Dept. of Civil & Environmental Engineering

Experimental and Numerical Analyses of Leachate from Air Cooled Blast Furnace Slag Materials

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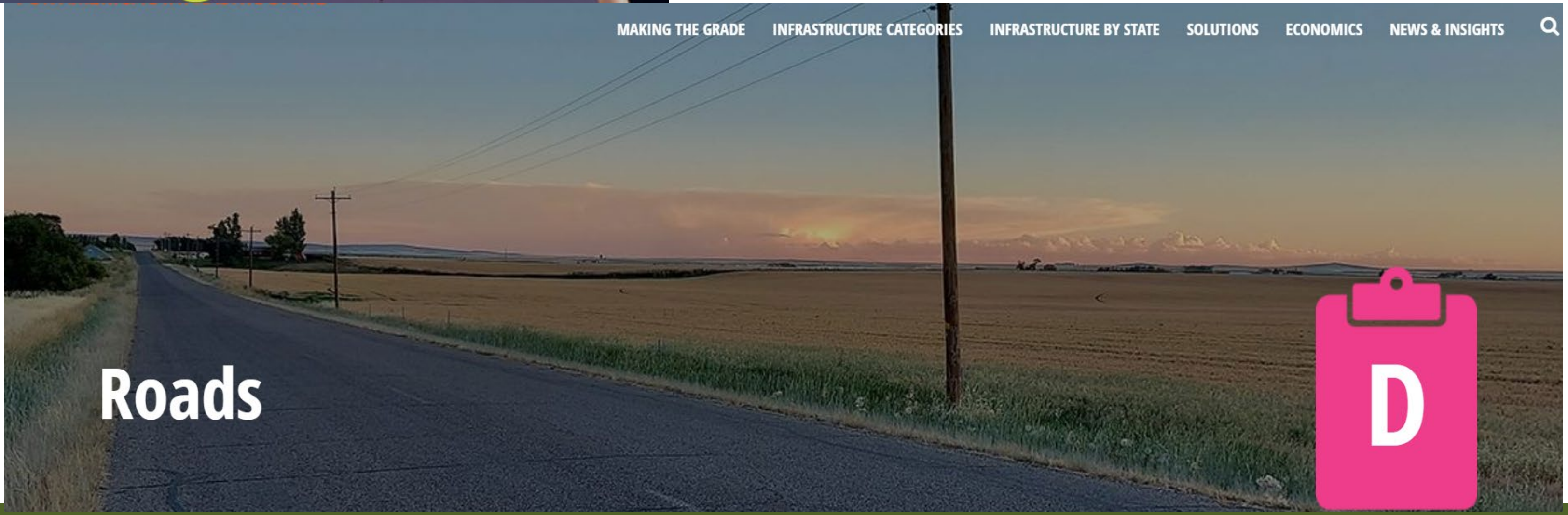
National Slag Association Conference

September 19, 2022

PROBLEM STATEMENT



PROBLEM STATEMENT

HIGHLIGHTS

The number of vehicle miles traveled on roads in "poor" condition has risen from

15% to more than 17% over the last decade.

Our nation's highways and roads move 72%, or

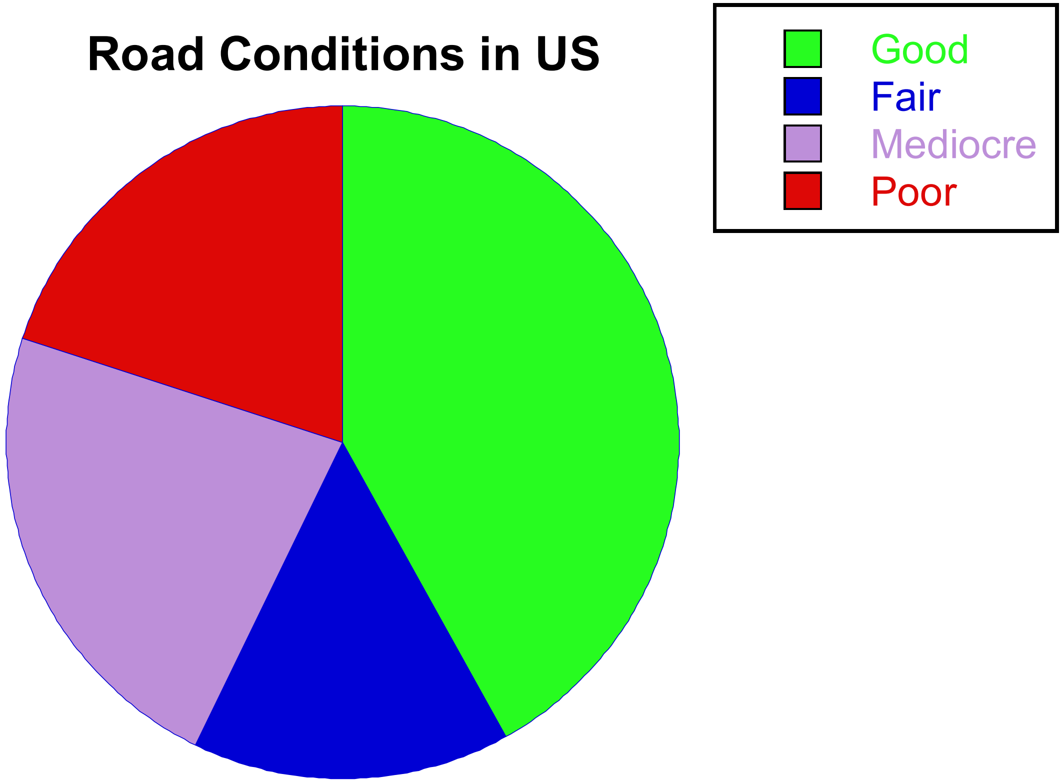
nearly $17 trillion, of the nation's goods;

43% of our public roadways

are in poor or mediocre condition.

PROBLEM STATEMENT

- 4 million miles of public roadways in the United States
- Vehicle miles traveled reaching more than 3.2 trillion in 2019, an 18% increase from 2000.



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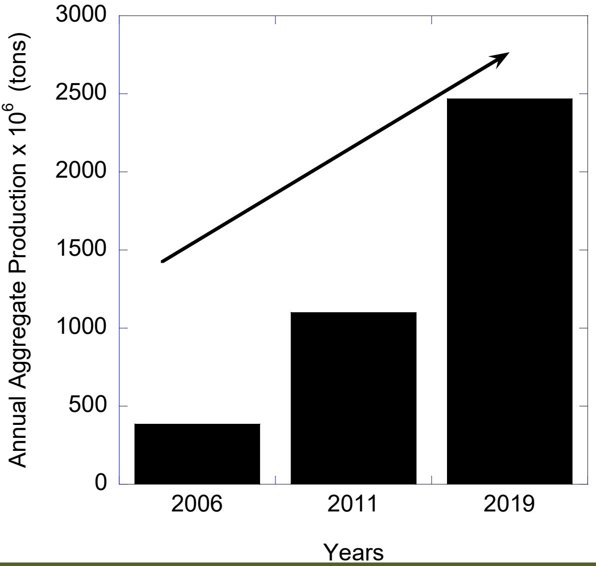

