Optimizing the Use of Water Extraction Tests for Water Chemistry Prediction

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Outline

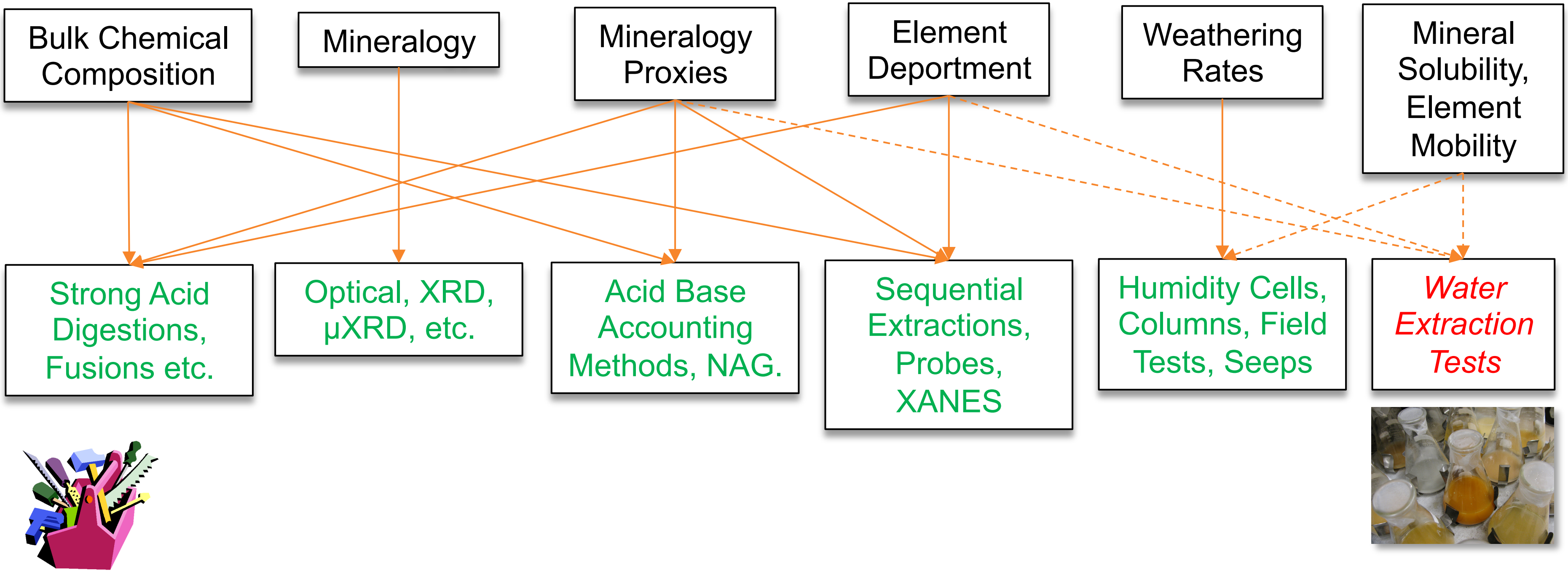
- What is a “Water Extraction Test”?
- Where do extraction tests fit into the toolbox?
- A very short history of extraction tests.
- What happens during an extraction test?
- Limitations and dependencies
- So what can I do with the data?

What is a Water Extraction Test?

- A number of procedures that involve rinsing a sample with water (or a weak acid solution) followed by analysis of the resulting leachate.
- Example: MEND Shake Flask Extraction

Source: Bureau Veritas

Where do extraction tests fit into the toolbox?



Bulk Chemical Composition

Mineralogy

Mineralogy Proxies

Element Deportment

Weathering Rates

Mineral Solubility, Element Mobility

Strong Acid Digestions, Fusions etc.

Optical, XRD, µXRD, etc.

Acid Base Accounting Methods, NAG.

