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The pH sensitivity of lime neutralization sludge stored sub-aqueously: A laboratory and field-based assessment

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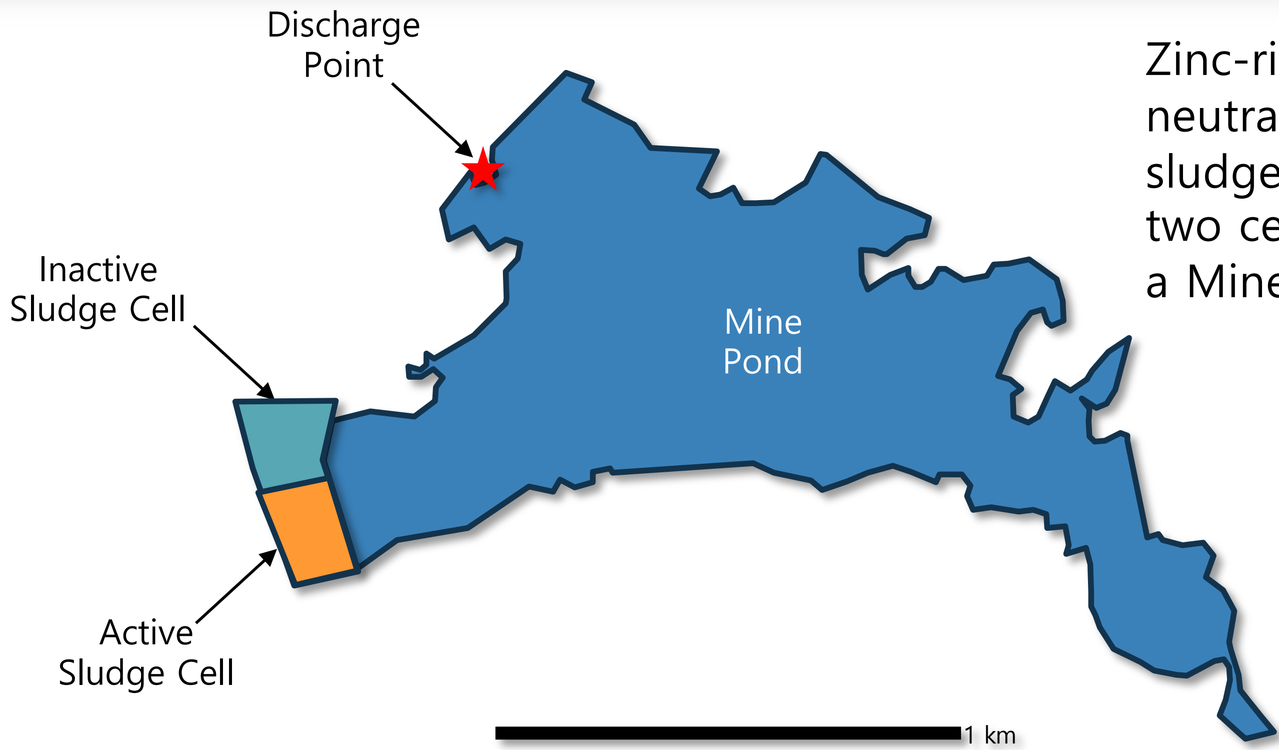
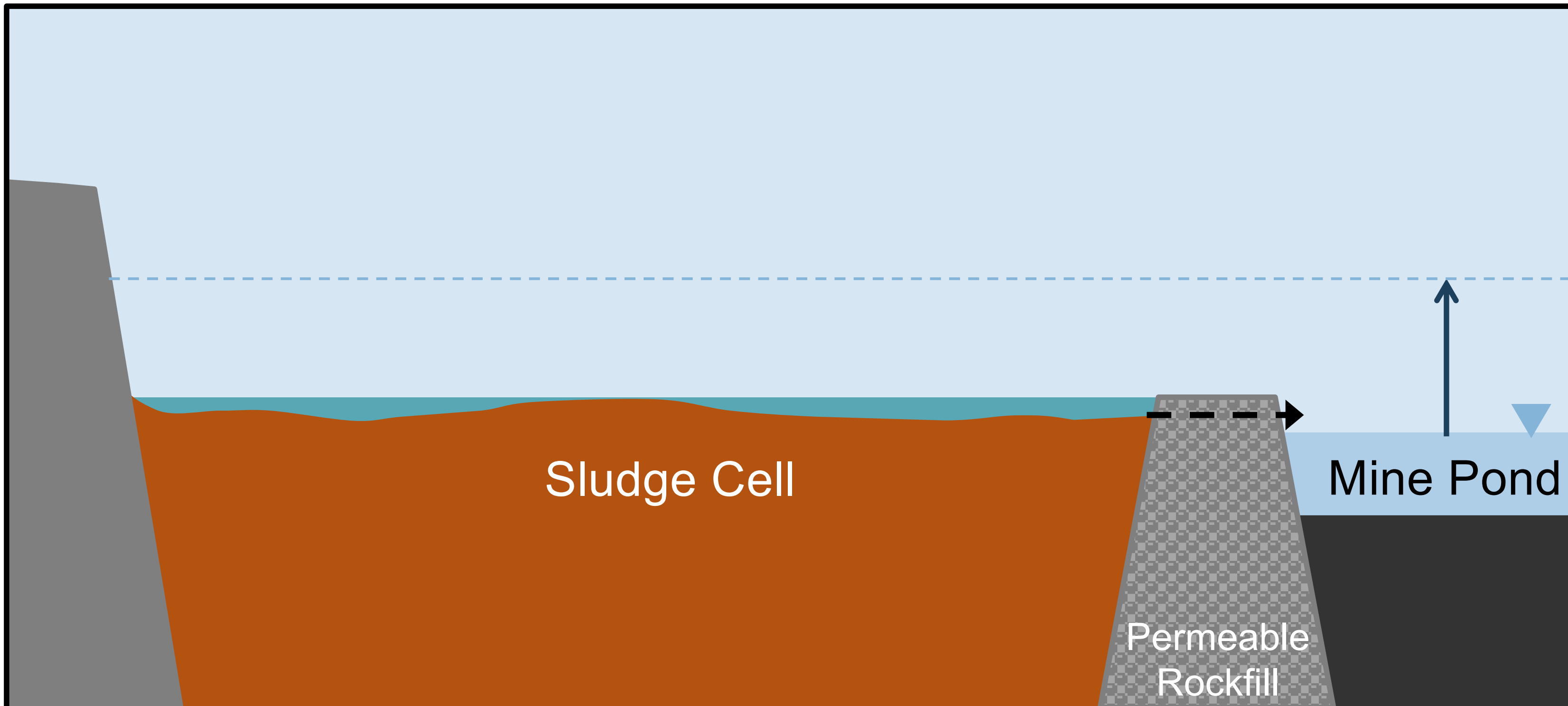
Introduction