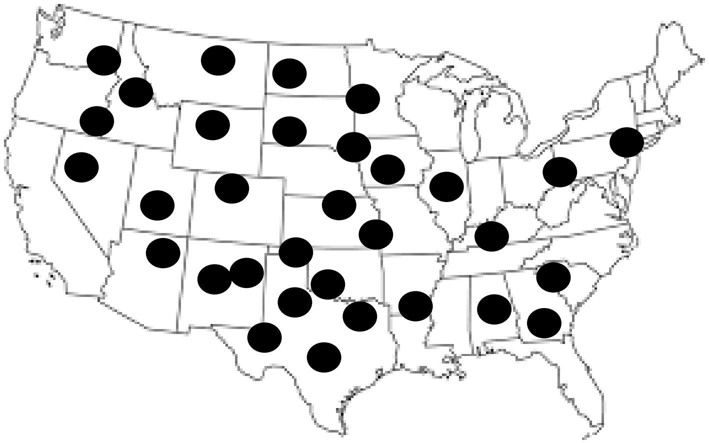

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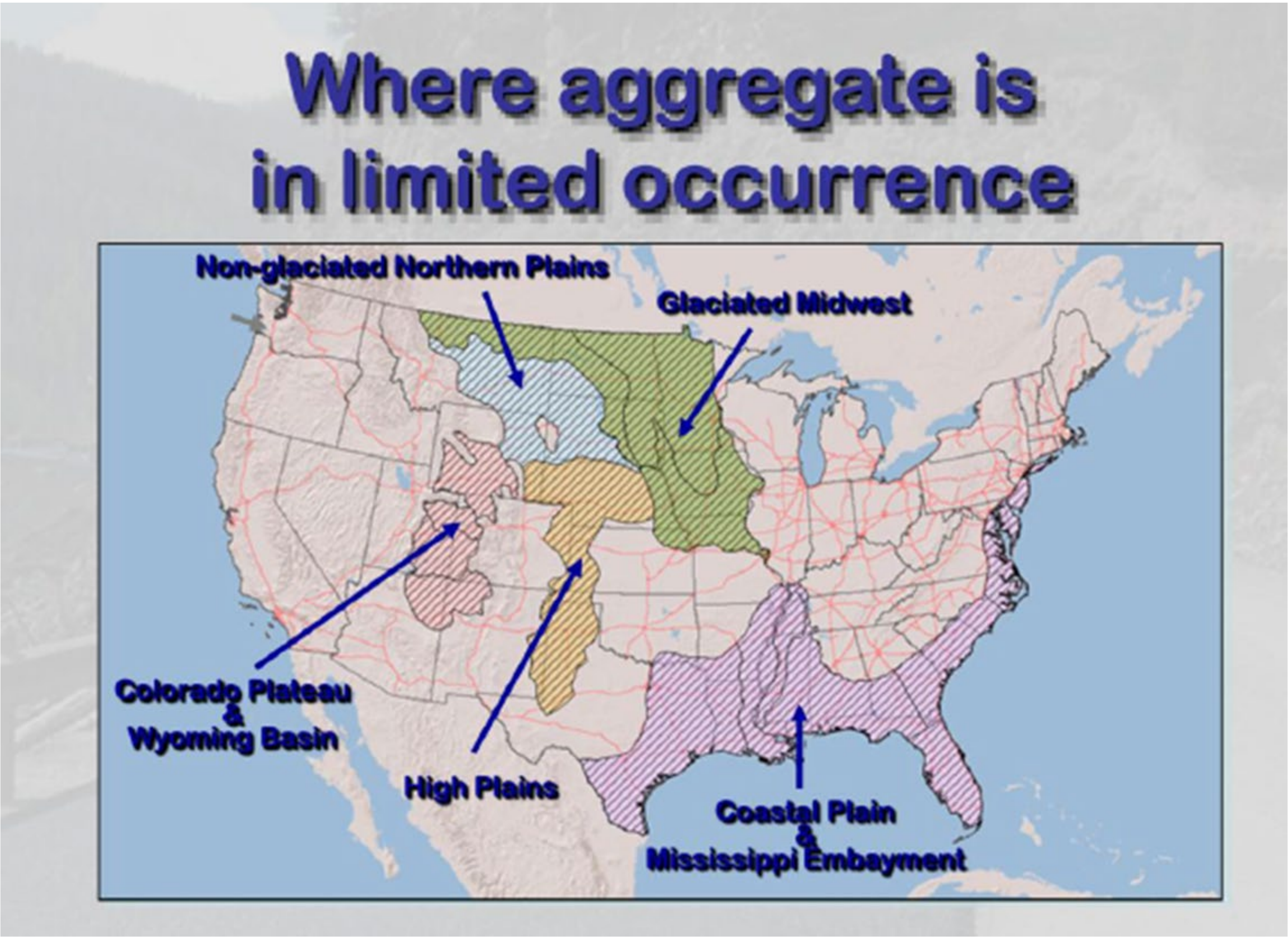

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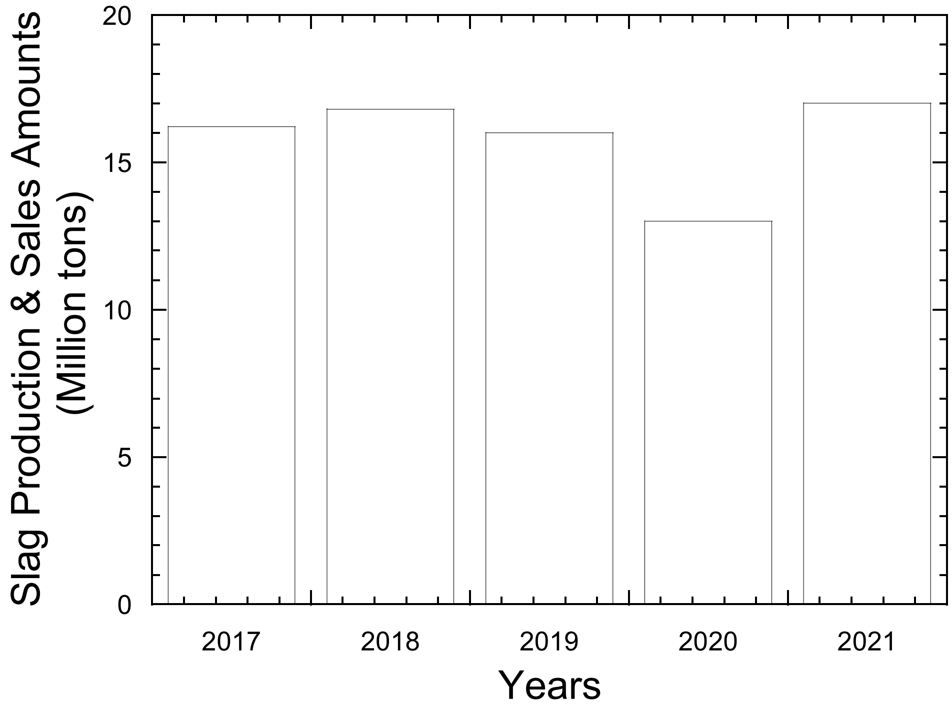
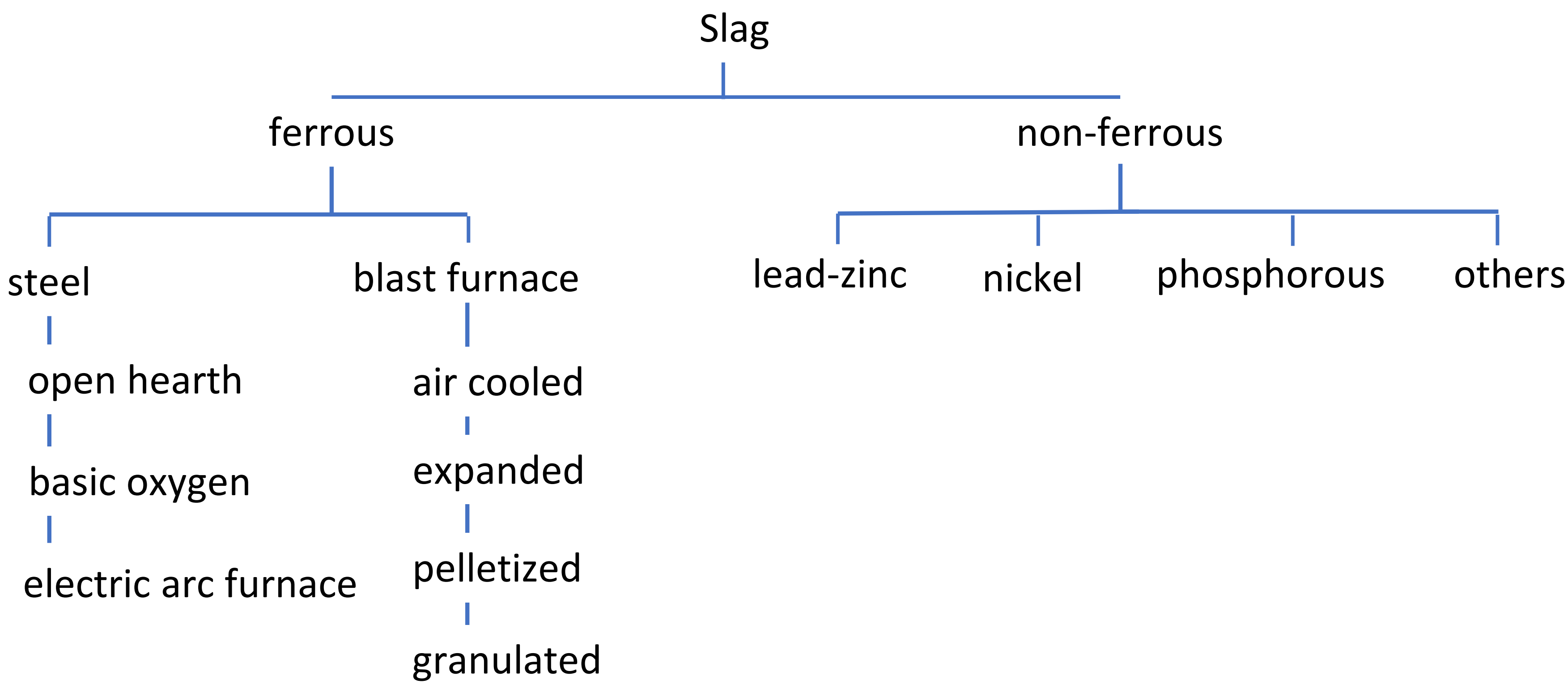