Sequential Extractions, Probes, XANES

Humidity Cells, Columns, Field Tests, Seeps

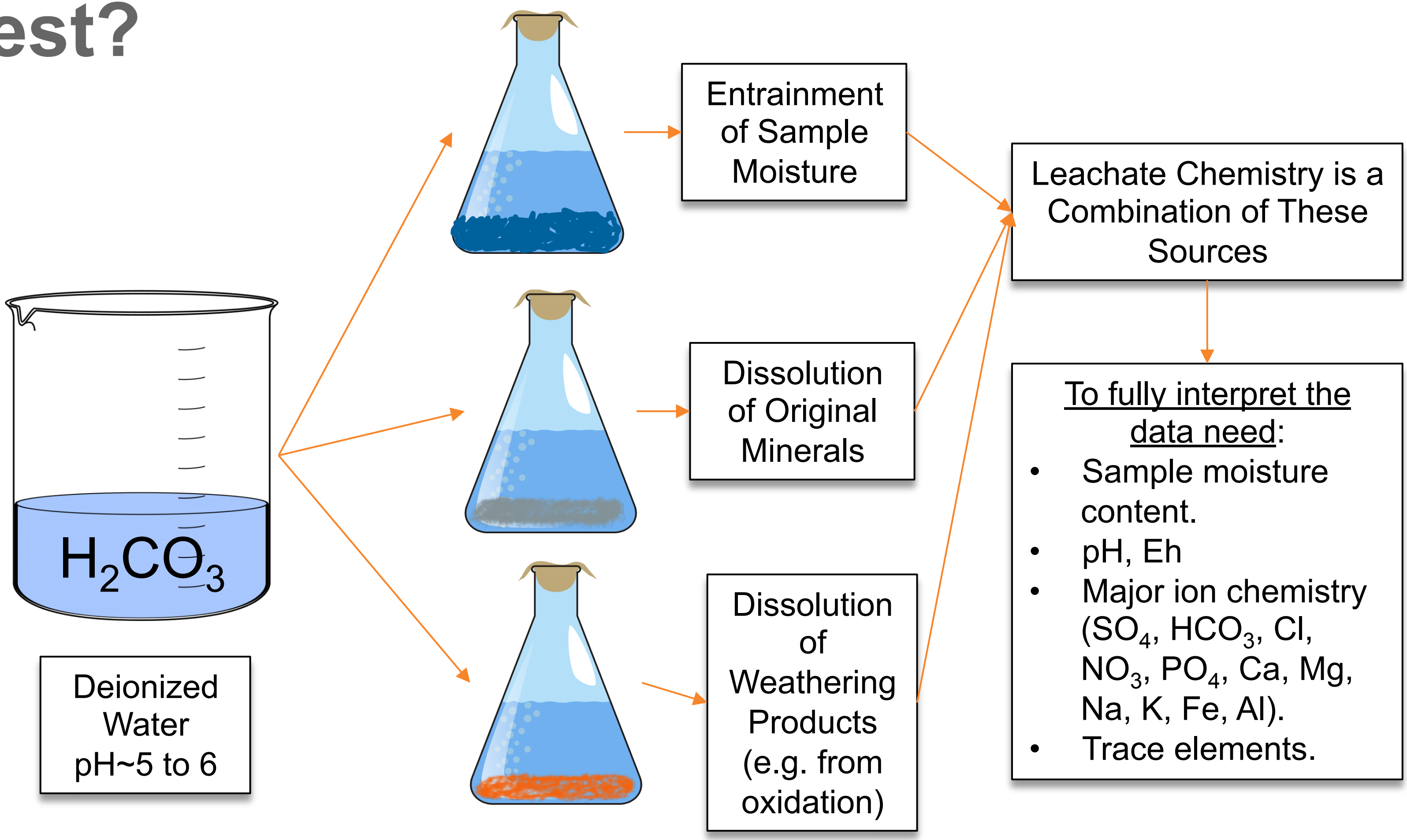
Water Extraction Tests

A very short history of extraction tests

- USEPA (20:1 liquid to solid)
  - 1976 - “Toxicity characteristic leaching procedure” – acetic acid extraction. Leachate chemistry compared to specified values for waste classification purposes.
  - 1994 - “Synthetic precipitation leaching procedure” – deionized water modified by mixture of nitric and sulphuric acids to pH 4.2 or 5.0.
- BC MEMPR (3:1 liquid to solid)
  - 1997 - modification of TCLP using deionized water and lower liquid-to-solid ratio.

These tests (and several others) are performed at liquid-to-solid ratios higher than natural conditions over a short time frame (usually 24 hours) on a screened sample.

What Happens During a Water Extraction Test?



Deionized Water
pH~5 to 6

Entrainment of Sample Moisture

Dissolution of Original Minerals

Dissolution of Weathering Products (e.g. from oxidation)

Leachate Chemistry is a Combination of These Sources

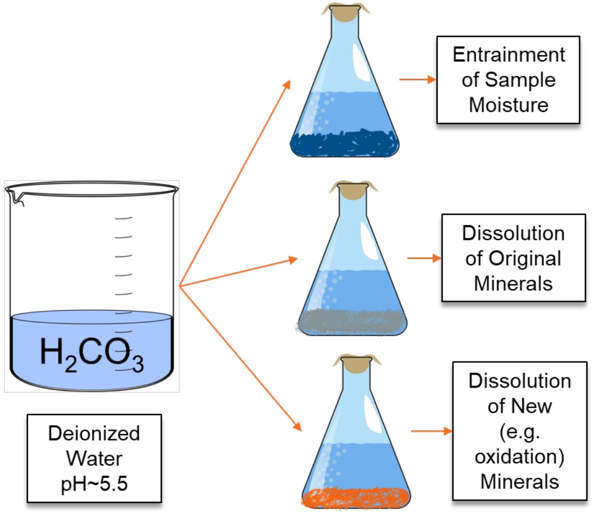
<u>To fully interpret the data need</u>:

- Sample moisture content.
- pH, Eh
- Major ion chemistry (SO_4, HCO_3, Cl, NO_3, PO_4, Ca, Mg, Na, K, Fe, Al).
- Trace elements.

