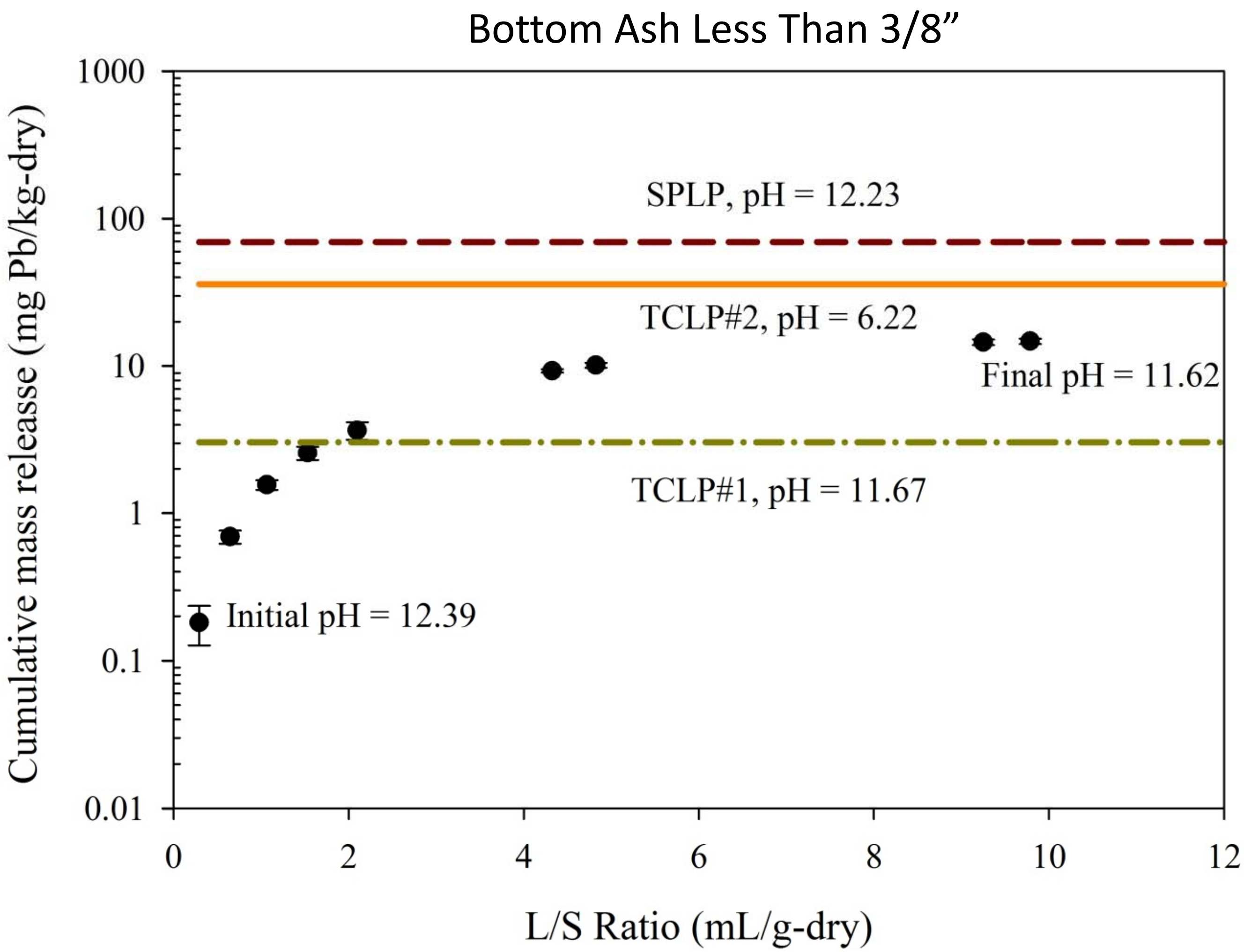
An Example Result: TCLP/SPLP (Bottom Ash Less than 3/8")



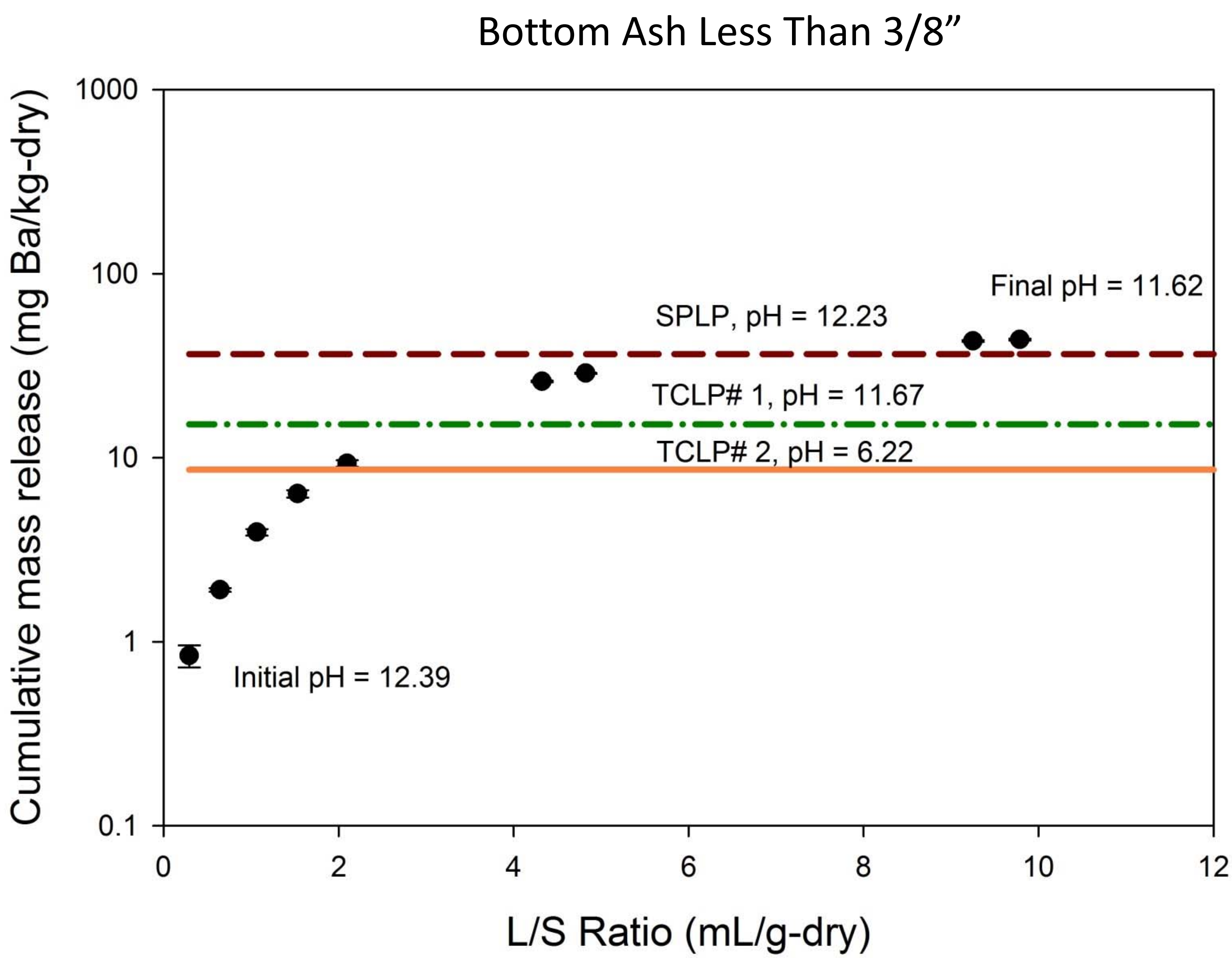
An Example Result : Column Test (Bottom Ash Less Than 3/8")