USGS (2022)

PROBLEM STATEMENT



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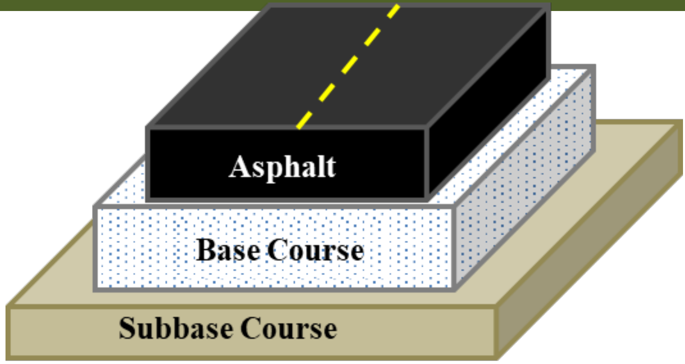


Environmental Impact

OBJECTIVES

Overall Goal: is to develop the leaching behavior of ACBFS generated leachate as well as guidance towards testing these materials for leachate

1st Goal – Literature Review

- Specific to ACBFS including unpublished industrial work

2nd Goal – Laboratory Tests

- Batch test
  - Rotating or stagnated condition
  - Impact of aging
  - Odor, pH, sulfur, calcium, metals, color in particular
- Sequential column leach tests

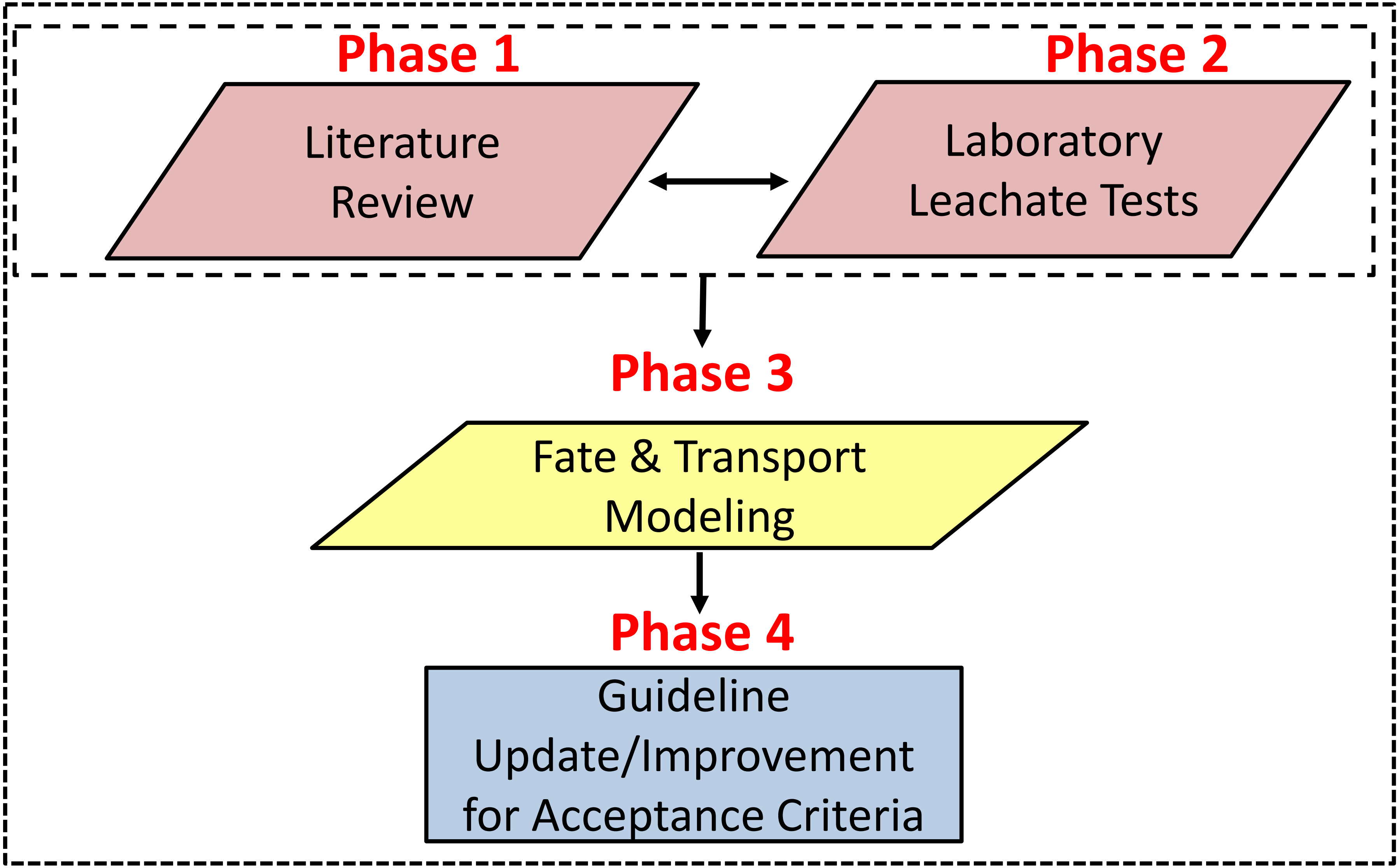
3rd Goal – Modeling

- Fate & transport modelling

4th Goal – Guideline development

- Develop acceptance procedures for ACBFS leachate

Overall Research Methodology



Objectives will be addressed with seven tasks

1. Project scope discussion meeting
2. Literature review
3. Collection of materials & physicochemical properties tests
4. Laboratory batch leachate tests
5. Laboratory column leachate tests
6. Chemical fate & transport modeling
7. Final report

