Black Butte Copper Project

Subaqueous and Subaerial Weathering Tests of Flotation and Paste Cemented Tailings

Katharine Seipel, Sr. Environmental Scientist
Damon L. Sheumaker, Project Scientist
Lisa Bithell Kirk, PhD, P.Geo., Principal Biogeochemist

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Goals

- Tintina's novel cemented paste tailings proposal and alternatives
- Kinetic Test Methods
  - Subaerial and subaqueous weathering
    - Conventional Flotation Tailings
    - Paste Cemented Tailings
- Results
- Implications

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PROPOSED AND ALTERNATIVE SCENARIOS

Conventional Handling of Tailings

- Tailings Impoundment
  - Flotation tailings
  - Subaqueous

- Dry Stack
  - Dewatered tailings
  - Sub-aerial

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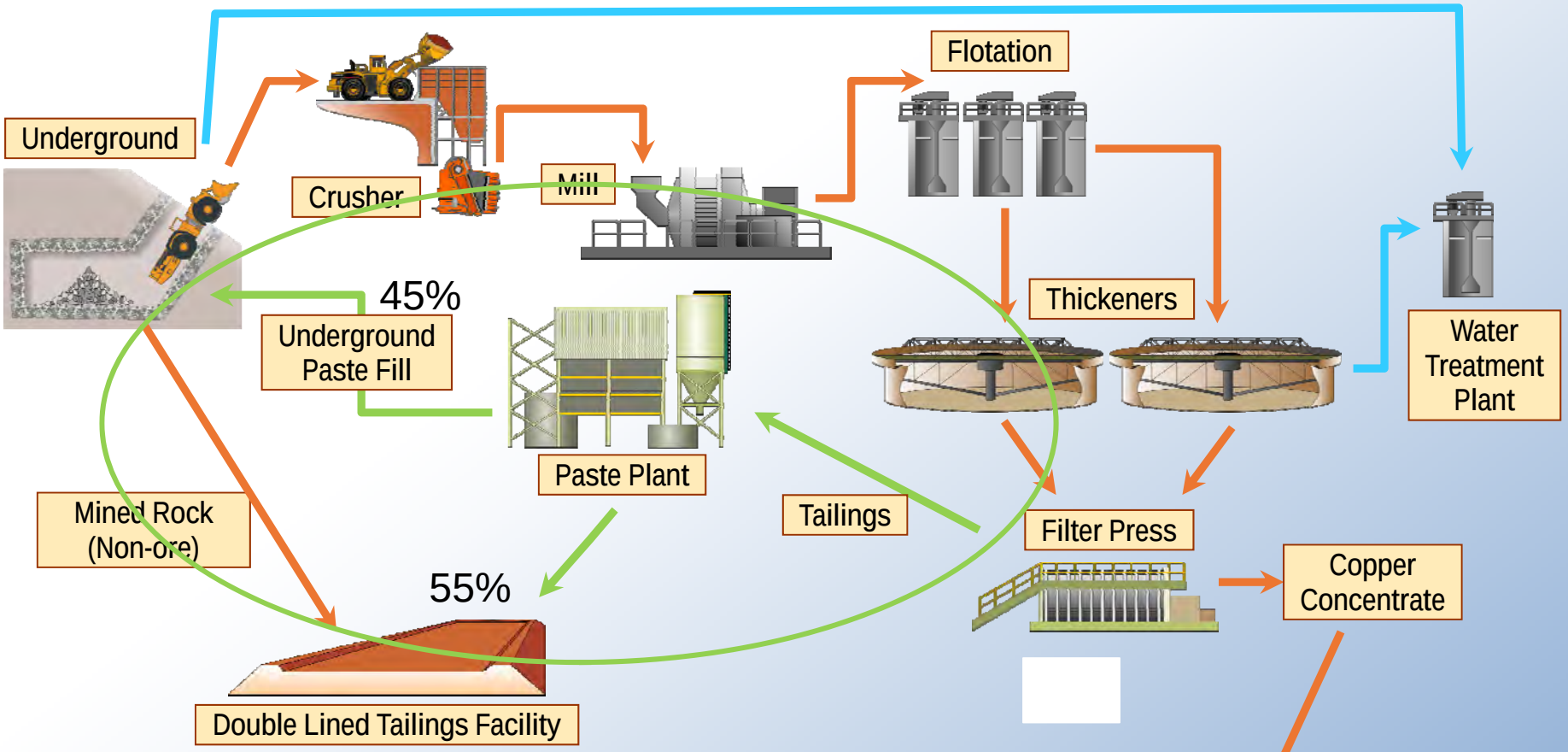
Black Butte – Processing