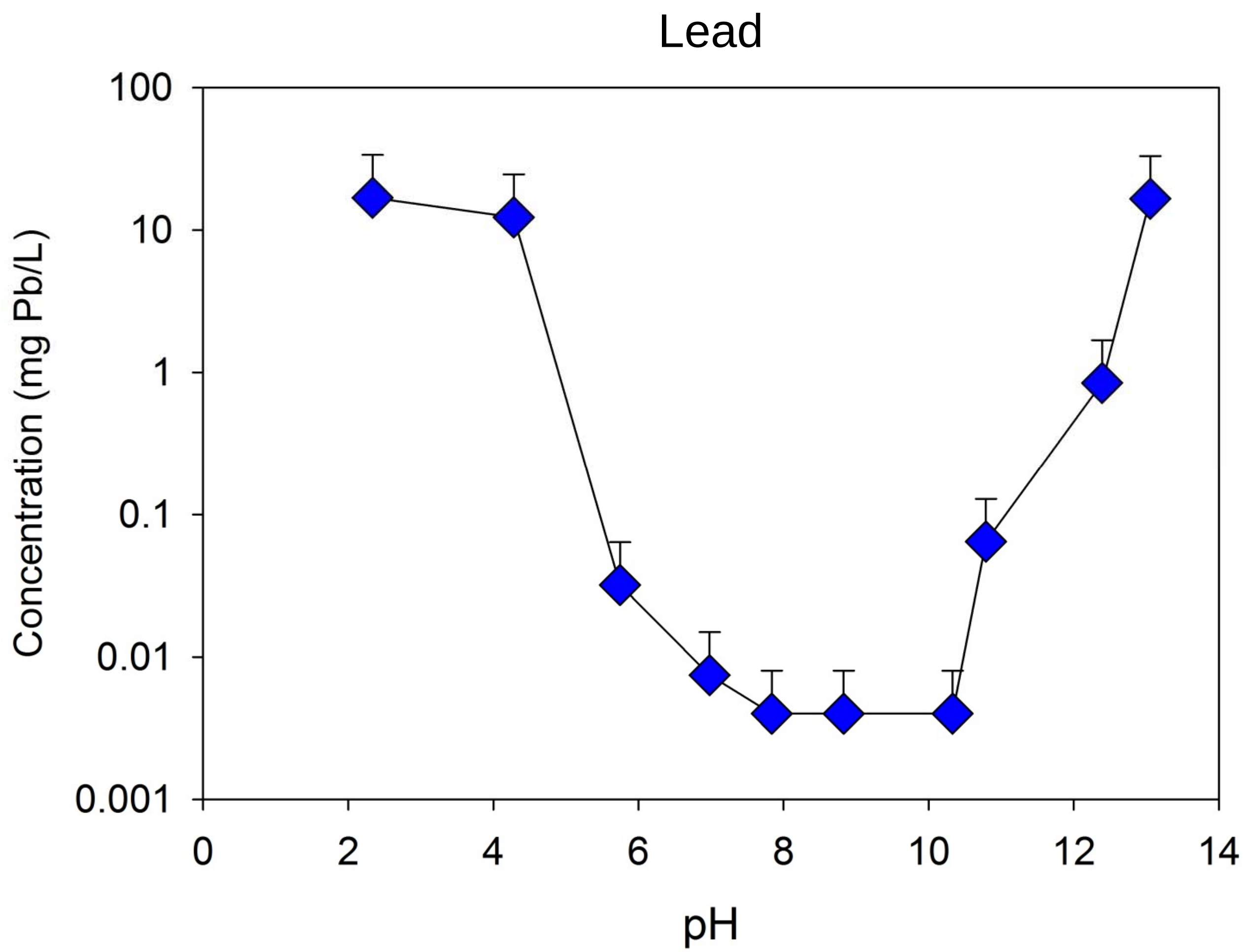
Concentrations Normalized to mg/kg



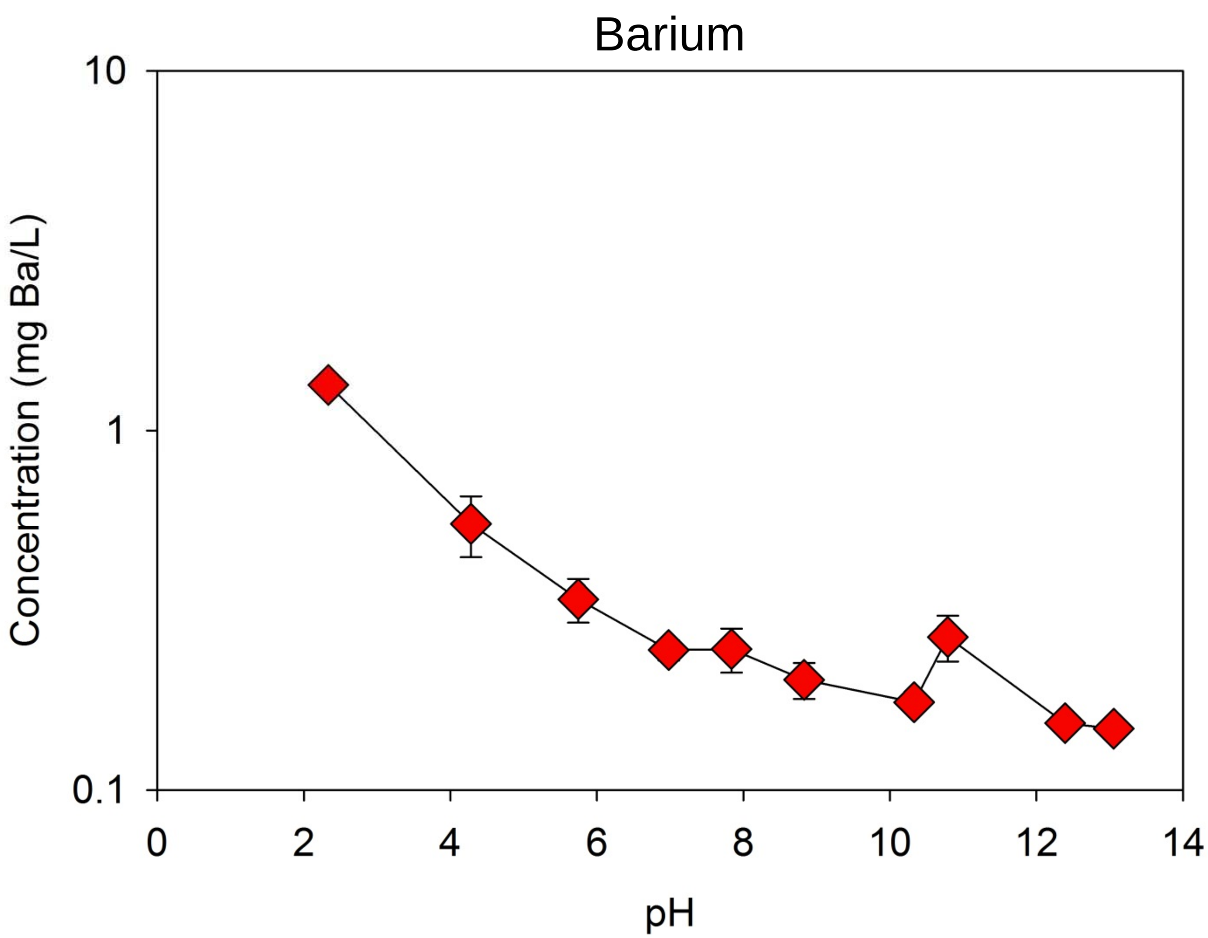
Comparing Leaching Tests



EPA Method 1313 Bottom Ash Less Than 3/8”