Task 2 – Literature Review

Specific attention will be given

- ❑ Sulfur leaching and sulfate formations in ACBFS and similar materials
- ❑ pH, oxidation-reduction potential (Eh), electrical Conductivity (EC)
- ❑ Potential leachable elements from ACBFS
- ❑ Alternative practical leachate test methods

Task 2 – Material Collection

ACBFS from 5 Different Mills

Untreated

Stockpiled:

Fresh & 1, 6, and 12 months

Treated

Stockpiled:

Fresh & 1, 6, and 12 months

Soils

Low plasticity clay

Silty Sand

Low plasticity Silt

Task 2 – Material Collection

PHYSICAL ANALYSES

- Standard Proctor (AASHTO T99)
- Moisture content (AASHTO T265)
- Sieve/hydrometer analyses (AASHTO T27)
- Atterberg limit (AASHTO T89, AASHTO T90)
- Specific gravity (G_s) (ASTM C127, C128, D854)
    - Oven dry G_s
    - Saturated-surface dry G_s
    - Apparent G_s

CHEMICAL ANALYSES

- pH
- Electrical conductivity (EC)
- Oxidation-reduction potential (Eh)

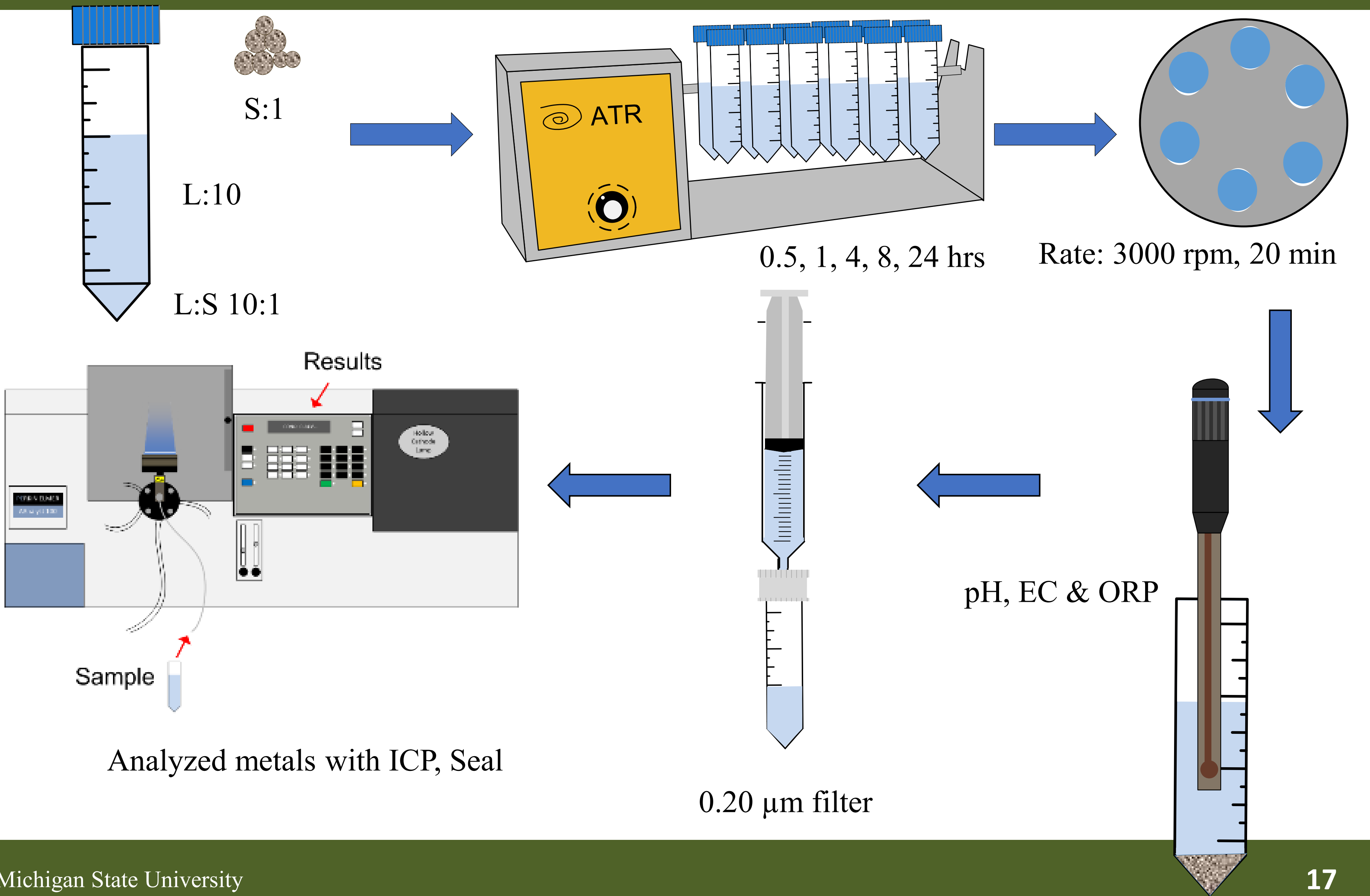
- XRF & XRD
    - Oxide contents and mineralogy
- Total Element Analyses

Task 4 – Laboratory Batch Leachate Tests

Test Method 1: Acceptance Procedures of ACBFS for Leachate Determination—ITM No. 212-19

Test Method 2: Standard Batch Leach Test – as a function of liquid-solid ratio in solid materials.

Task 4 – Laboratory Batch Leachate Tests



Task 4 – Laboratory Batch Leachate Tests

- **Initial Leachate Analysis:**
  - pH
  - Odor
  - Color
  - Electrical conductivity (EC)
  - Oxidation-reduction potential (Eh)

- **Heavy and Trace Metals of Concern:**
  - Chromium (Cr), Copper (Cu), Iron (Fe), Manganese (Mn), Zinc (Zn) and others.

- **Other Metals and Anions of Interest:**
  - Calcium (Ca)
  - Magnesium (Mg)
  - Sulfate (SO_4) Total inorganic Carbon (TIC)
  - Total organic Carbon (DOC)