Zinc-rich lime neutralization sludge stored in two cells within a Mine Pond

Introduction



Not To Scale

Objectives

- Assess geochemical stability of sub-aqueously stored sludge under a range of pH conditions
  - Analytical testing
- Rough estimate of possible impact to mine pond discharge point water quality
  - Conservative mixing model between the sludge cells and mine pond

Outline

- Methods
- Results
  - Leach tests
  - Mixing model
- Discussion
- Conclusions

Methods

Sampling

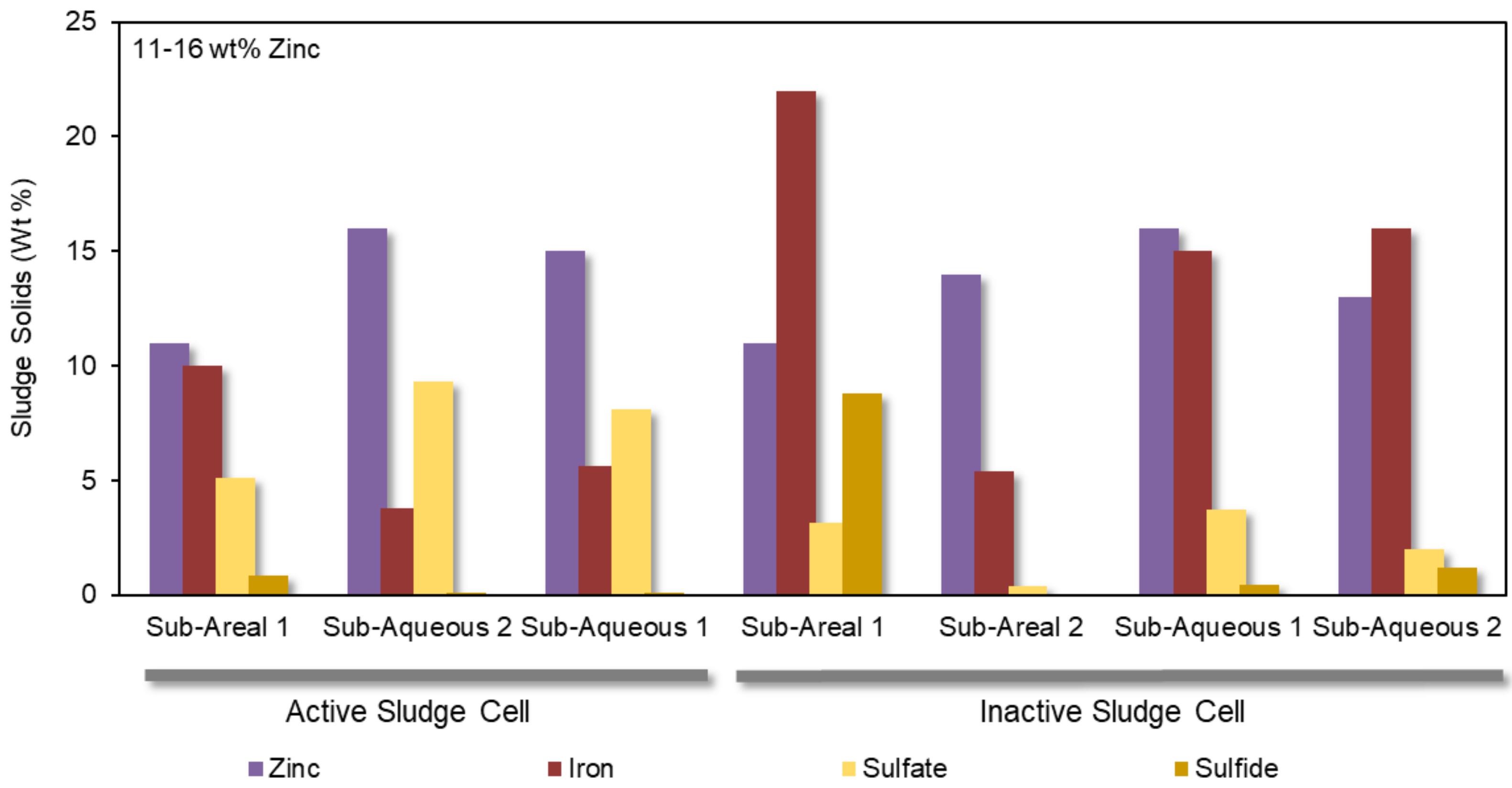
Inactive Cell sub-aerially exposed

Active Cell sub-aerially exposed

Sub-aqueous sample collection

Sub-aqueously stored sludge

Sludge Composition



Water Chemistry

- Collected at the same time as sub-aqueous samples
  - Managed (limed) Pond water at discharge point
  - Inactive cell supernatant
  - Active cell supernatant