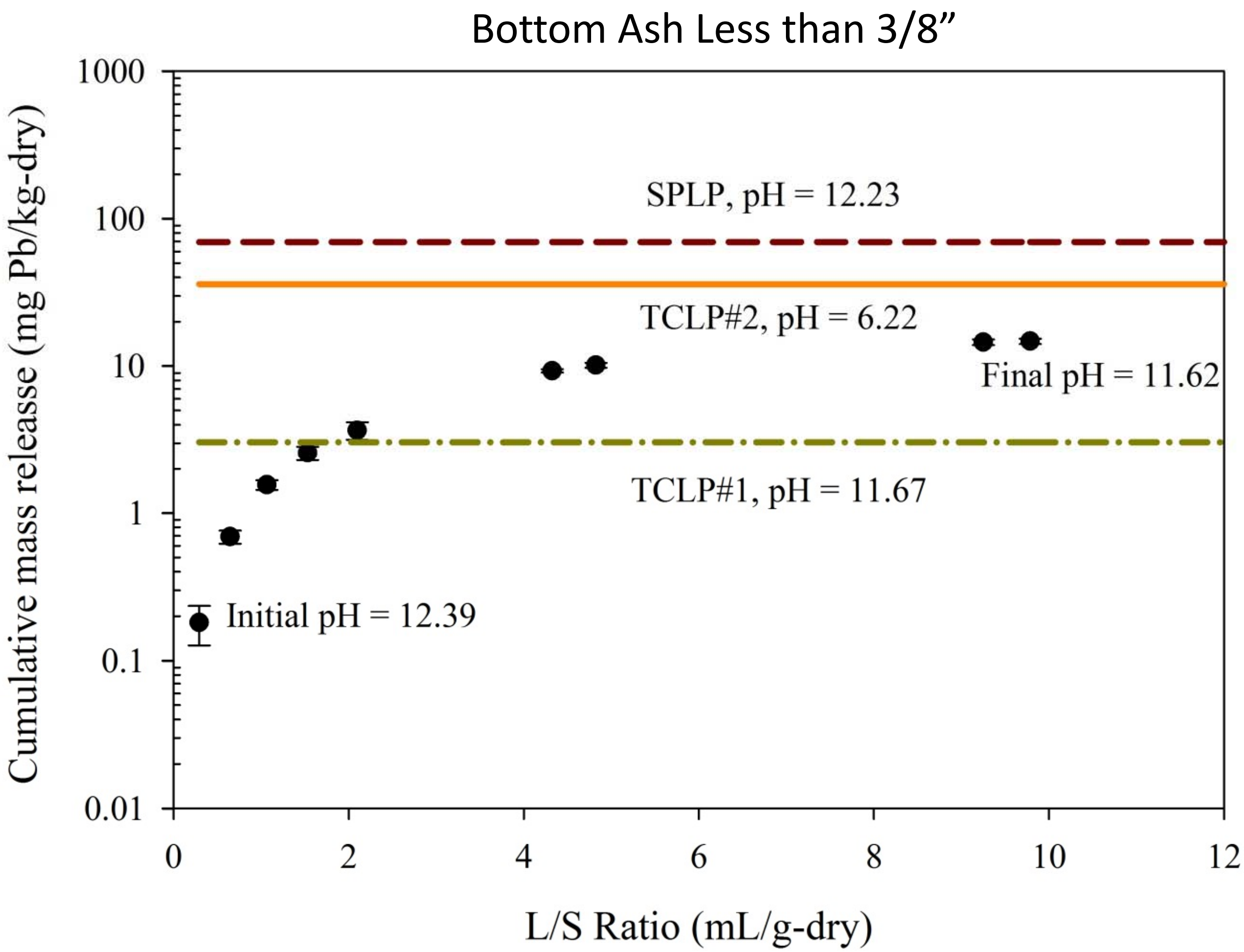


EPA Method 1313 Bottom Ash Less Than 3/8”

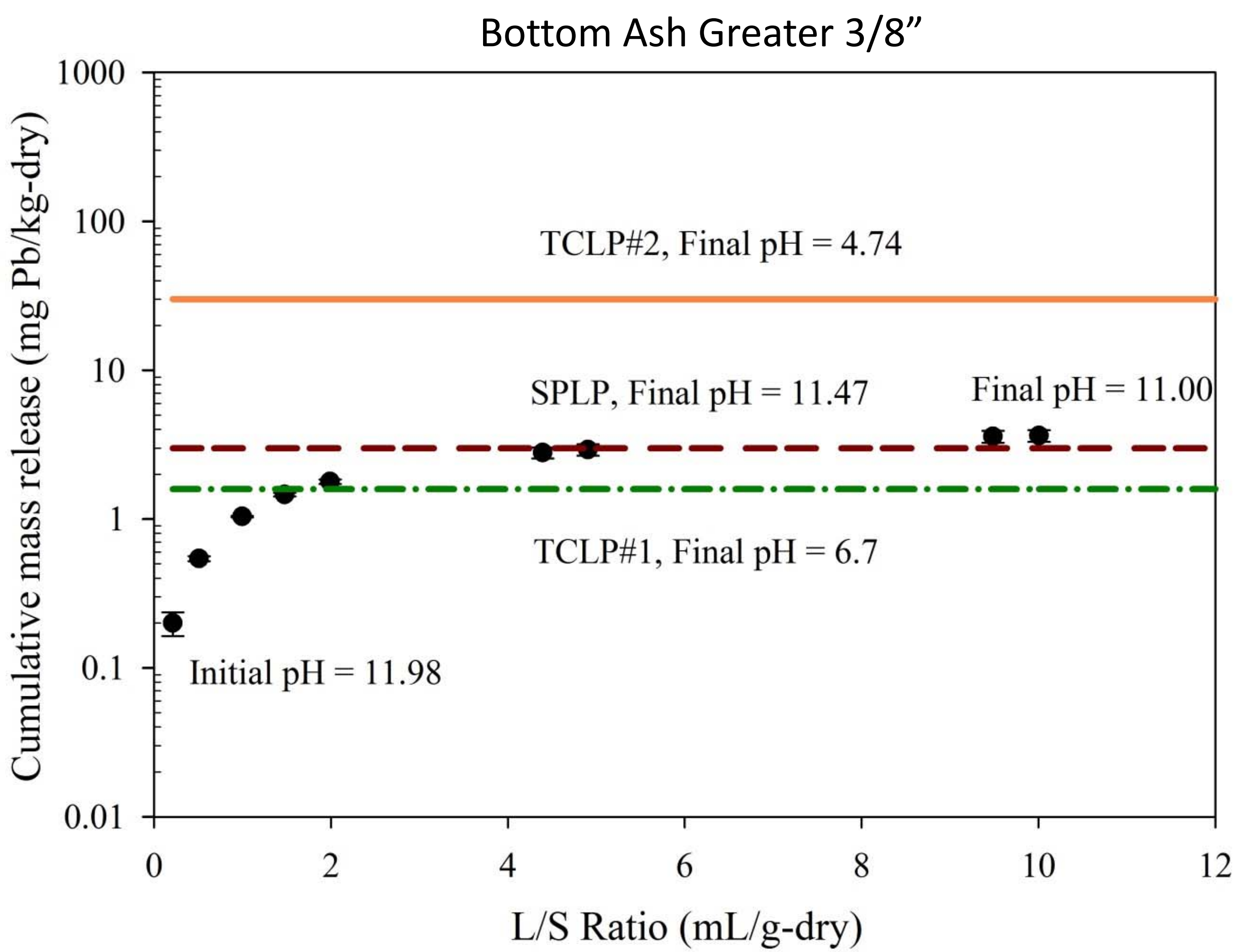


Does the Particle Size Effect Trace Metal Leachability?

Comparing Particle Size



Comparing Particle Size



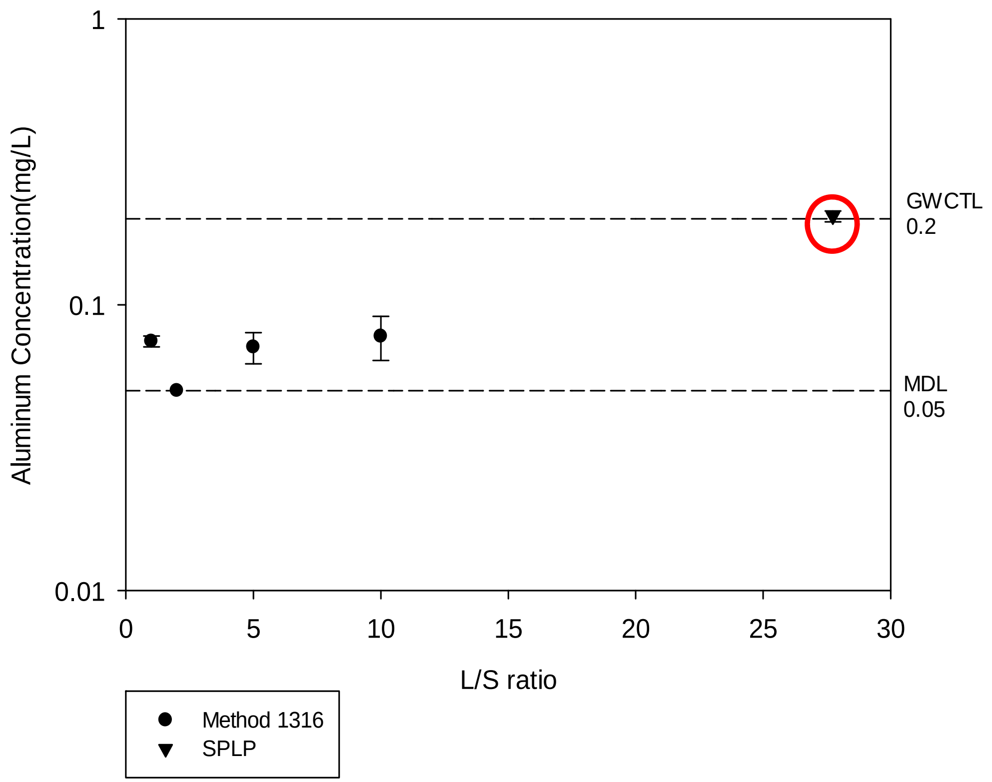
Particle Size

- Batch test can’t account for all variables that affect leaching
- Many factors control leaching:
  - pH is a major factor
  - Specific element solubility
  - Particle size

Assessing the Differences Between the SPLP and LEAF Batch Leaching Methods

How Does SPLP Compare to LEAF?