Equipment

Tumbler

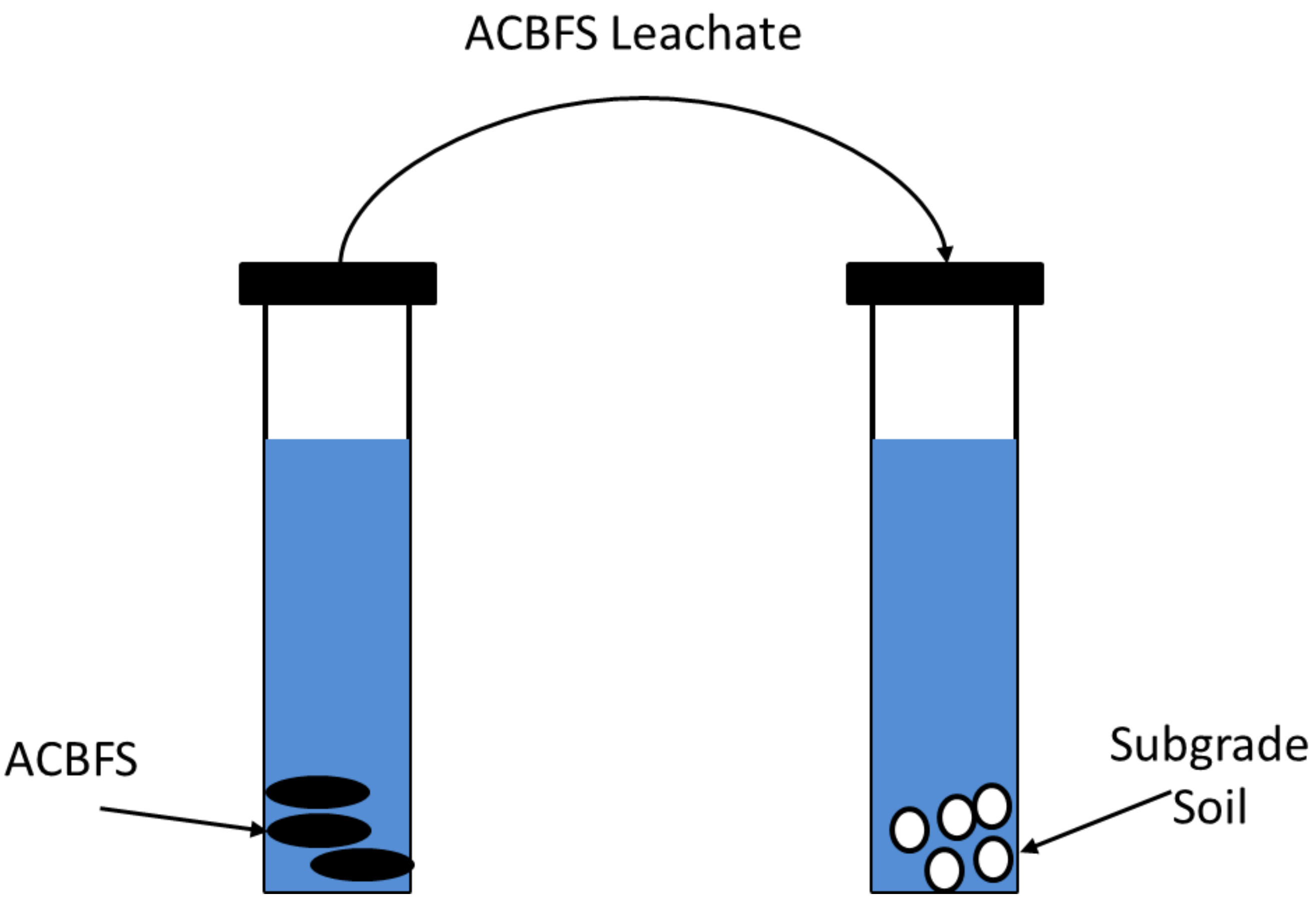
Inductively coupled plasma (ICP-MS)