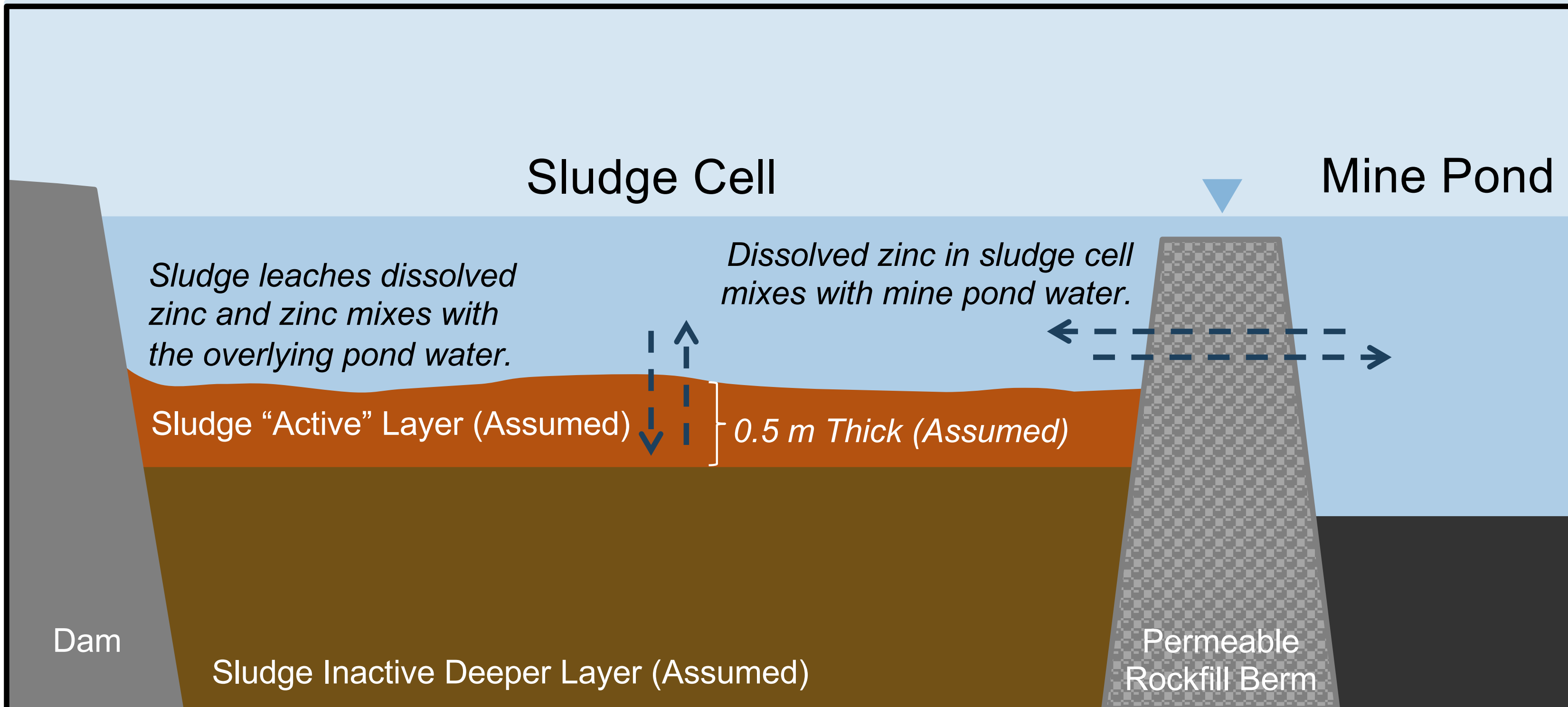
Mixing Model Source Concentrations

- Sludge Cell supernatants
- Standard Shake Flask Extractions (SFE) (3:1 liquid-solids)
  - Deionized (DI) water extractant
- Buffered pH SFE (10:1 liquid-solids)
  - Low: pH 5.6 – 6.4
  - Neutral: pH 7.1 – 7.3
  - High: pH 8.3 – 9.2
  - Buffered DI and pond water extractants
- “Bucket” tests (~1:1 liquid-solids)
  - ~Weekly sampling of pond water supernatant of sludge stored sub-aqueously without agitation
  - No pH control
  - 4-5°C first 3 weeks; 20°C final 4 weeks

Conservative Mixing Model

Variables:

- Source Term
  - pH
  - Lab vs Field
  - Liquid to Solids Ratio
  - Shaken vs Undisturbed
- Mixing Volume



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Mixing Zones

Variables:

- Source Term

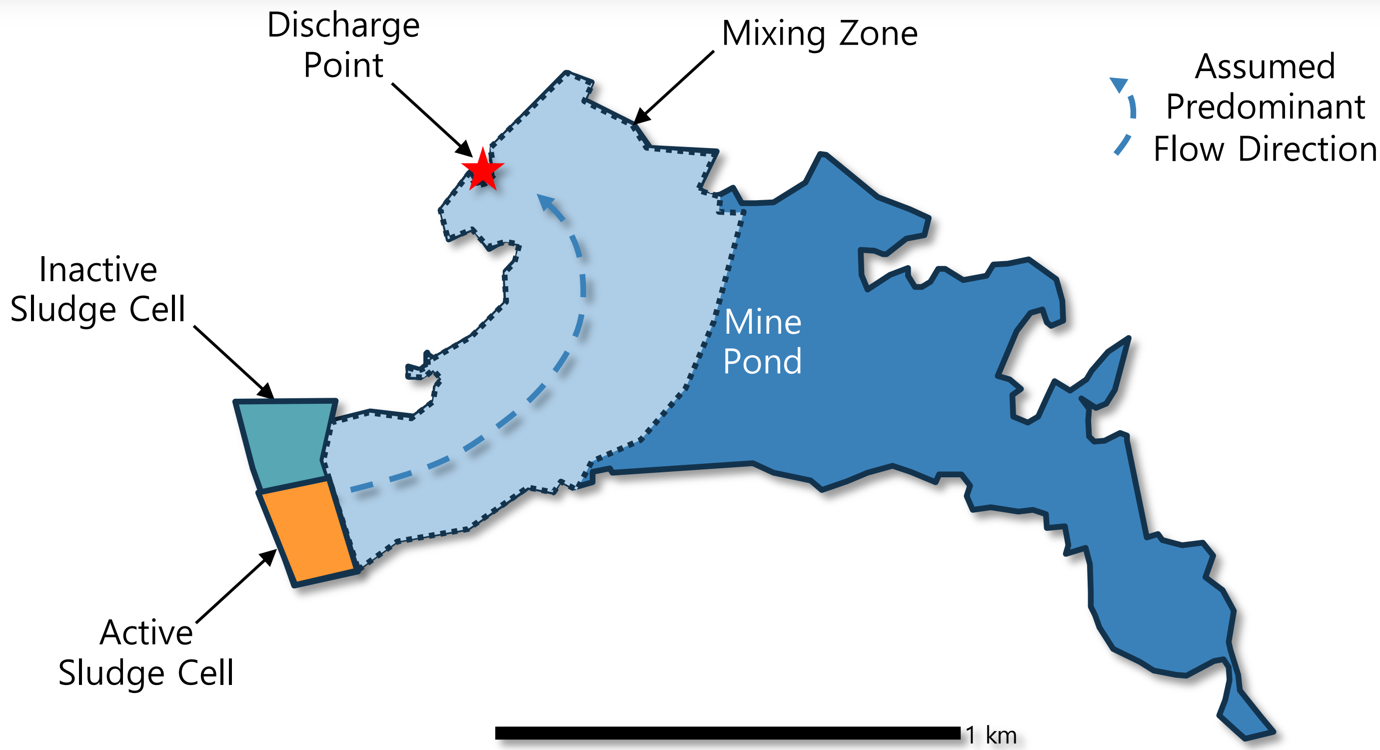
  pH

  Lab vs Field

  Liquid to Solids Ratio

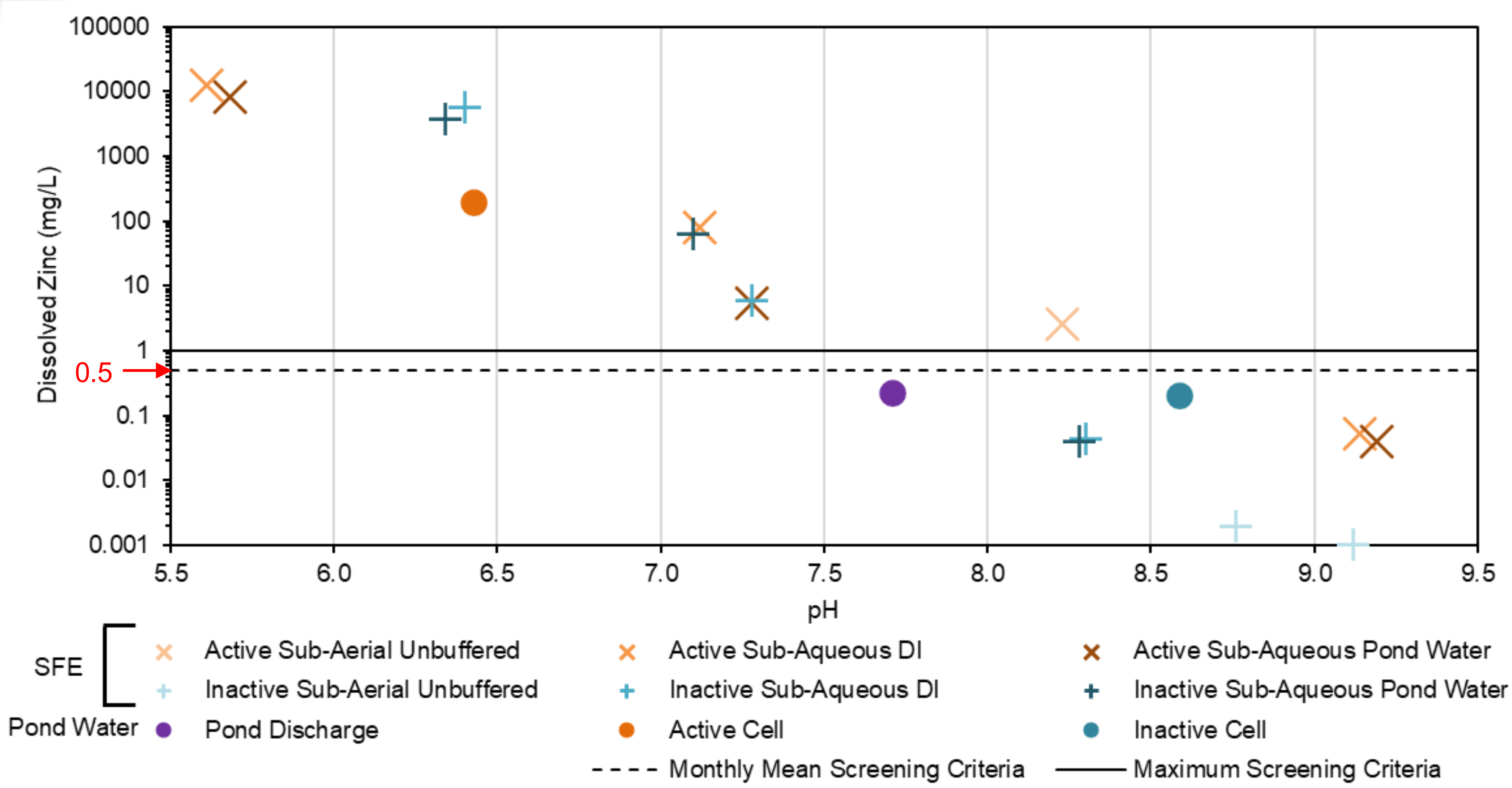
  Shaken vs Undisturbed

- Mixing Volume

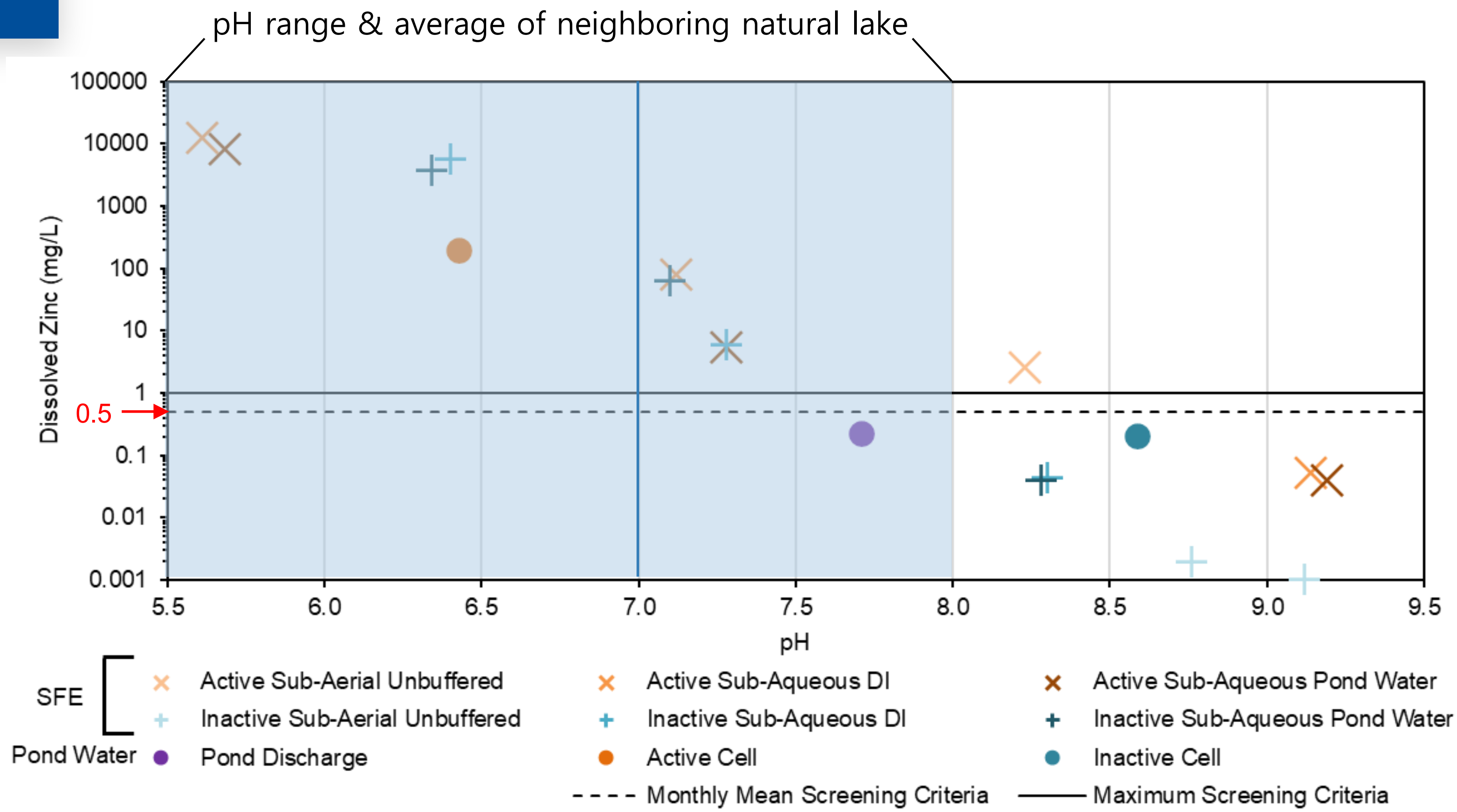


Results

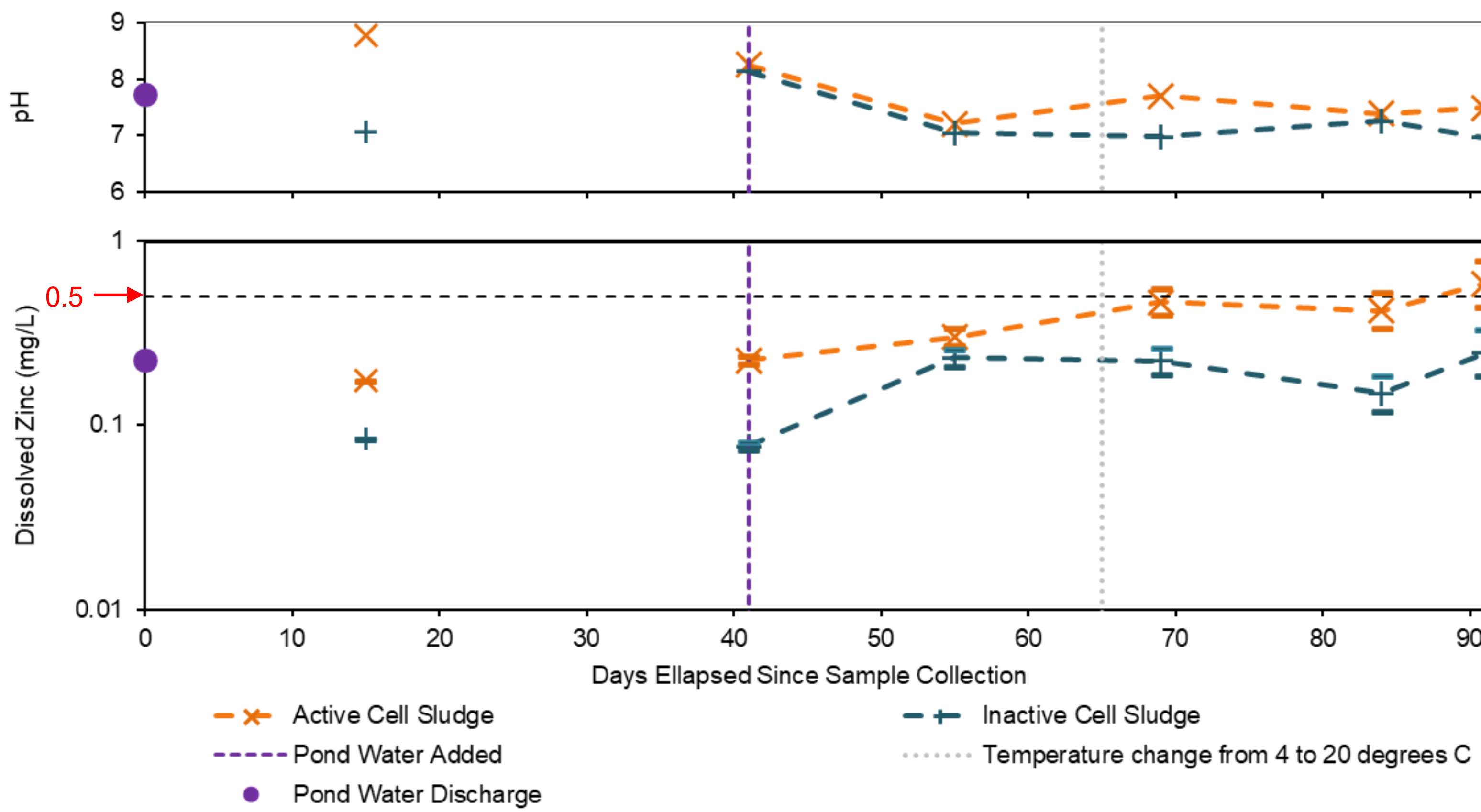
Shake Flask Extractions & Pond Water



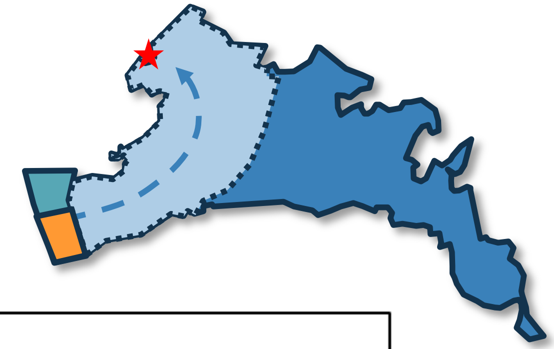
Shake Flask Extractions & Pond Water

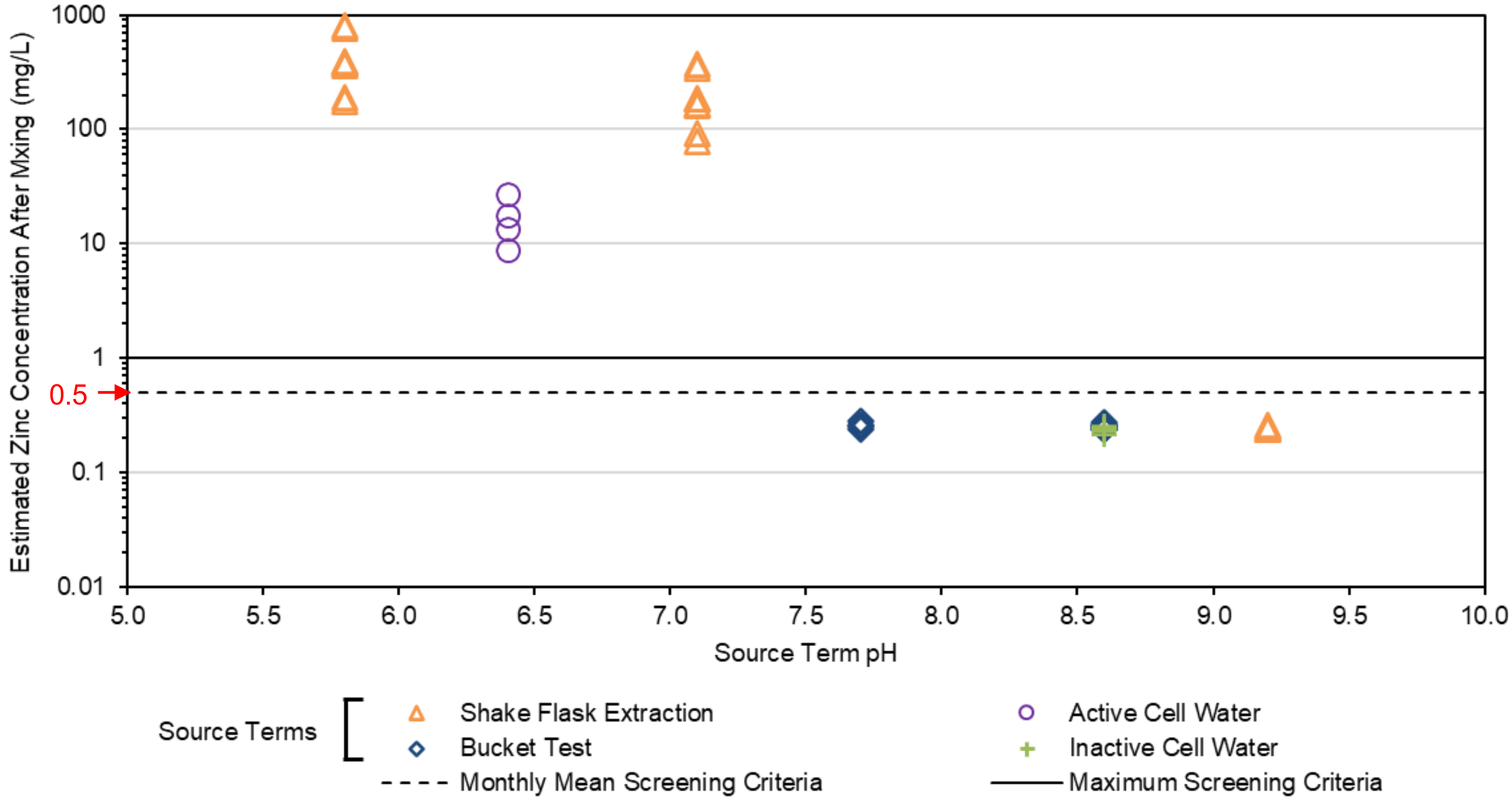


Bucket Tests

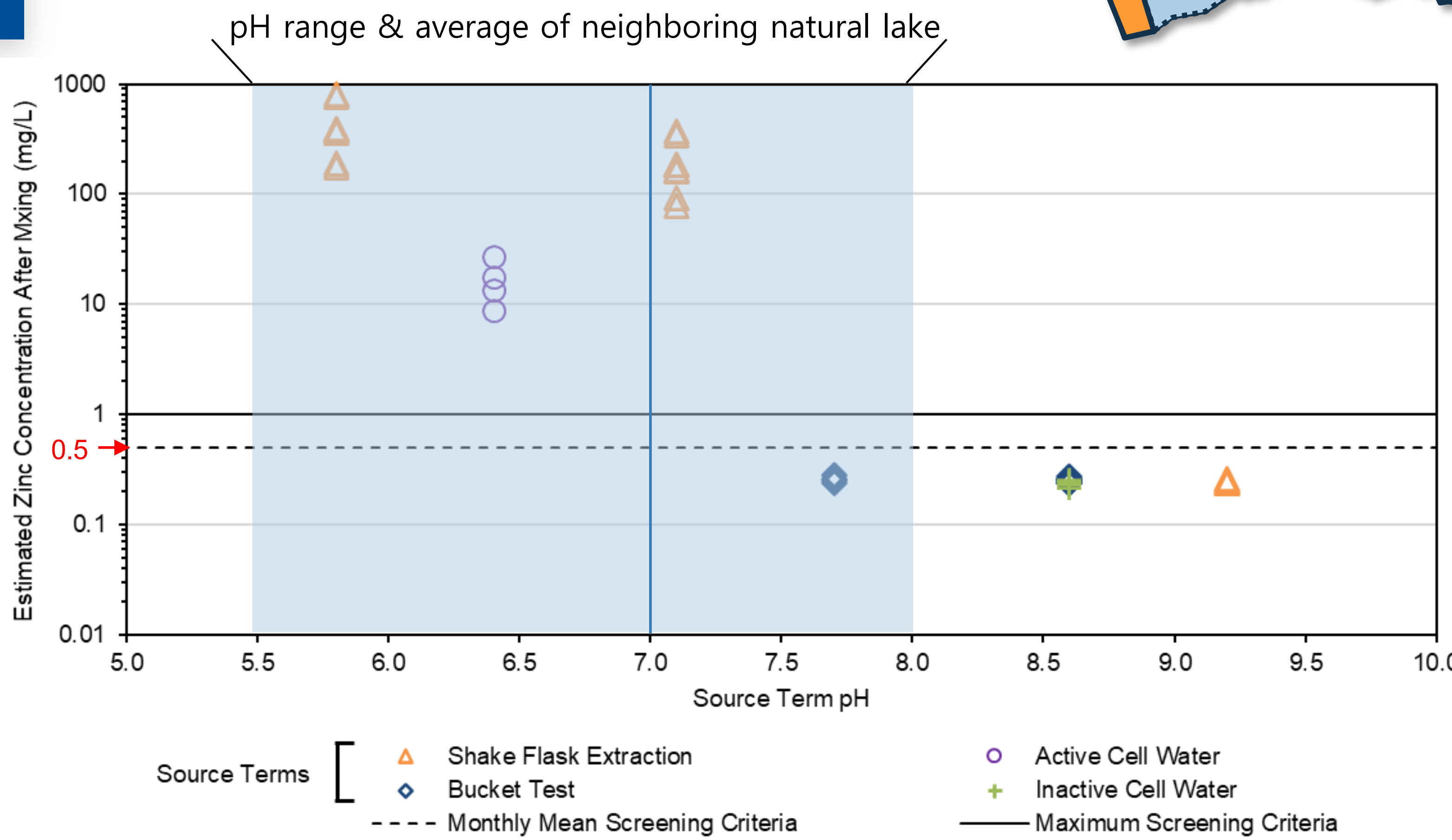