- Correlation between laboratory leaching tests and beneficial use conditions



Aluminum release as a function of L/S
SPLP result is added for comparison

Differences Between SPLP and LEAF

Parameters	SPLP	LEAF (1313, 1316)
Solution	SPLP Solution (pH=4.2)	Reagent Water
Time	18 hours	Particle Size Dependent (Up to 72 hours)
L/S	2000 mL-eluent/100 g-wet	10.0 ml-eluent/g-dry material
Particle Size	pass 3/8" sieve	Various
Filter	0.7 µm glass fiber	0.45 µm polypropylene

Particle Size (85% less than) (mm)	US Sieve Size	Minimum Dry Mass (g-dry)	Contact Time (h)	Recommended Vessel size (mL)
0.3	50	20 ± 0.05	24 ± 2	250
2.0	10	40 ± 0.1	48 ± 2	500
5.0	4	80 ± 0.1	72 ± 2	1000

Table 1. Extraction Parameters as Function of Maximum Particle Size (LEAF)

Synthetic Precipitation Leaching Procedure (SPLP)

- A key leaching test in risk assessment for the beneficial use of solid waste materials
- Historically important in the field of solid waste management
- Simulates waste material exposure to slightly acidic rainfall conditions
- Results often compared to the GWCTL for decision making

LEAF Methods

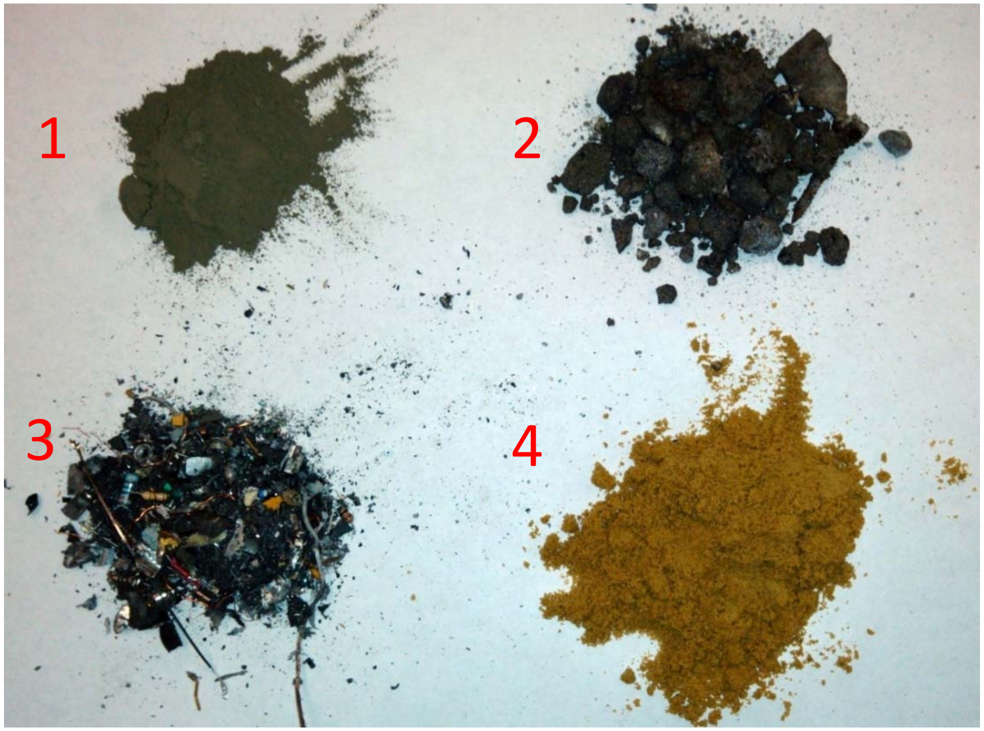
- Provides a more robust dataset
- Wider range of pH and site-specific conditions

However….

- Lack of guidance on how to properly interpret the data
- Inappropriate use of the large volume of data is possible
- Increased range of pH may not be representative of actual site conditions
- May contradict SPLP data
- Inconsistency

Materials

ID	Sample	Particle Size Reduction
1	Coal Fly Ash	N/A
2	WTE Bottom Ash	3/8” and #4 Sieve
3	Electronic Waste	3/8” and #4 Sieve
4	Mine Tailings	N/A