TOC Analyzer

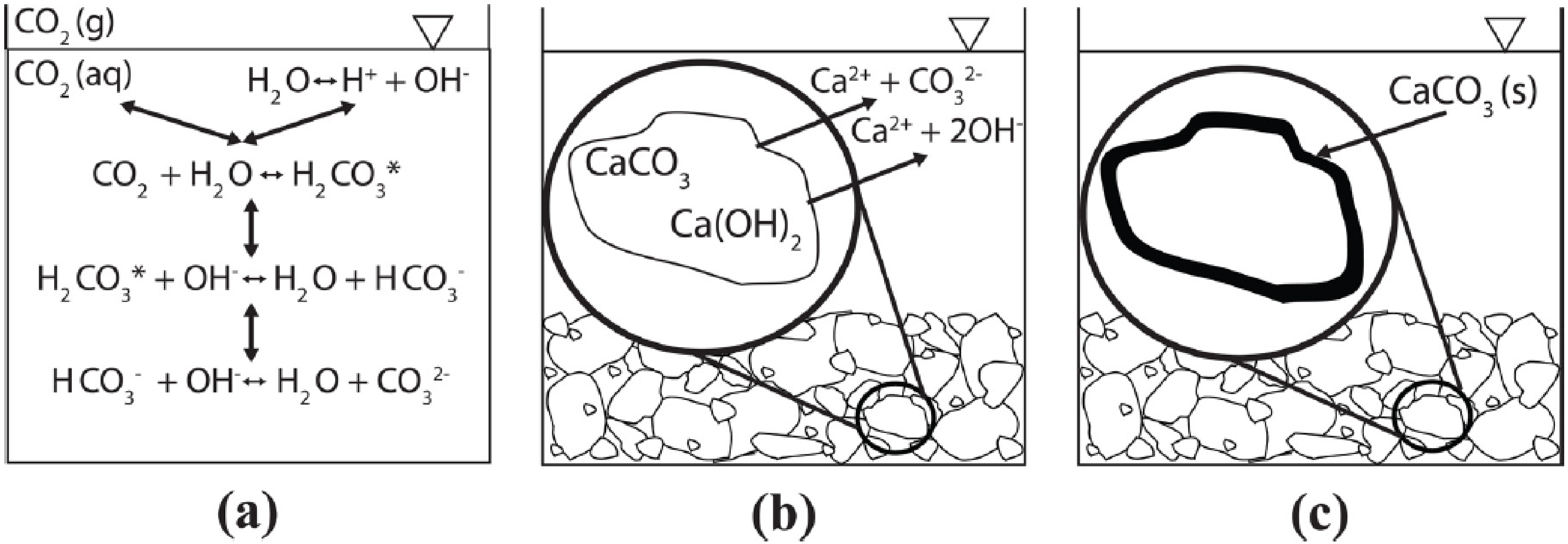
Seal AQ2 Analyzer

pH Meter

Task 4 – Sequential Batch Leachate Tests

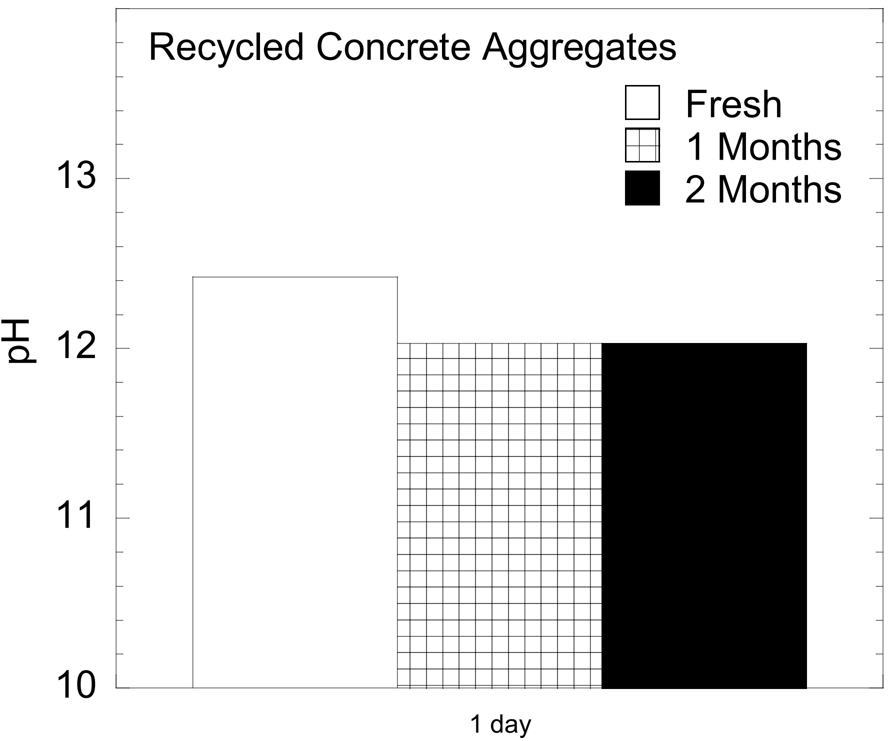


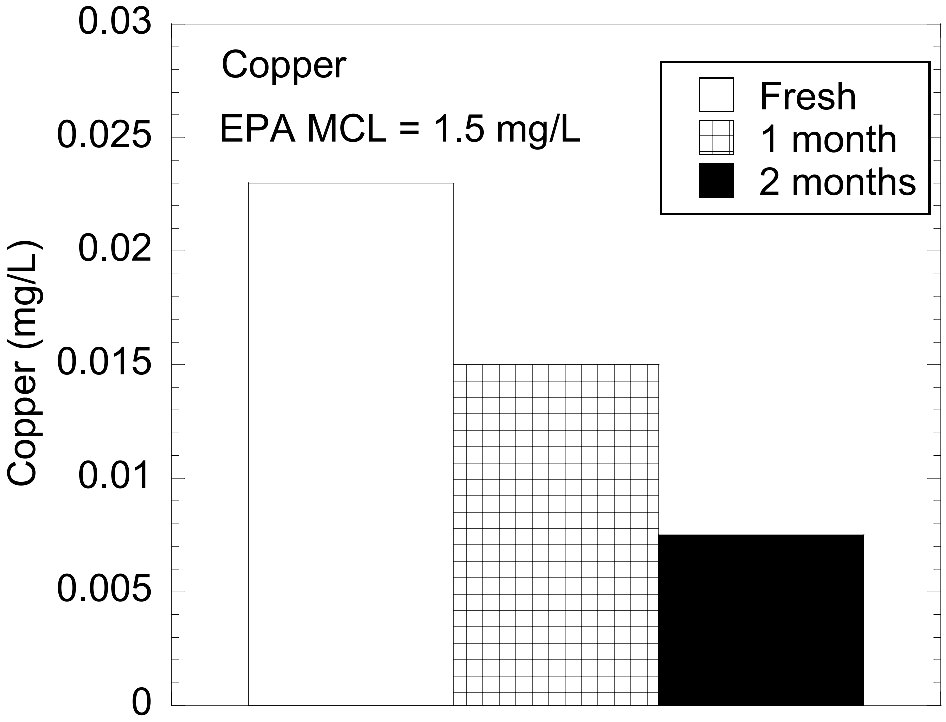
Impact of Carbonation on Leachate Characteristics



(a) Carbonate system of natural waters; (b) dissolution of calcium hydroxide and calcium carbonate from RCA surface; (c) carbonation of RCA surface as represented by the black layer. Notes: RCA = recycled concrete aggregate

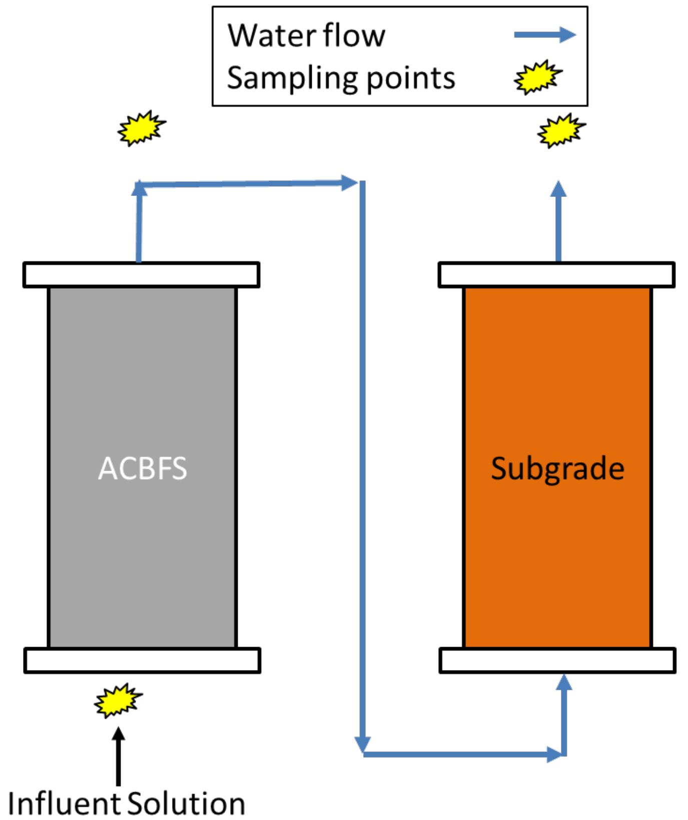
Impact of Carbonation on Leachate Characteristics





Bestgen et al. (2016)

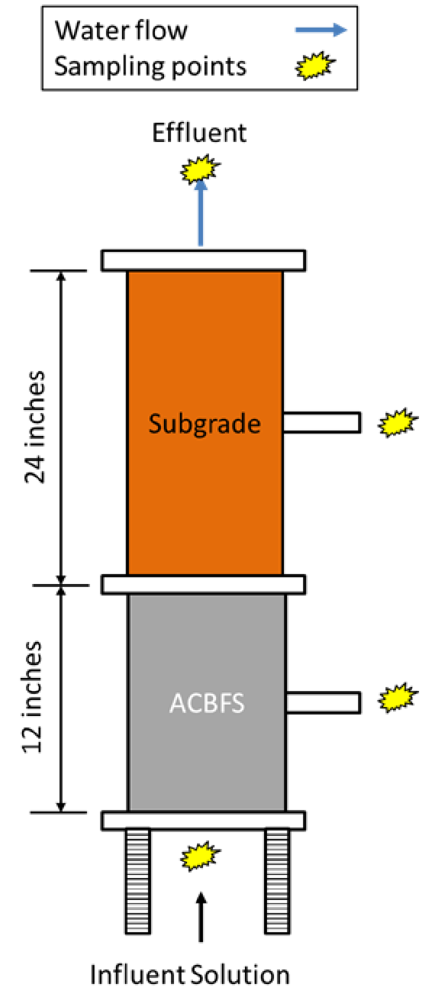
Task 5–Laboratory Column Leach Test (CLT)



Reactor 1: RCA Column

Reactor 2: Subgrade Column

METHOD 1



METHOD 2

Task 6 – Chemical Fate & Transport Modeling

HP1-Coupled Hydrus-1D and PHREEQC

Introduction to HP1:

- A reactive transport model incorporating advection, diffusion, and reaction will be used to model the change in pH and leached chemicals as a function of time, travel distance through subgrade and adjacent soils.