Limitations and Dependencies

Limitations and Dependencies

- The type of sample, how it has been stored and how it was prepared for testing can all affect the leachate chemistry



Deionized Water pH~5.5

Entrainment of Sample Moisture

Dissolution of Original Minerals

Dissolution of New (e.g. oxidation) Minerals

Extraction test on a fresh tailings sample will be influenced by entrained process water

Crushed samples have fresh mineral surfaces that may show short term effects (e.g. ion exchange, adsorption)

The duration of weathering prior to testing can affect the available soluble amount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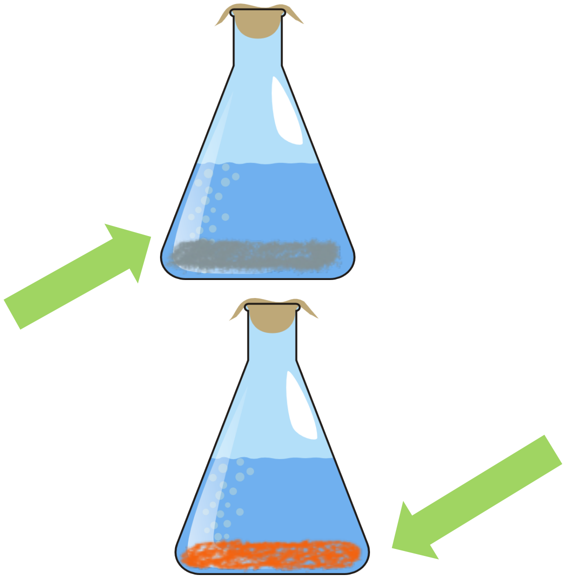
19IGGT-02 BOX 20
62.01m
65.04m
63.42m
66.0m
67.0m



Limitations and Dependencies

- The liquid-to-solid ratio is much higher than most natural conditions
  - Most immediate implication is that concentrations in the leachate will likely be lower than natural contact waters.
  - Need to be very cautious about assuming concentrations reflect natural conditions.

Limitations and Dependencies

- The liquid-to-solid ratio is much higher than most natural conditions
  - pH can be affected by dilution.

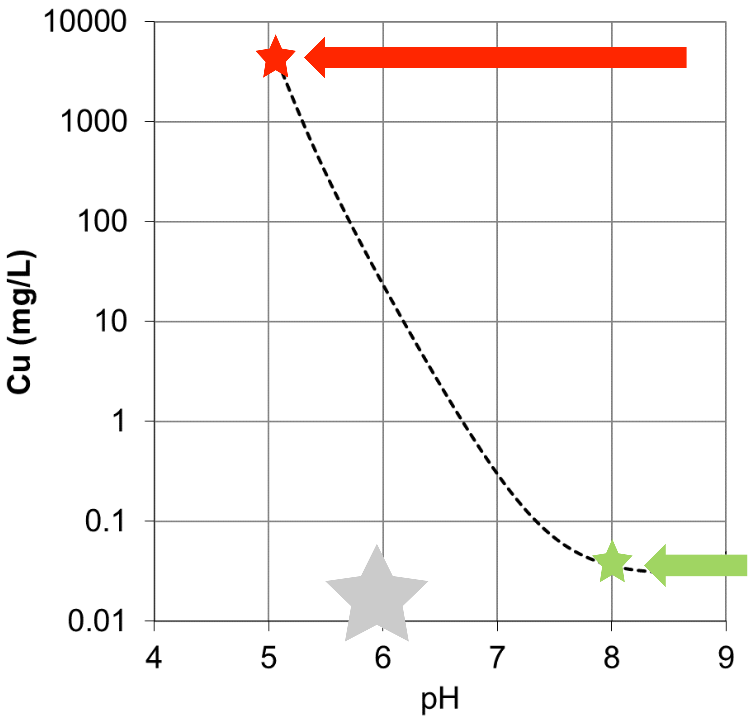
Condition	Water to solid ratio	Contact water pH
SFE Leach test	3:1	4.9
Rinse test	1:1	3.5
Low Ratio Leach Test	0.4:1	3.0
Site conditions	~0.04:1	?