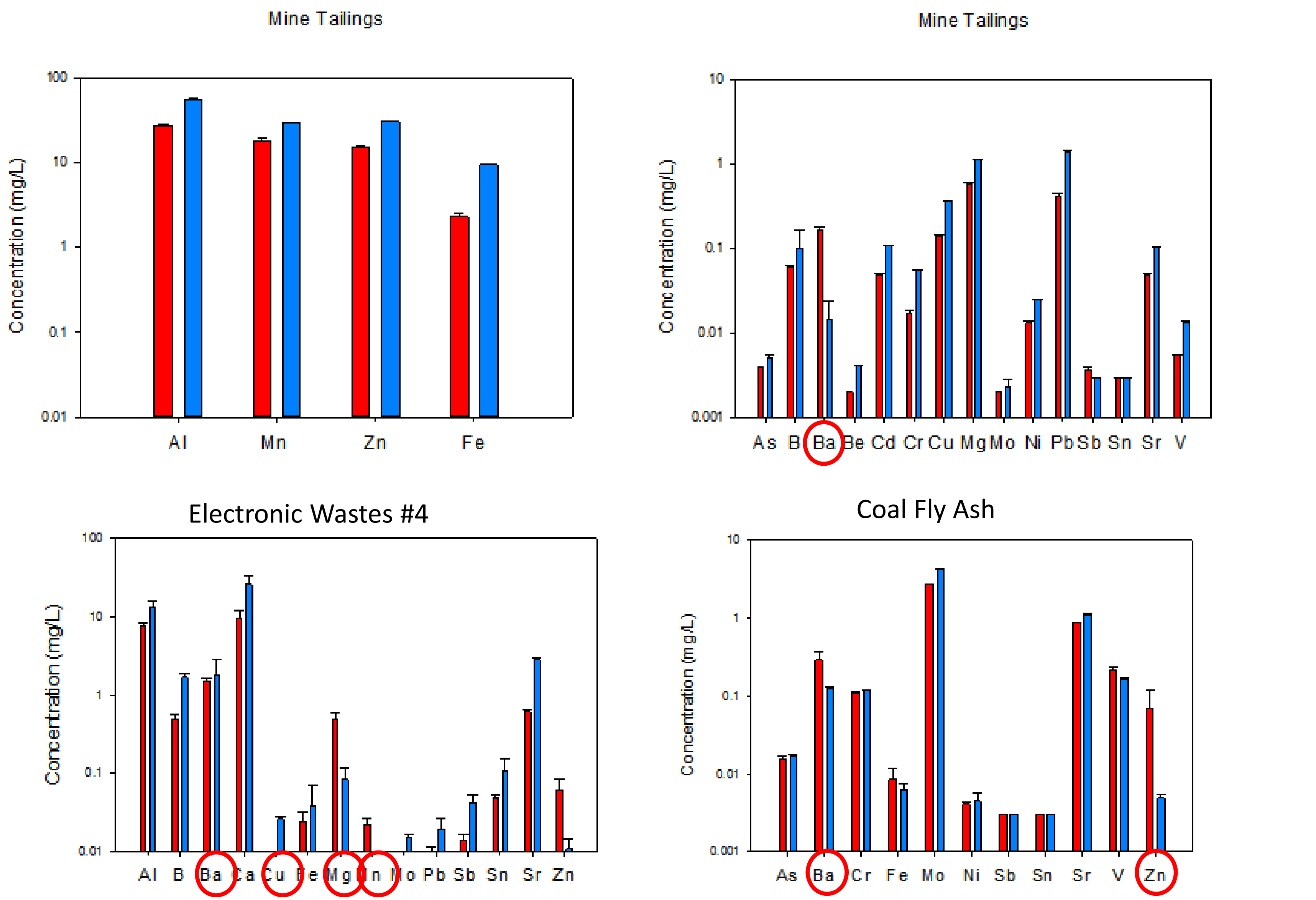


Methodology

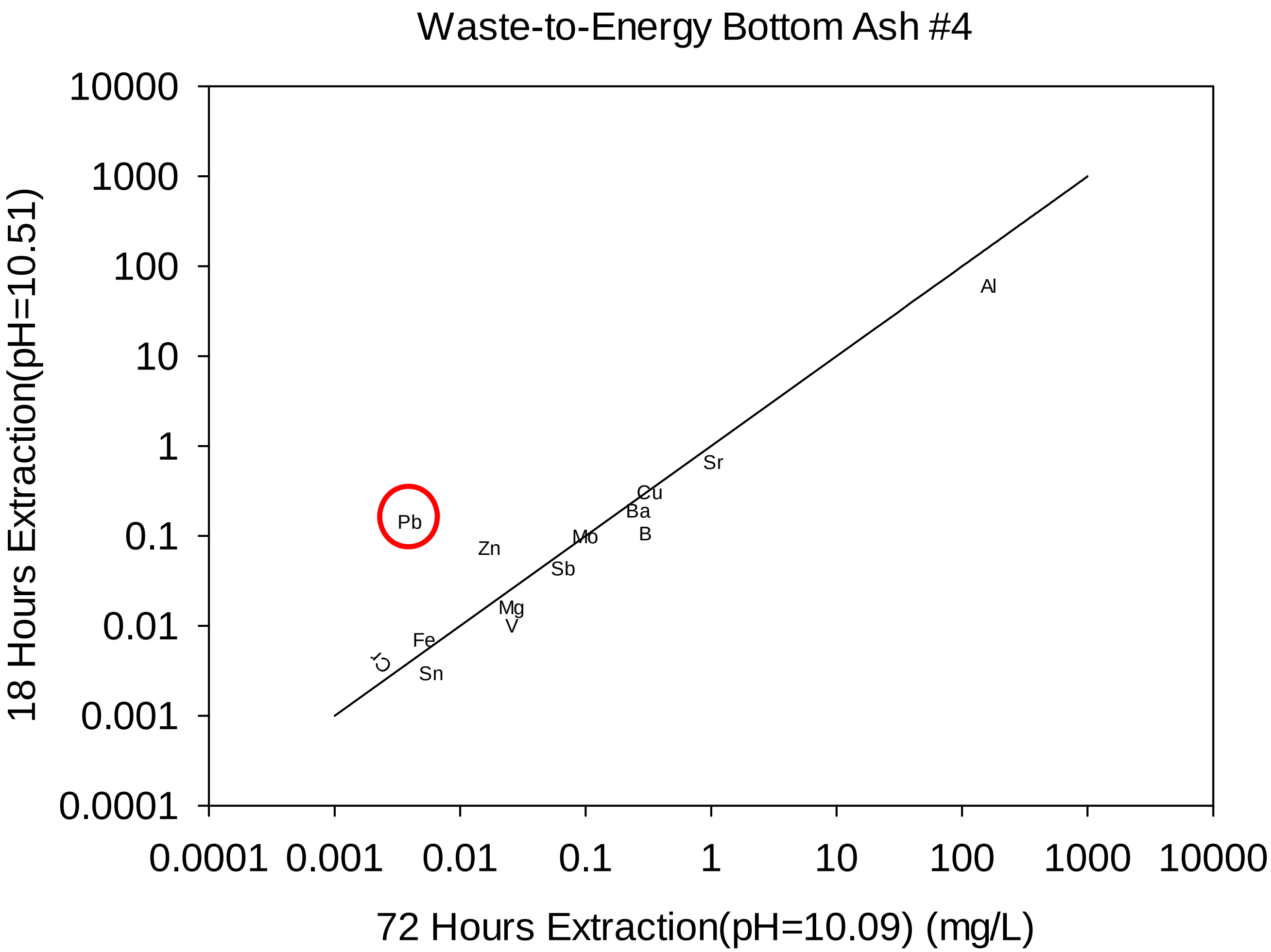
	Evaluation of Each Factor				
Parameter	**Solution**	**Time**	**L/S**	**Particle Size**	**Filter**
Solution	S, s	S	S	S	S
Time	T	T, t	T	T	T
L/S	L	L	L, l	L	L
Particle Size	Z	Z	Z	Z, z	Z
Filter	F	F	F	F	F, f

S=Reagent Water s=SPLP solution T=72 hrs t=18hrs L=10.0 ml-eluent/g-dry material
l=2000 mL-eluent/100 g-wet material Z=#4 sieve z=3/8” sieve
F=0.45 µm f=0.7µm