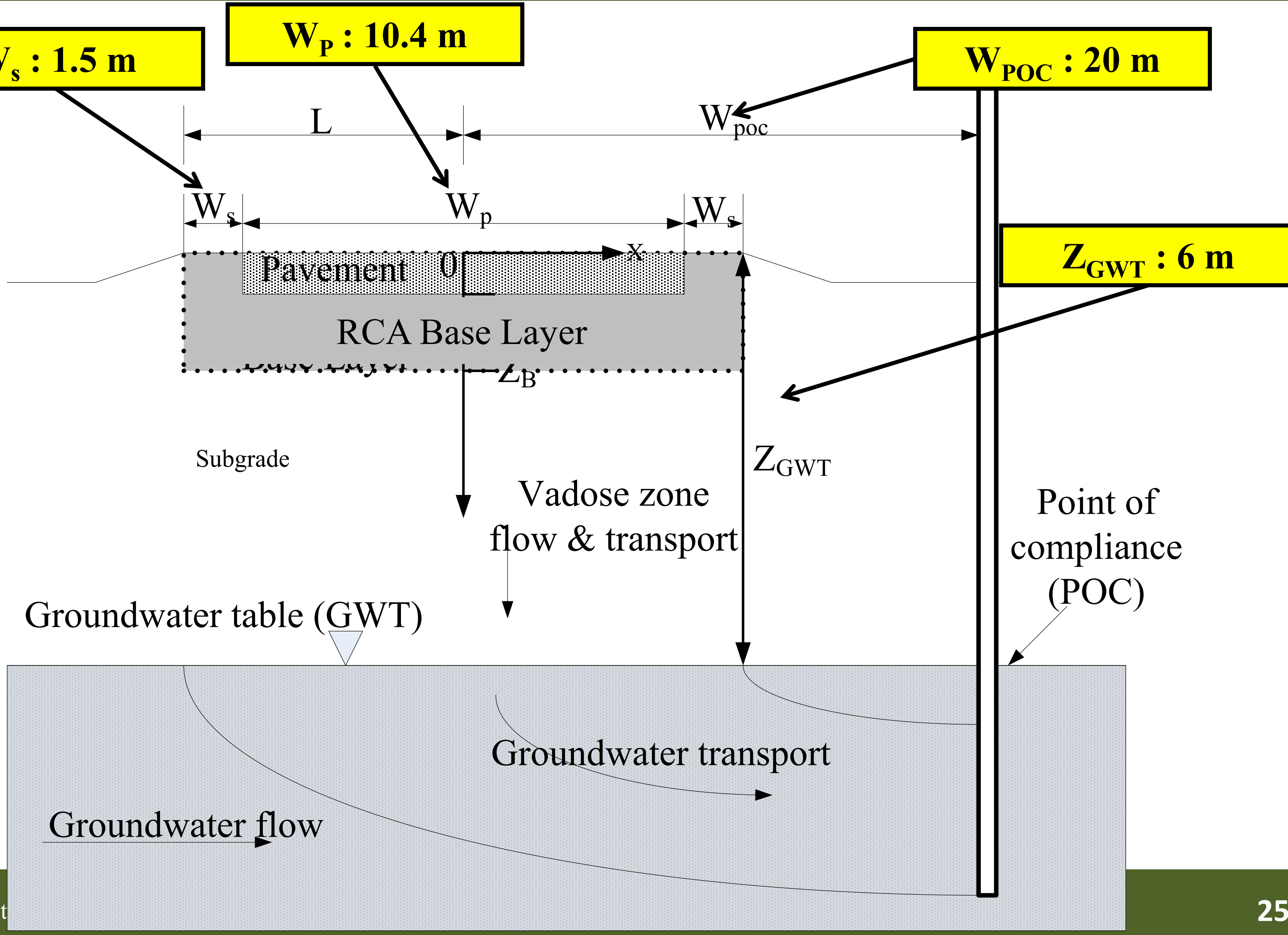
Advantages of HP1:

- Contains modules simulating (1) transient water flow, (2) the transport of multiple components, (3) mixed equilibrium/kinetic biogeochemical reactions, and (4) heat transport in one-dimensional variably saturated porous media (soils). HP1 is a significant expansion of the individual Hydrus-1D and PHREEQC programs by preserving most of their original features.

Outcome of HP1:

- Determining pH and transported leached chemicals from slag at a specific location (both in horizontal and vertical directions) in the field scenario.

Task 6 – Chemical Fate & Transport Modeling



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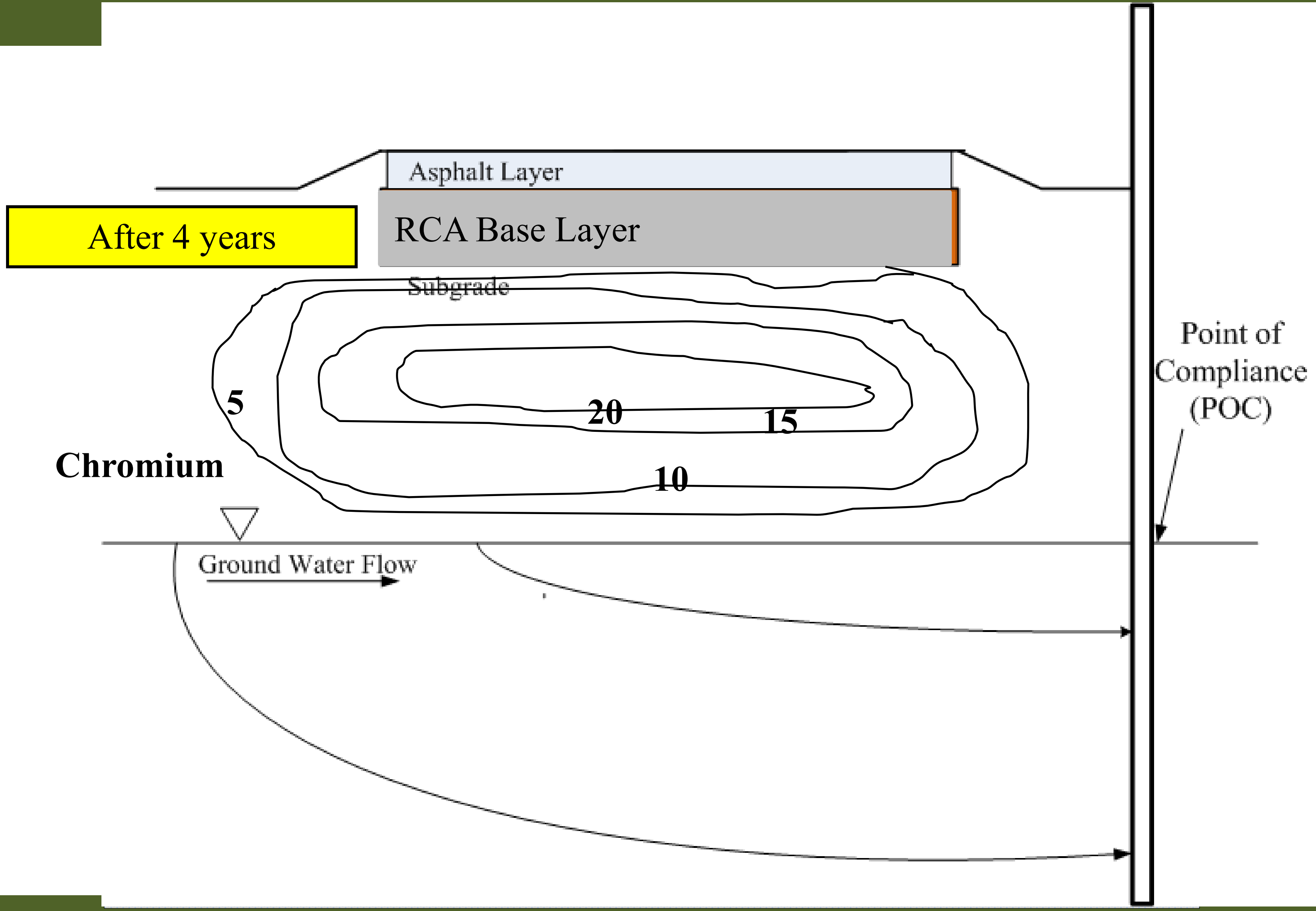