Material Characteristics

- Tailings
  - 100% Sub 30 micron size
  - Hydraulic conductivity
    - k = 10^{-6} cm/s
  - Sulfidic
    - NNP = -772 T $CaCO_3$/kT
- Paste Cement – 2% and 4%
  - Binder half cement, half slag
  - Hydraulic conductivity
    - k=10^{-8} cm/s
  - Still acidic
    - NNP 2% = -749 T $CaCO_3$/kT
    - NNP 4% = -738 T $CaCO_3$/kT

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Cemented Paste Tailings Backfill

- Continuous Backfilling of Stopes
  - 4% binder required for cut-and-fill method
  - Limits surface area for oxidation
    - Reduced sub-aerial exposure underground
      - $k = 10^{-8}$ cm/s
  - Submerged in groundwater at closure

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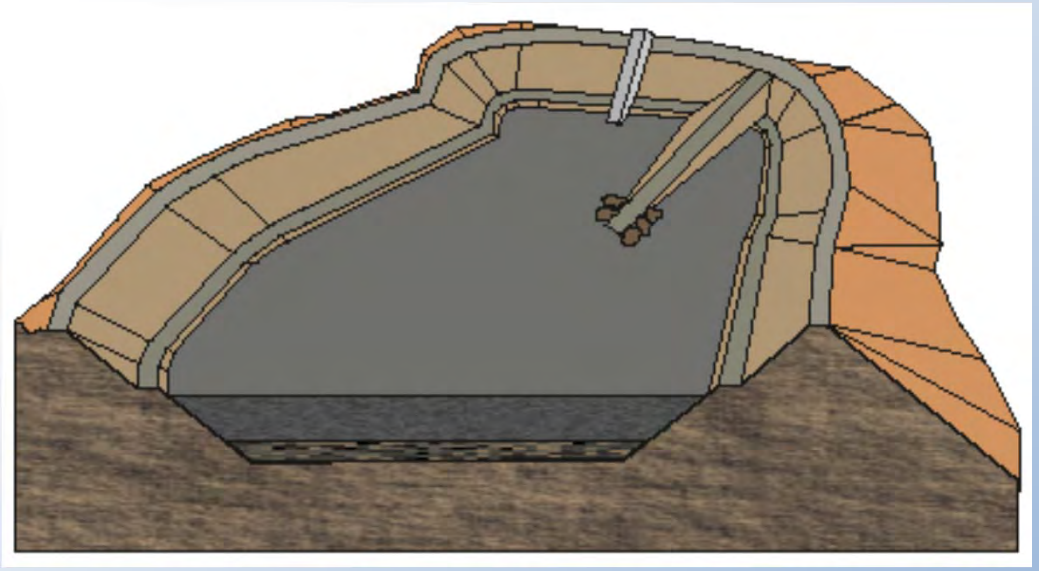
Surface Cemented Tailings Facility

- Paste cemented tailings with 0.5–2% binder
- Continuous additions of paste tailings as thin lifts
  - Typically 1 week, max 8 weeks
  - Surface weathers until next lift is applied
- Rock drain, with co-disposal of waste rock near ramp, collects seepage for treatment
- Option to provide a minimal cap by increasing binder during interim closure and at end of mine life
- Continuously drained facility readily capped with synthetic cover at closure