2 pH units can be 10^4 difference in copper concentrations

Source: A Practical Guide to Recognizing and Limiting Acid Rock Drainage in Non-Mining Environments, NWT Geoscience Forum, 2019

  - Need to be very cautious about assuming concentrations reflect natural conditions

Limitations and Dependencies



Low pH diluted to higher pH in the test – copper concentration lower than contact water

High pH diluted to lower pH in the test – copper concentration higher than contact water

Limitations and Dependencies

- Extraction period is typically 24 hours
  - Much shorter than contact time in most waste disposal configurations – can easily be years.
  - The contribution of slowly dissolving minerals may not be reflected in the time frame of the test.

- Particle size distribution
  - For practical reasons, tests are performed on a sieved sample which may be much finer than the actual materials

So What Can I Do with the Data?

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- Amount of readily soluble constituent available for leaching, for example:
  - How much sulphate will flush when the ore is processed?
  - How much nitrate is present as a residual from explosives?
  - How much load could be leached as waste is disposed under water?

- Simple calculation for concentration in leachate [M] and leach ratio: Q
  - [M] (mg/L) x Q (L/kg)
  - 100 mg/L x 3 L/kg = 300 mg/kg

So What Can I Do with the Data?

Cautions

- Sample representivity (all aspects)
- Scaling for particle size tested vs actual particle size of material.
- pH controlled parameters may have limited solubility.
- Kinetics of dissolution.

So What Can I Do with the Data?

- Estimate pore water chemistry $[M]_p$ from leached load and gravimetric moisture content (θ, fraction) and water density (ρ):

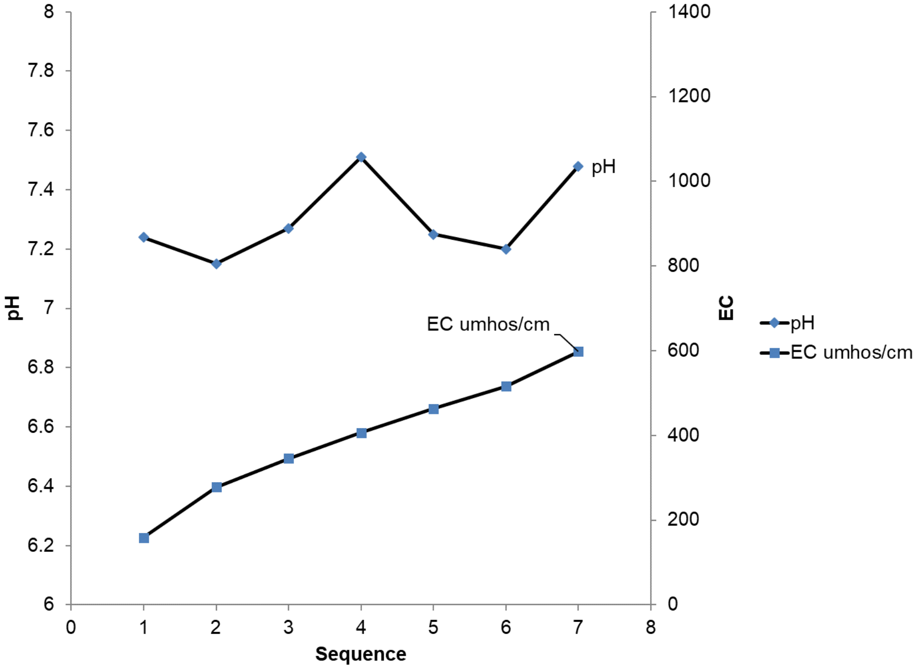
$$[M]{\downarrow}p = [M]\cdot Q\cdot \rho/\theta$$

- Interpret resulting chemistry using equilibrium chemistry model (e.g. PHREEQC)
- Example, $\theta=0.1$

$$[M]{\downarrow}p = 100\ (mg/L)\ x\ 3\ (L/kg)\ x\ 1\ (kg/L)/0.1\ (kg/kg)\ = 3000\ mg/L$$

So What Can I Do with the Data?

- Interpret solubility constraints.
  - Use equilibrium modelling on [M] and $[M]_p$
  - Modify procedure to change leach ratio (Q).
  - Consider exposing fresh sample with leachate from extraction test.



So What Can I Do with the Data?

- All uses of the data require interpretation to account (or scale) for test conditions.
- Direct use of the leachate data (such as comparison with water quality guidelines and standards) is rarely likely to be meaningful.

Conclusions

- Carefully consider the objective of performing the test (as with any procedure), the type of sample being tested, how it has been stored, duration of storage and how it was prepared.
- Crushing can introduce short term effects which are not meaningful in the long term. Generally samples should be tested using the original particle size distribution.
- Complete interpretation of results requires full ion chemistry.
- Water extraction data require a cautious approach to interpretation due to the numerous limiting factors.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