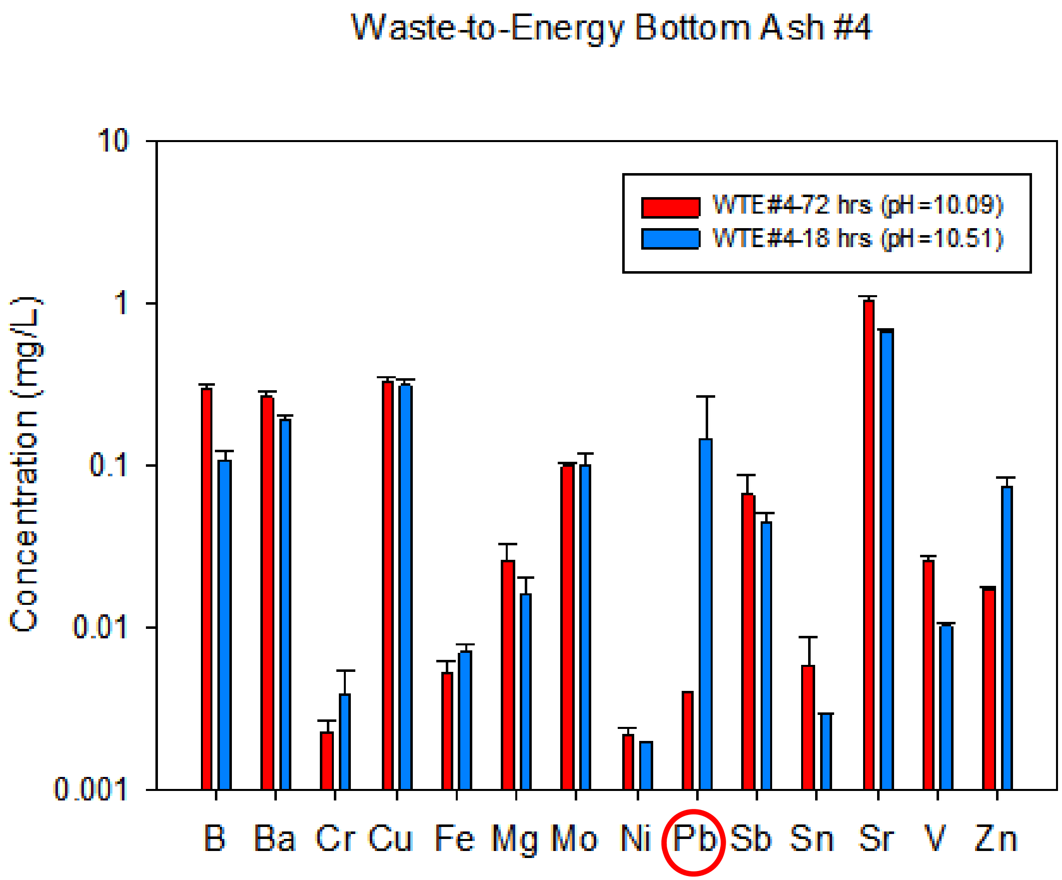
LEAF and SPLP Conducted by the Book



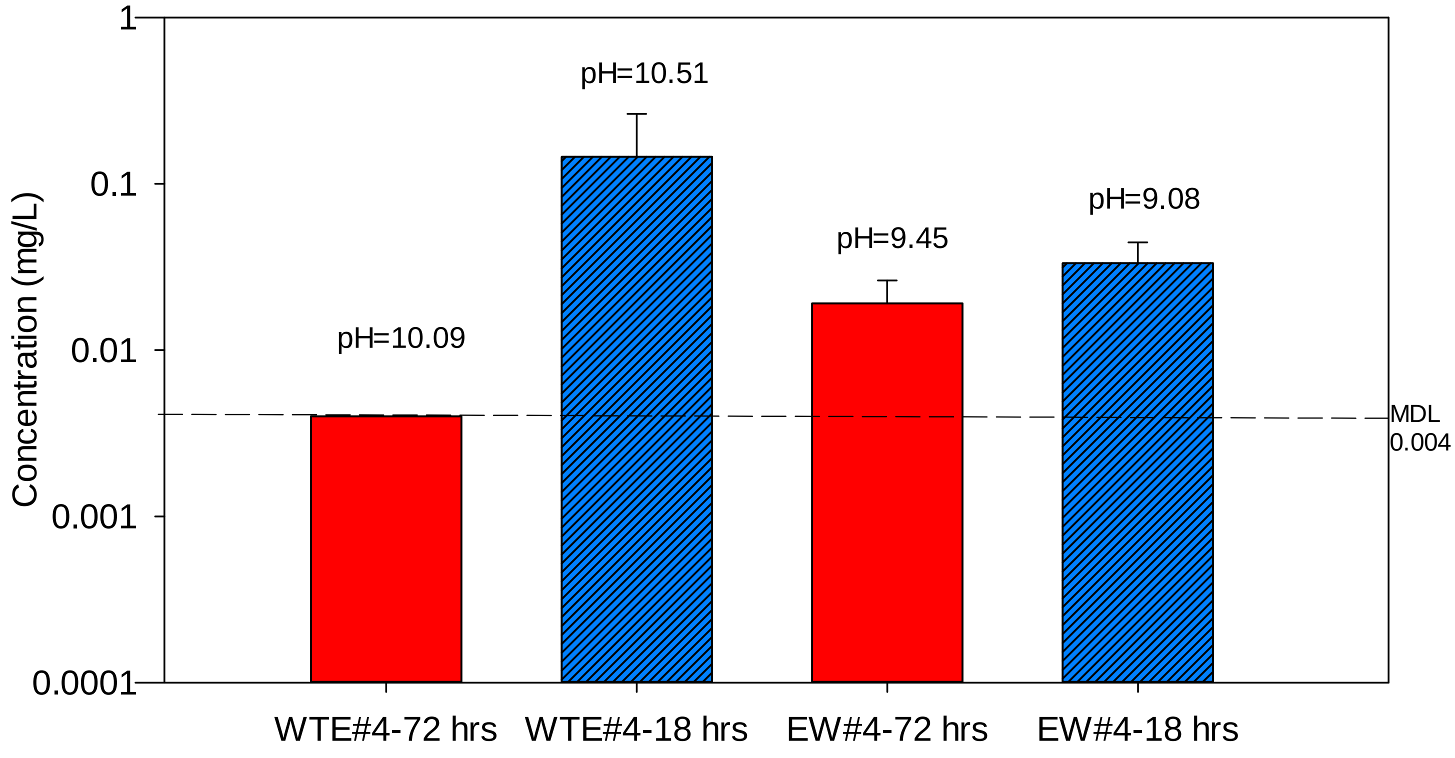
Influence of Extraction Time



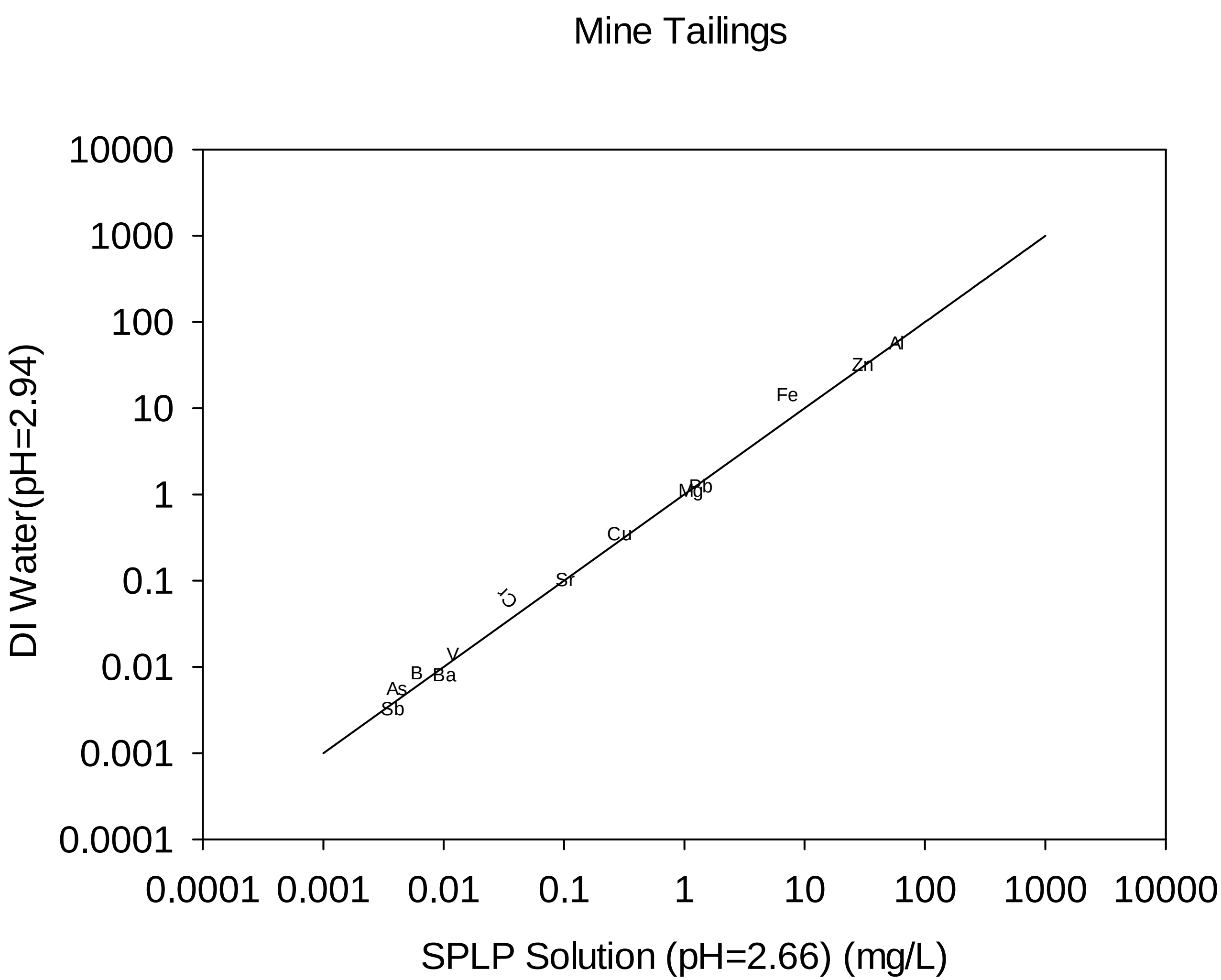
Influence of Extraction Time



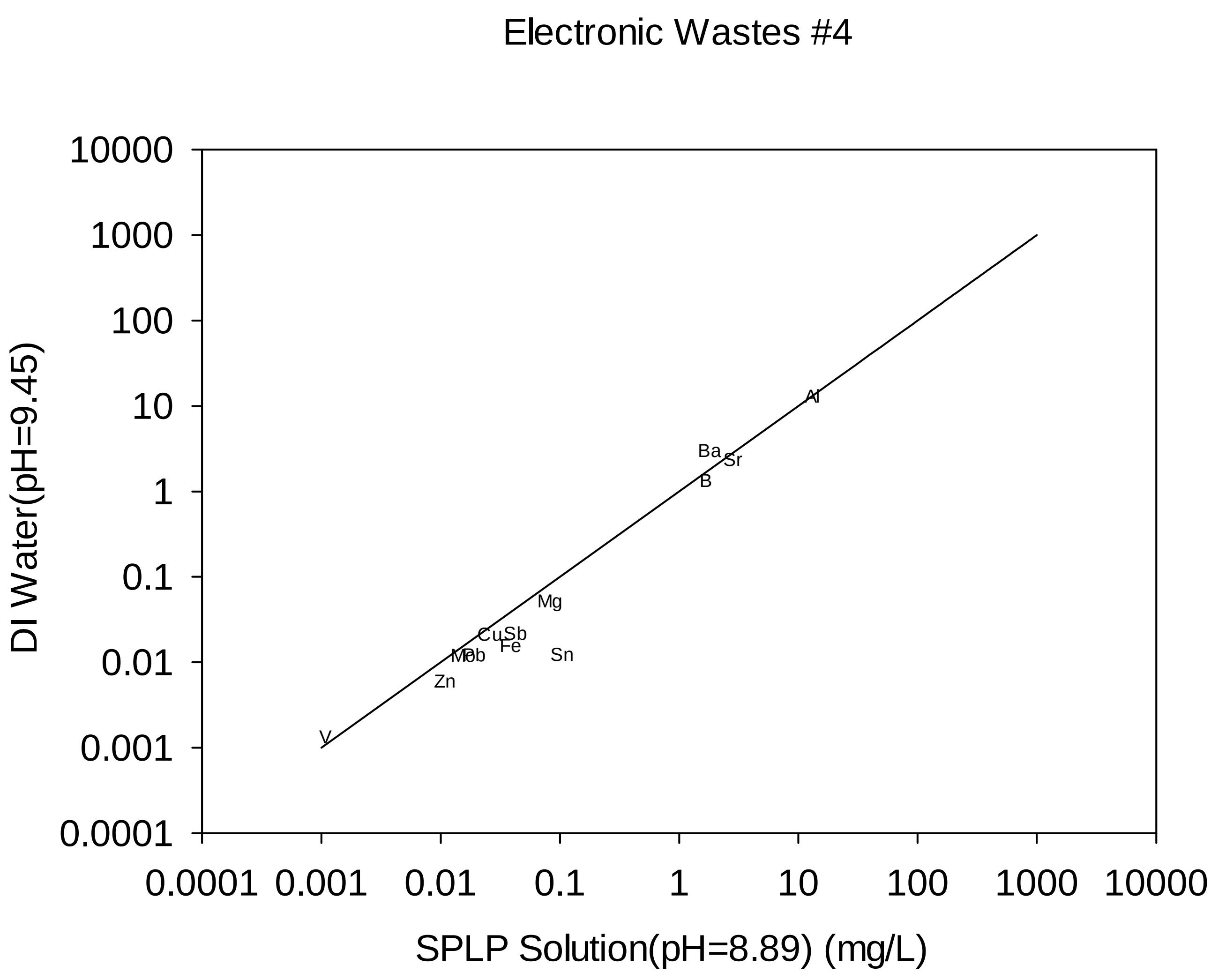
Extraction Time-Lead



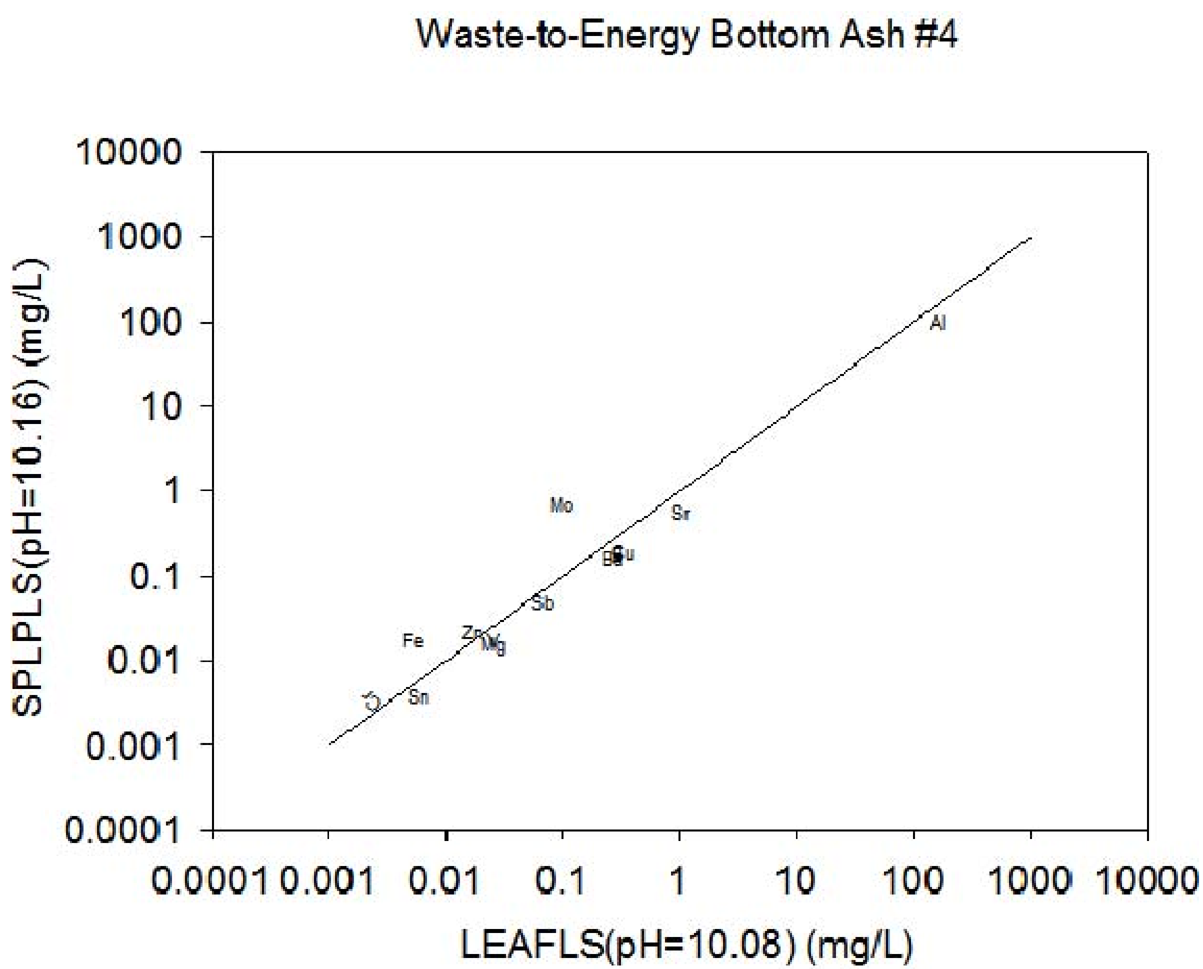