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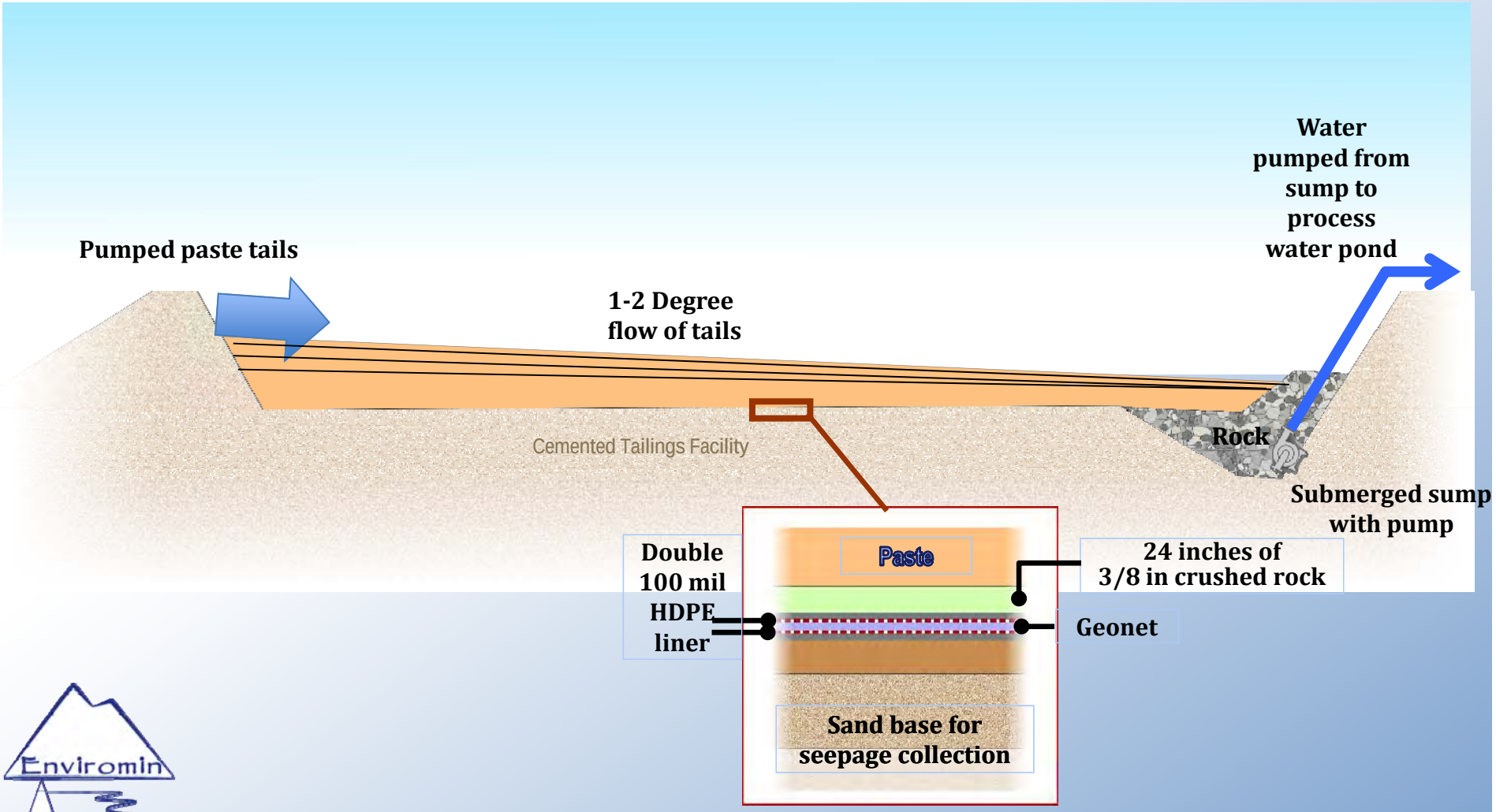
Cross section of Cemented Tailings Facility- Black Butte Copper Project