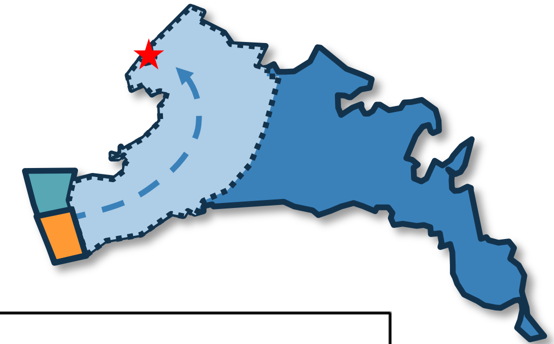
Mixing Model Results





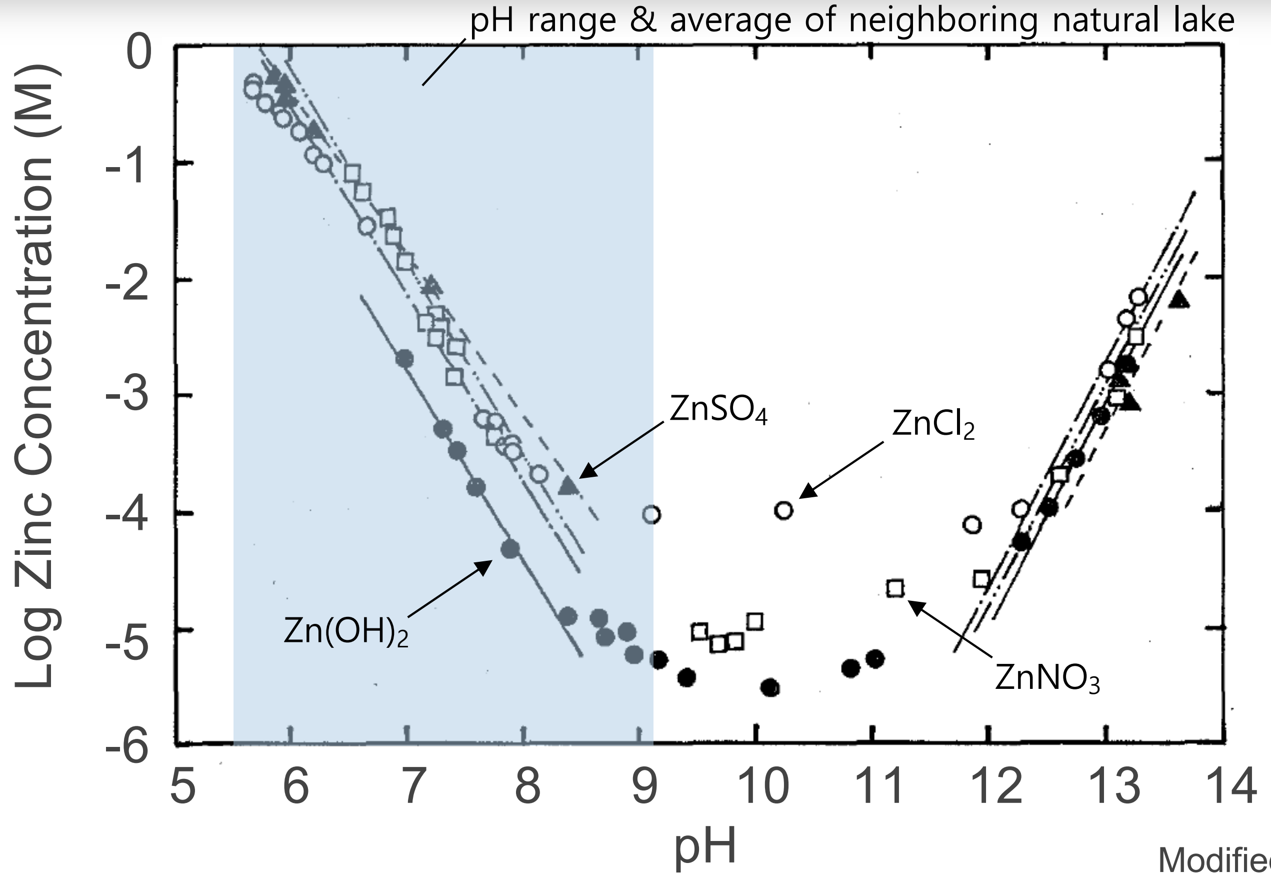
Mixing Model Results





Discussion

Zinc Compound Solubilities

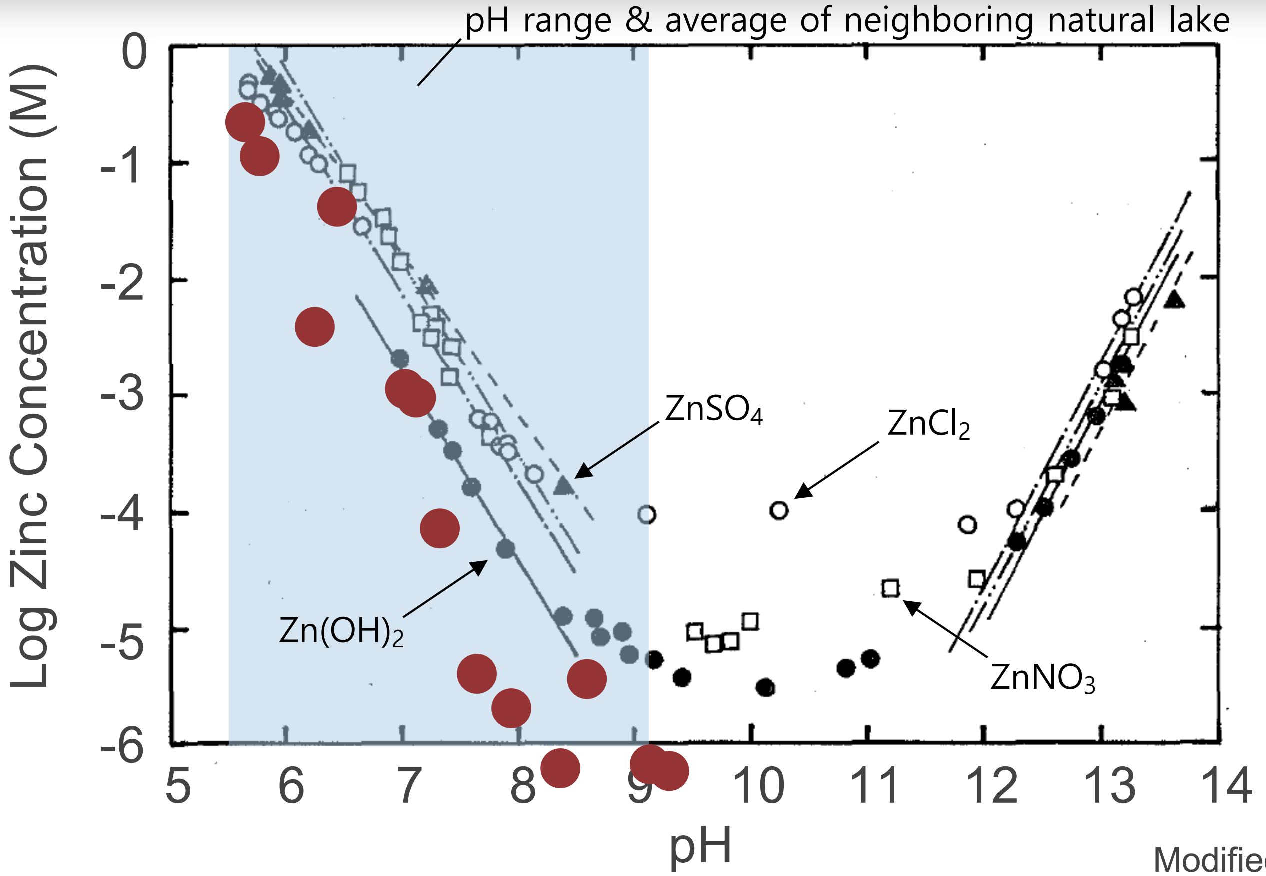


At pH ~6, zinc solubility is approximately 10,000 times greater than at pH 9

Modified from Takada et al. 1978

Zinc Compound Solubilities

Results from this study's leach testing overlain



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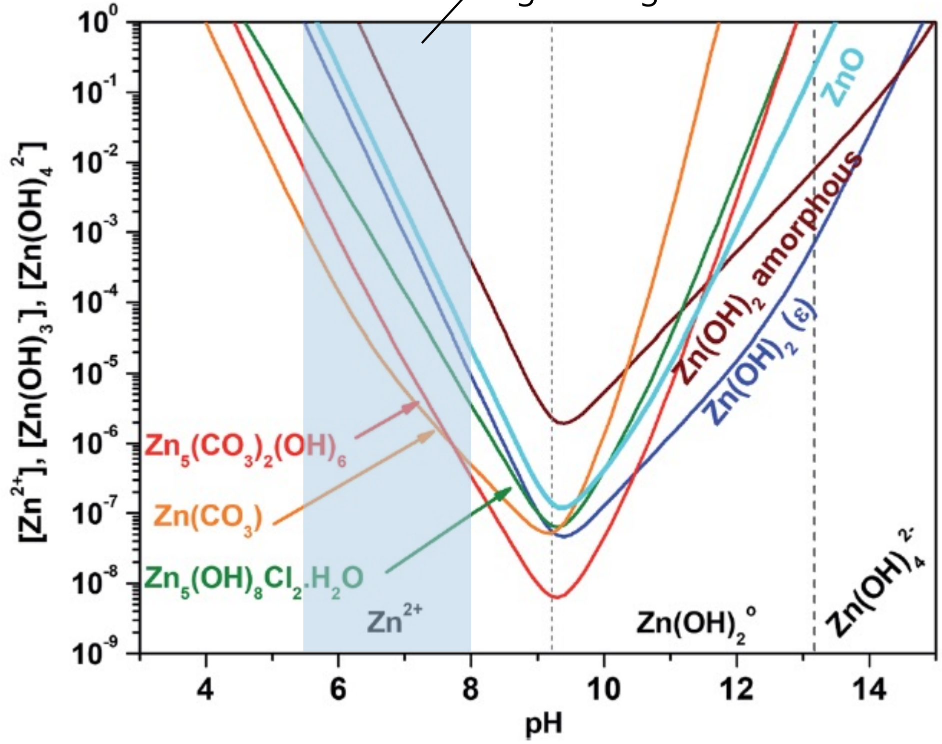