Influence of Extraction Solution



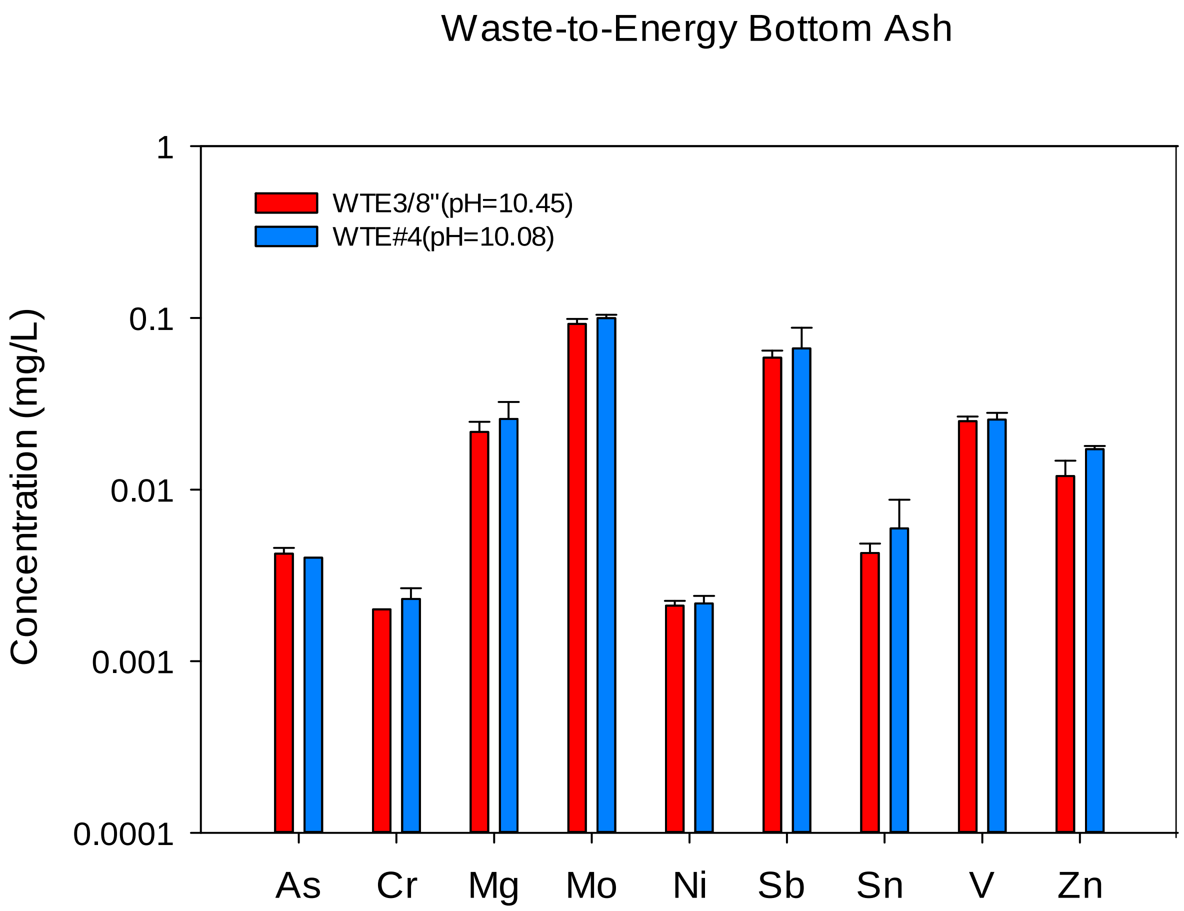
Influence of Extraction Solution



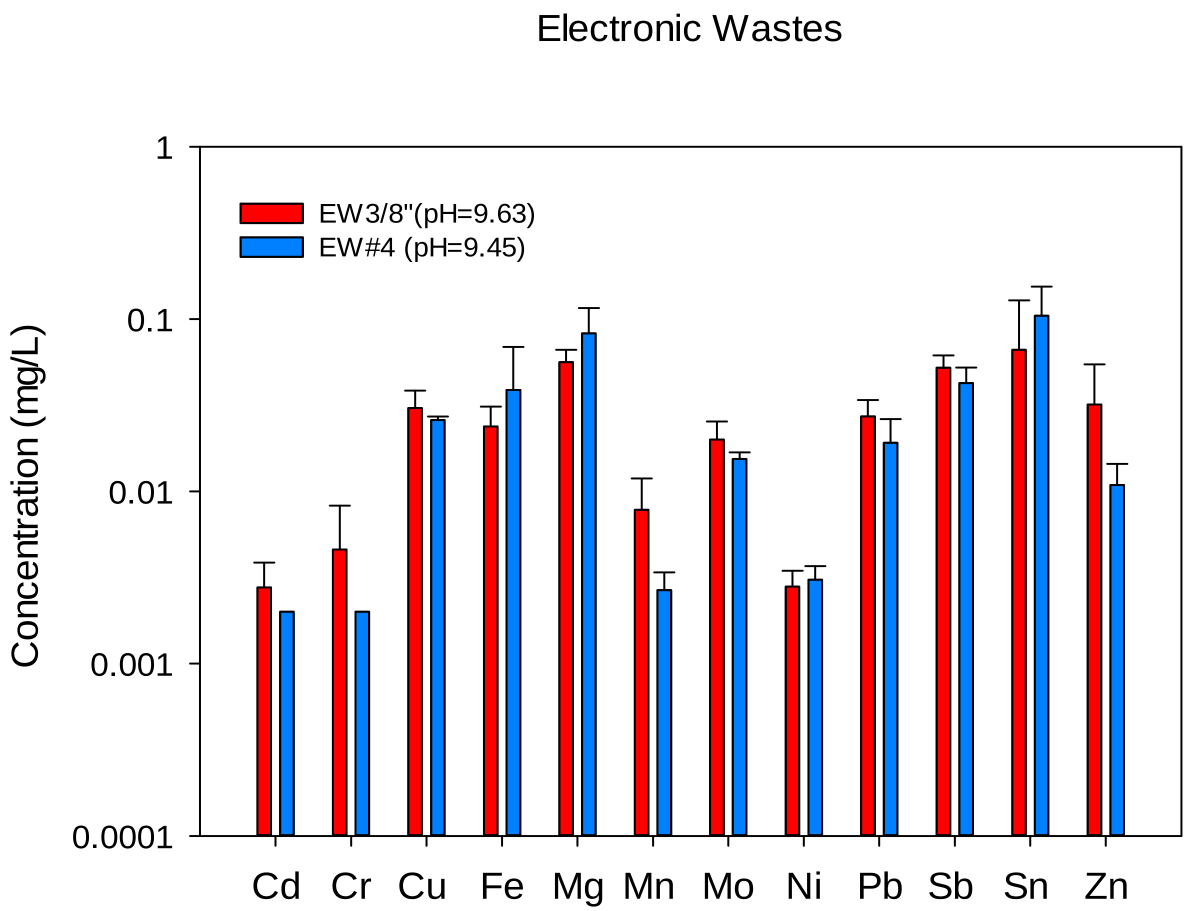
Influence of Liquid to Solid Ratio



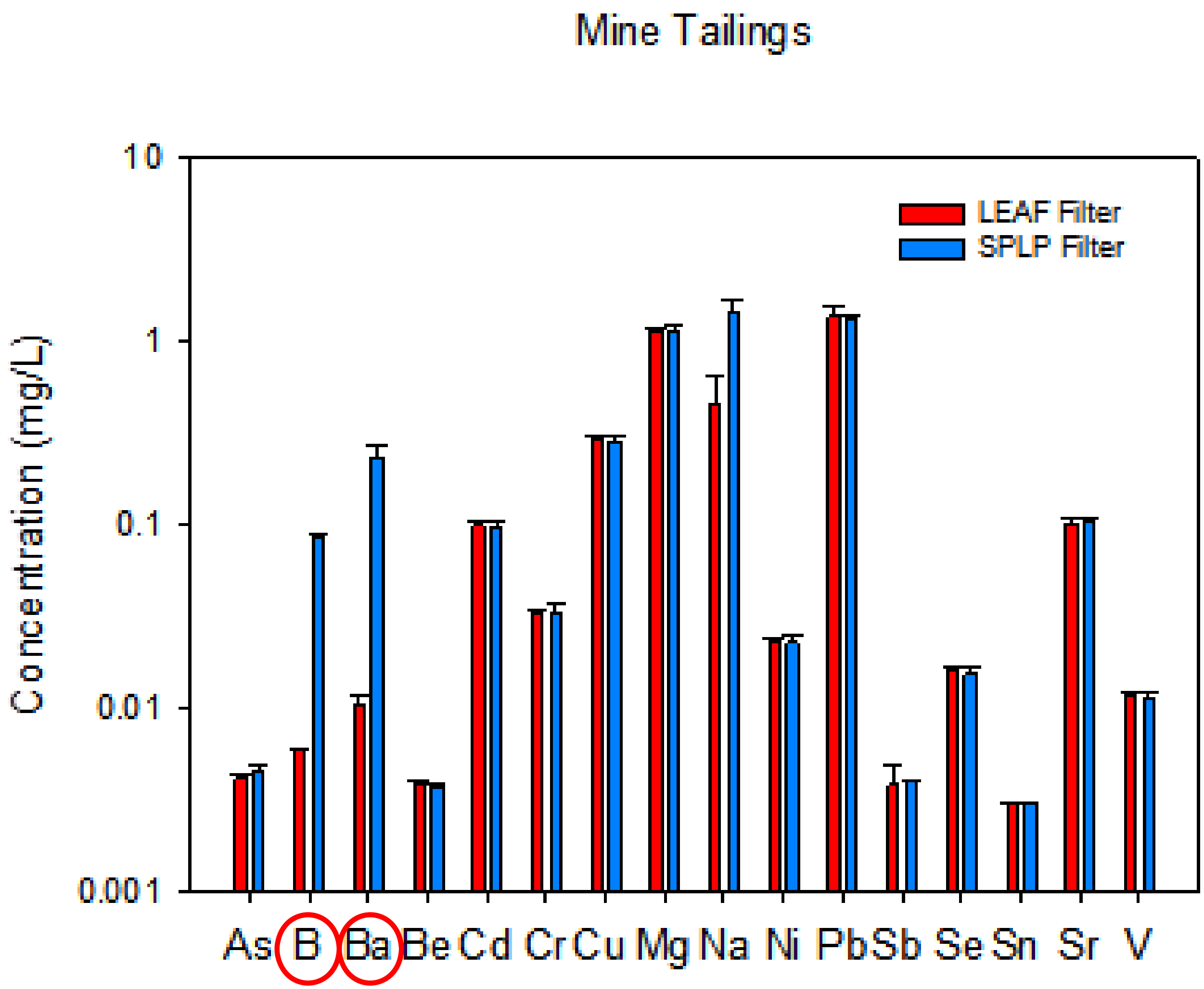
Influence of Particle Size



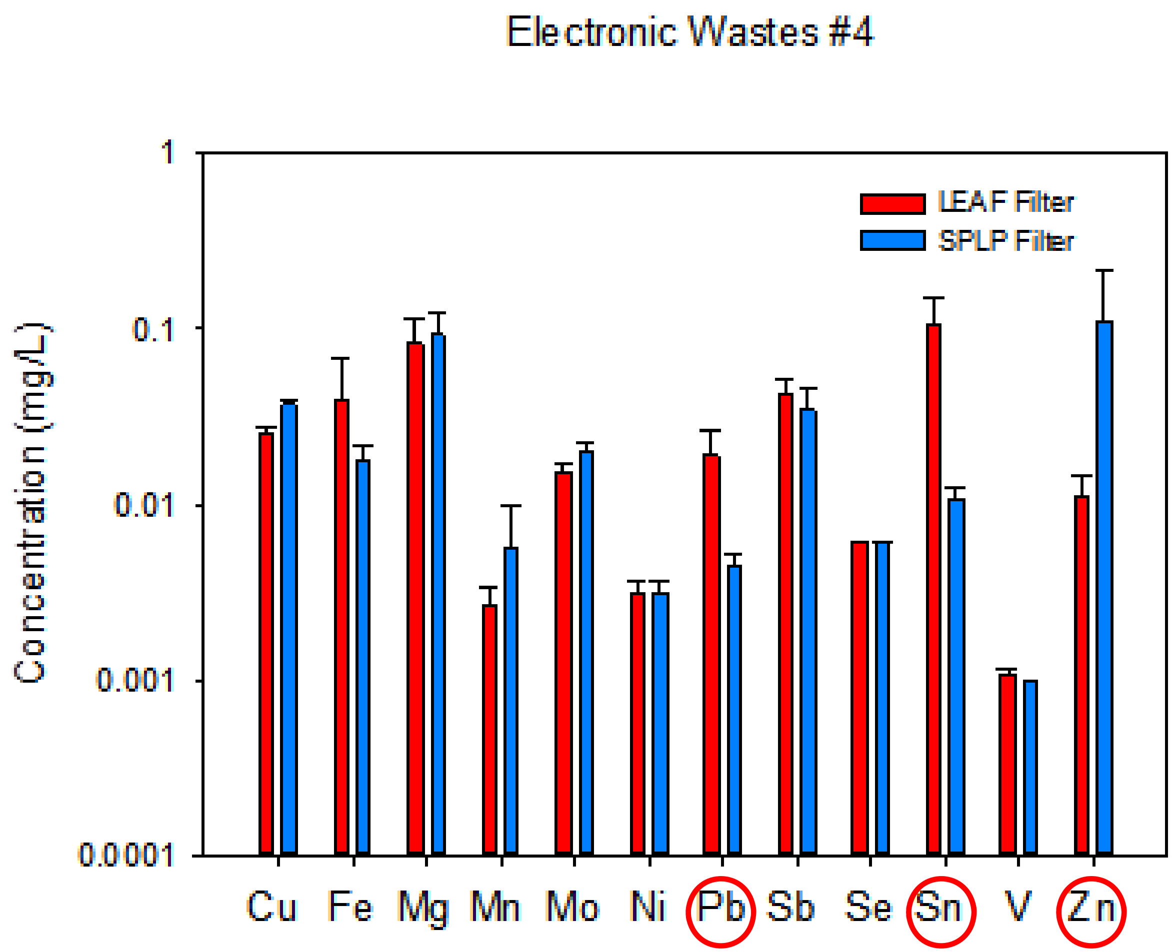
Influence of Particle Size



Influence of Filter



Influence of Filter



Feedback from TAG

- What information would you like to see?
- What is the best way to present the information so that the Florida solid waste community can readily access and utilize?

http://pages.ees.ufl.edu/townsend/

http://pages.ees.ufl.edu/townsend/research/hc14/