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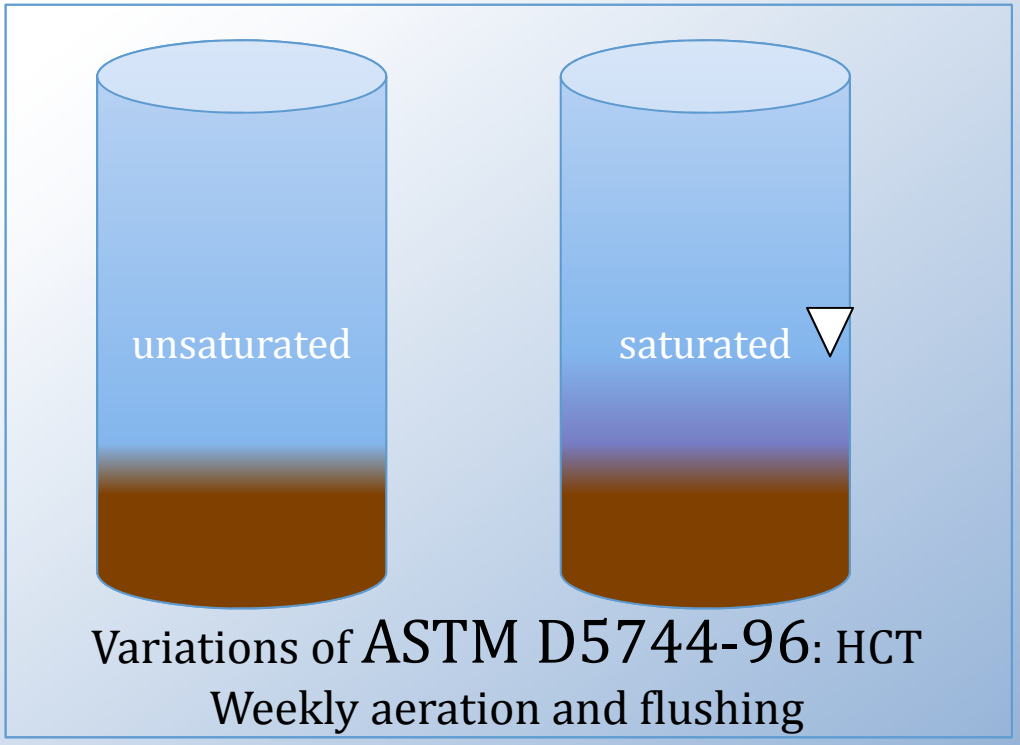
Tailings Disposition	Method	Conditions
Dry Stack	Conventional HCT (ASTM D5744)	Cyclic wetting and drying of tailings-oxic
Subaqueous Tailings Pond	Saturated HCT (ASTM D5744)	Saturated tailings-suboxic



Variations of ASTM D5744-96: HCT
Weekly aeration and flushing

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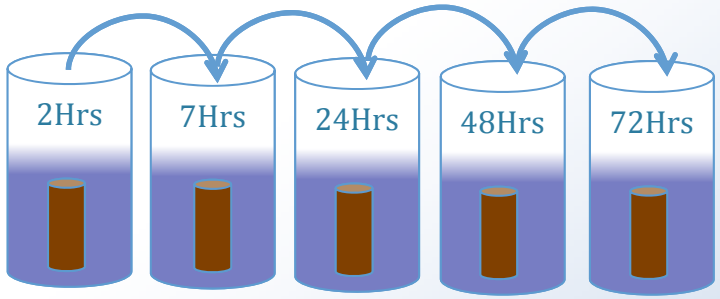
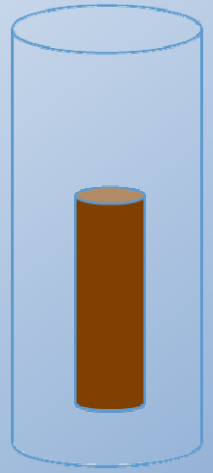
Tailings Disposition	Method	Conditions
Cemented paste-backfilled stopes 4% binders	Diffusion test ASTM 1308	Saturated, sub-oxic conditions
Cemented Tailings Facility 4% binders	Paste cylinder in HCT ASTM D5744	Cyclic wetting and drying of paste tailings
Cemented Tailings Facility 0.5–2% binders	Paste cylinder in HCT ASTM D5744	Cyclic wetting and drying of paste tailings