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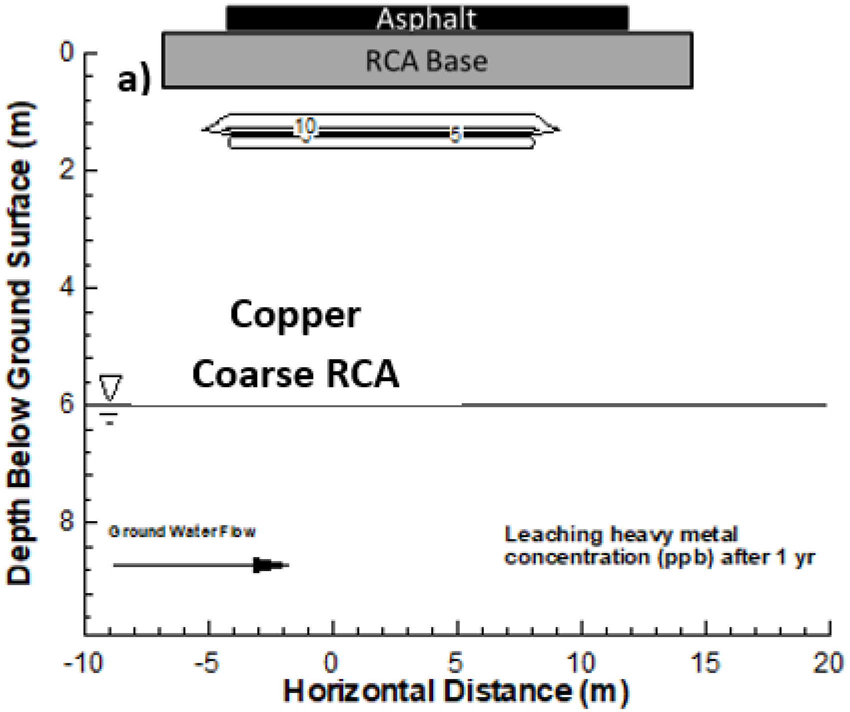

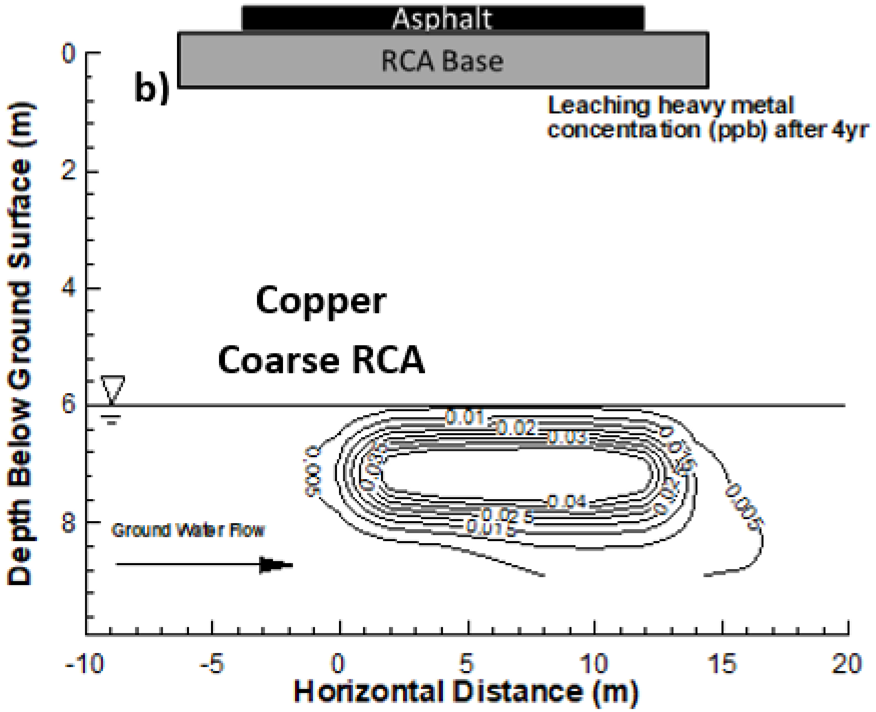

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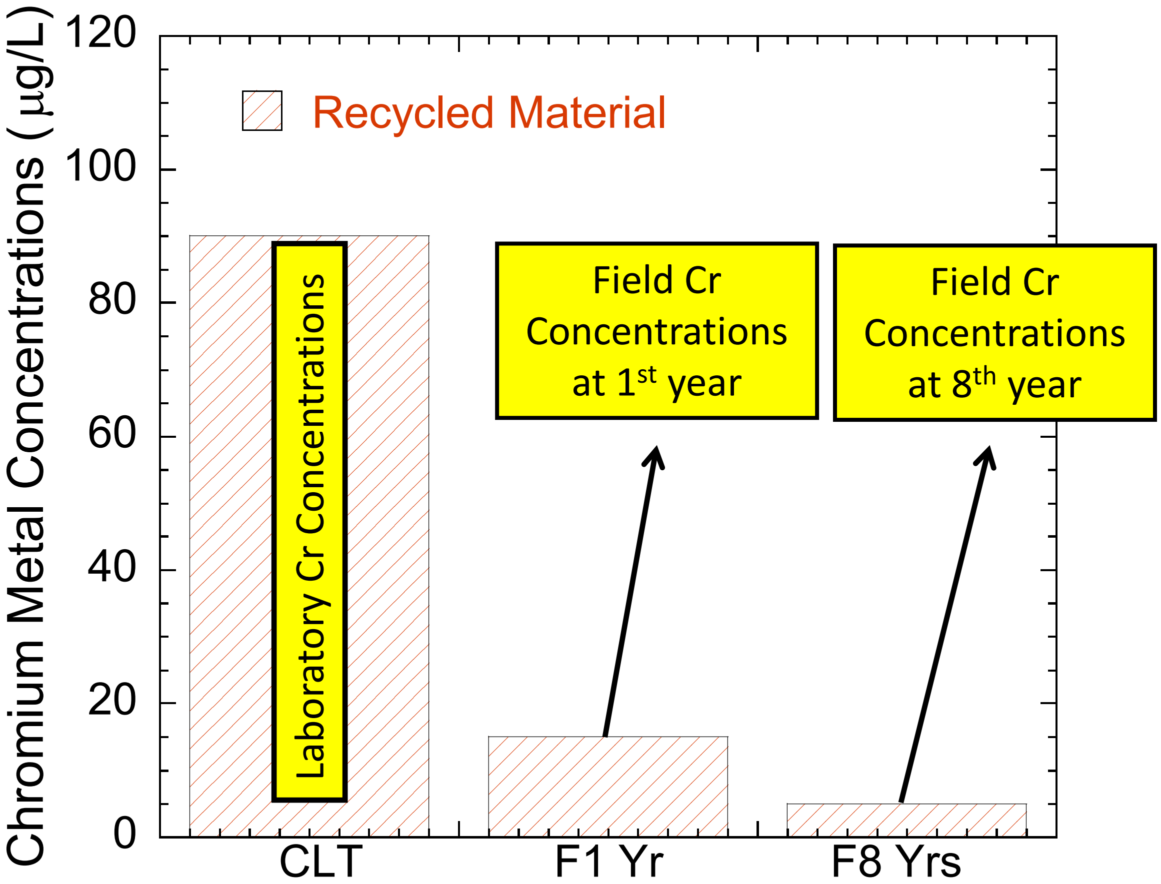

Notes: CLT=Column leach tests, F1 years,=Field concentrations at 1st year, F8 years, Field concentrations at 8th year

Questions to be Addressed

- What is causing the leachate to form from ACBFS (e.g., mineral formation, percentages of the minerals)?
- How does ACBFS leachate behavior change over time?
- What is the environmental impact of ACBFS use in roadway systems?
- What is the predicted impact of leached elements from ACBFS in the field?
- Do the current methods need an improvement to determine the acceptance of ACBFS materials?

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Questions?