At pH ~6, zinc solubility is approximately 10,000 times greater than at pH 9

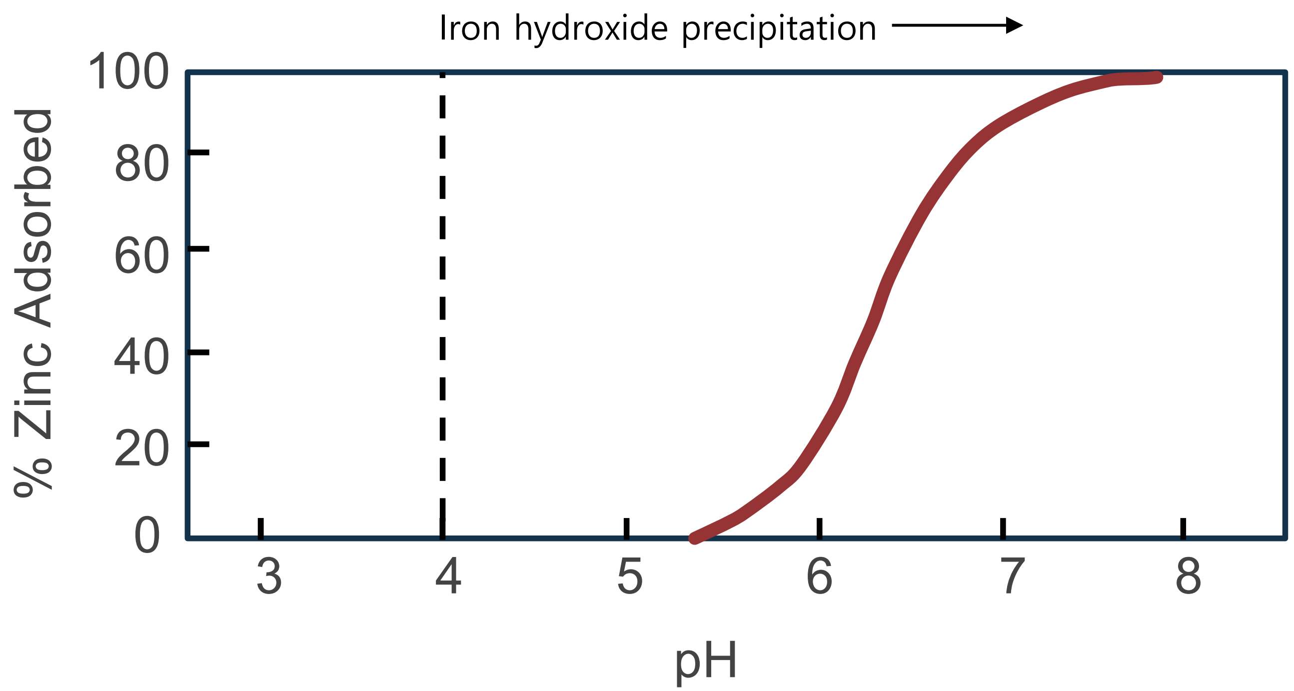
Zinc Carbonate and Hydroxide Solubilities

pH range & average of neighboring natural lake



Modified from McMahon et al. 2019

pH-Dependent Zinc Sorption on Ferrihydrite



Based on Stumm and Morgan 1996

Conclusions

Zinc is increasingly soluble as pH drops from pH >8 to pH 5.5 consistent with

- Zinc compound solubilities
- Zinc pH-based sorption affinity to iron oxyhydroxides

Different analytical techniques – SFE, buckets tests, & field measured sludge cell water – provide some "external" analytical consistency regarding sludge sensitivity to pH

Sub-aqueously stored sludge

- May settle at bottom of pond but remain as a loose floc (not consolidate)
- Potential significant risk to (closure) pond water quality if pH drops below pH 7.0-7.5 (this study) or pH 8 (theory)

QUESTIONS?

Aknowledgements

Brent Usher, Neal Lemoine, Dale Sprague, Alex Fitzpatrick (KCB)

Rob Irwin, Catharine Arnold (SGS Canada Inc.)

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References

McMahon, M.E.; Santucci, R.J.-Jr. and Scully, J.R. 2019. “Advanced chemical stability diagrams to predict the formation of complex zinc compounds in a chloride environment.” Royal Society of Chemistry Advances 9, 19905–19916.

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