...etc...

ASTM C1308: Diffusion testing

Repeats on 24 hr cycle (after first 24 period) for a total of 11 days.



ASTM D5744
Standard HCT

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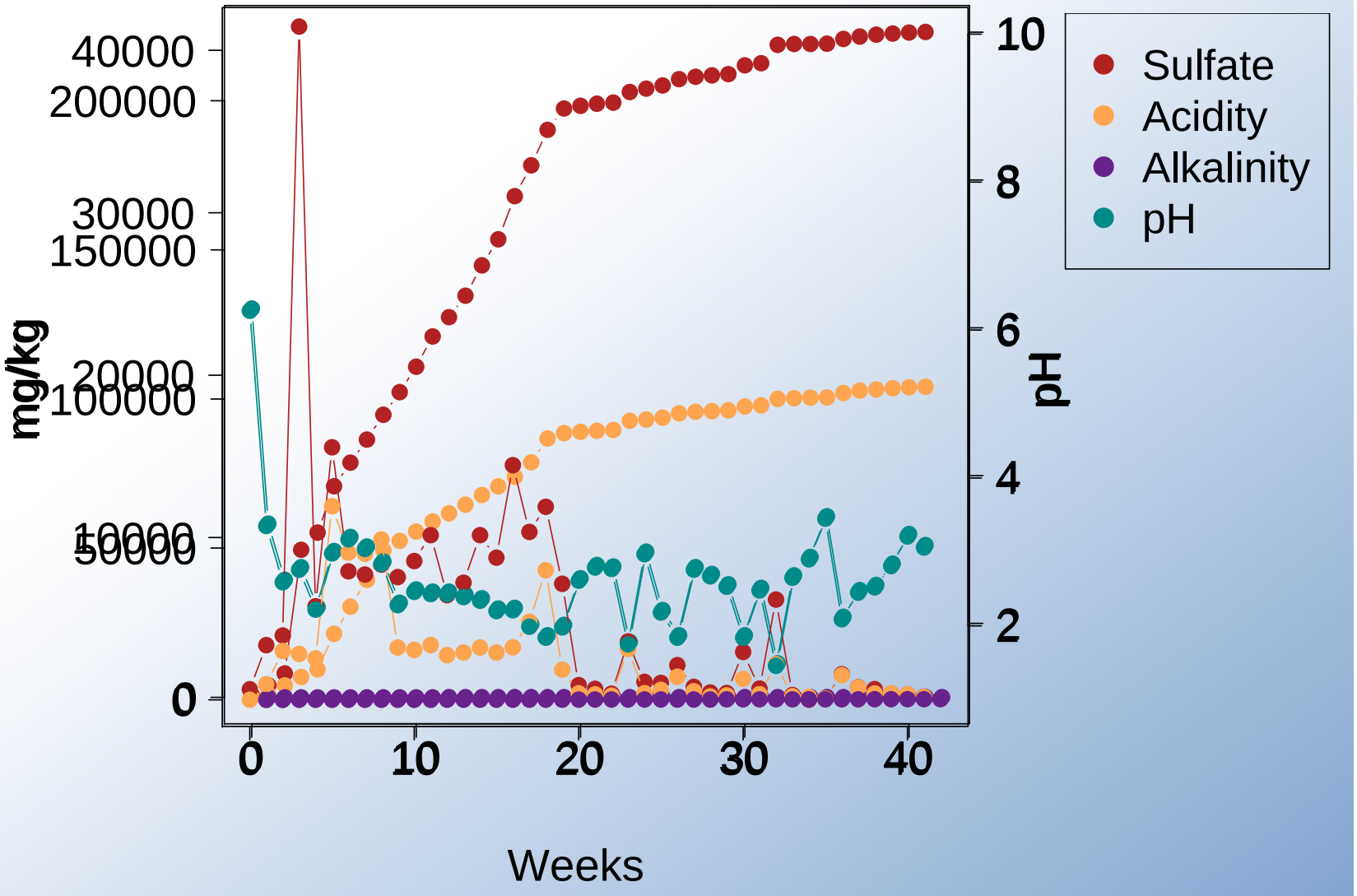
Details of Geochemical Tests

CONVENTIONAL HCT OF NON-AMENDED TAILINGS

Conventional HCT of Tailings



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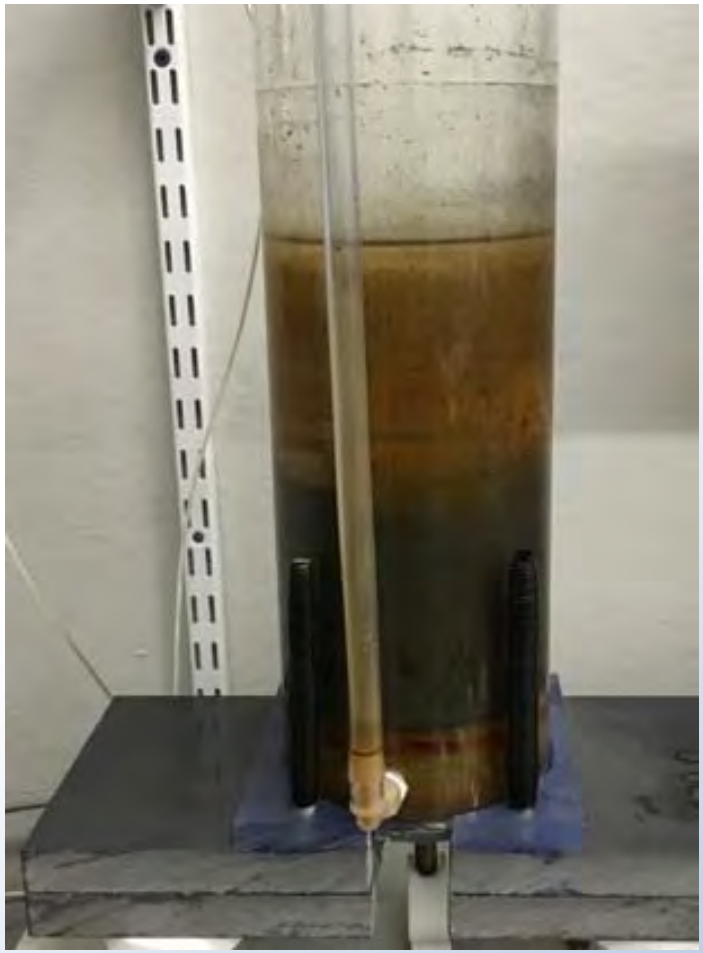
Details of Geochemical Tests

SATURATED HCT OF RAW TAILINGS

Saturated HCT of Raw Tailings



- Conventional HCT test of flotation tailings (non-amended) under subaqueous conditions

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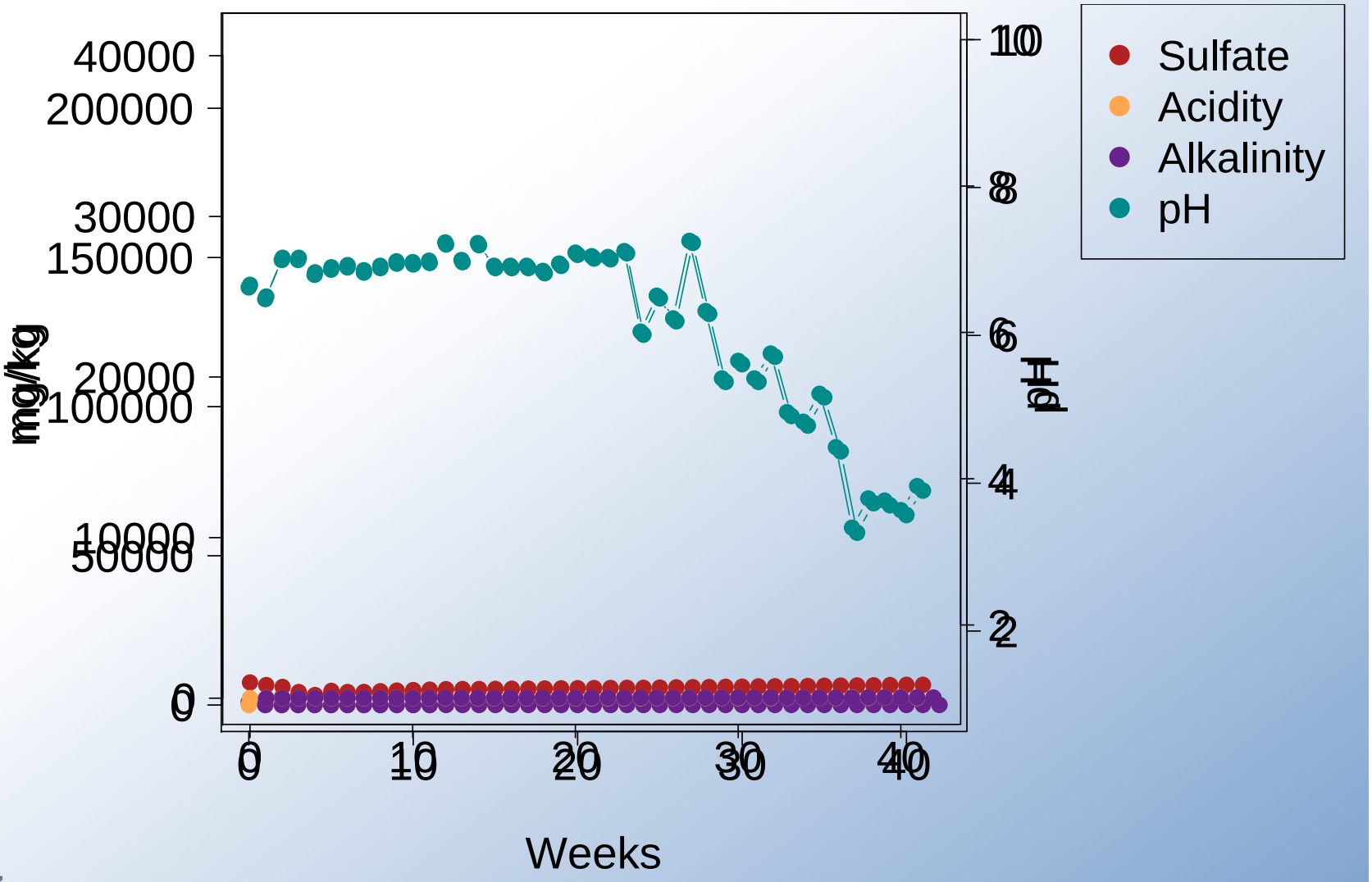
Saturated HCT of Raw Tailings



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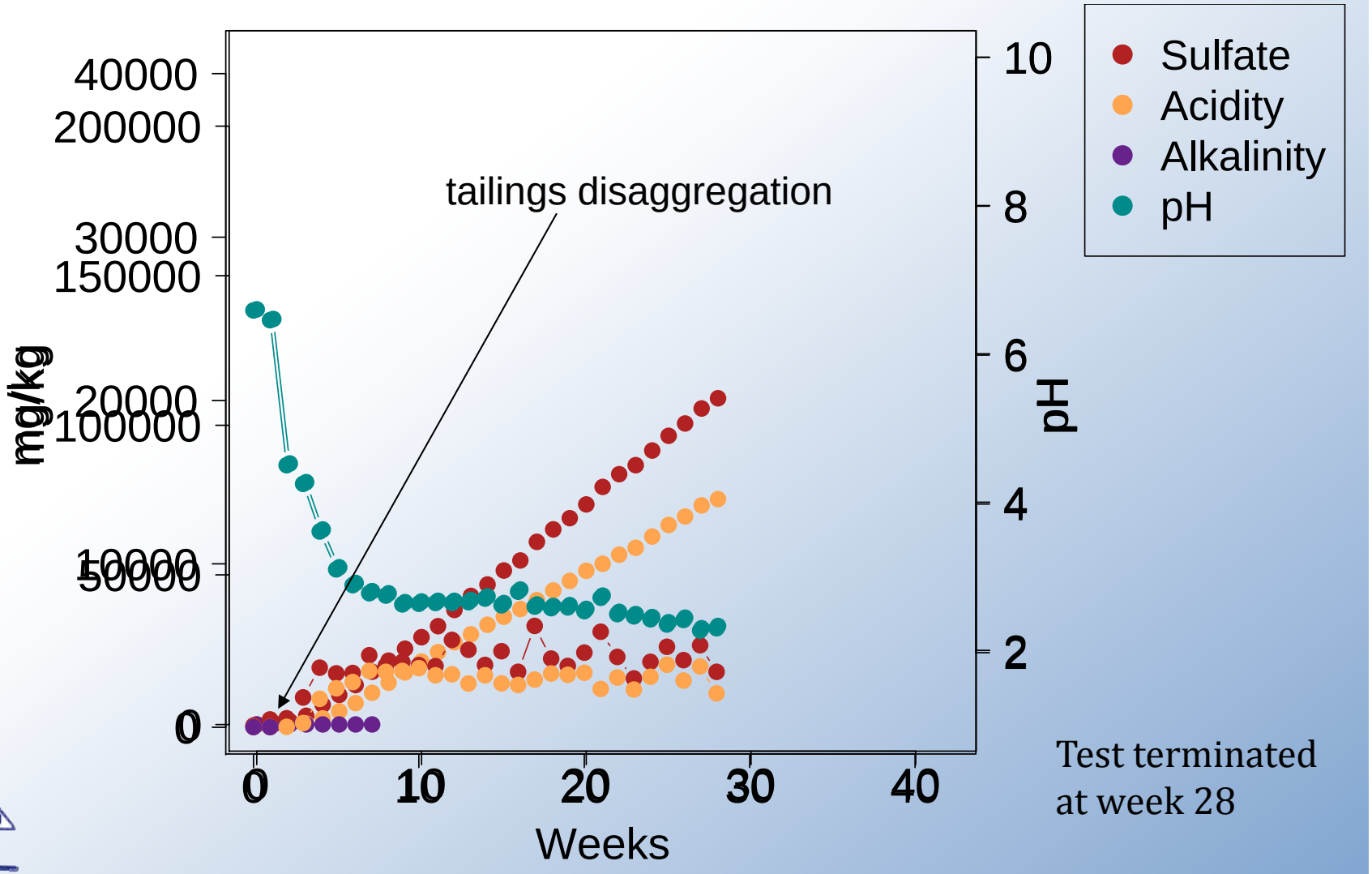
Details of Geochemical Tests

HCT OF PASTE TAILINGS

HCT of Paste Tailings: 2% Binders



Test terminated at week 28

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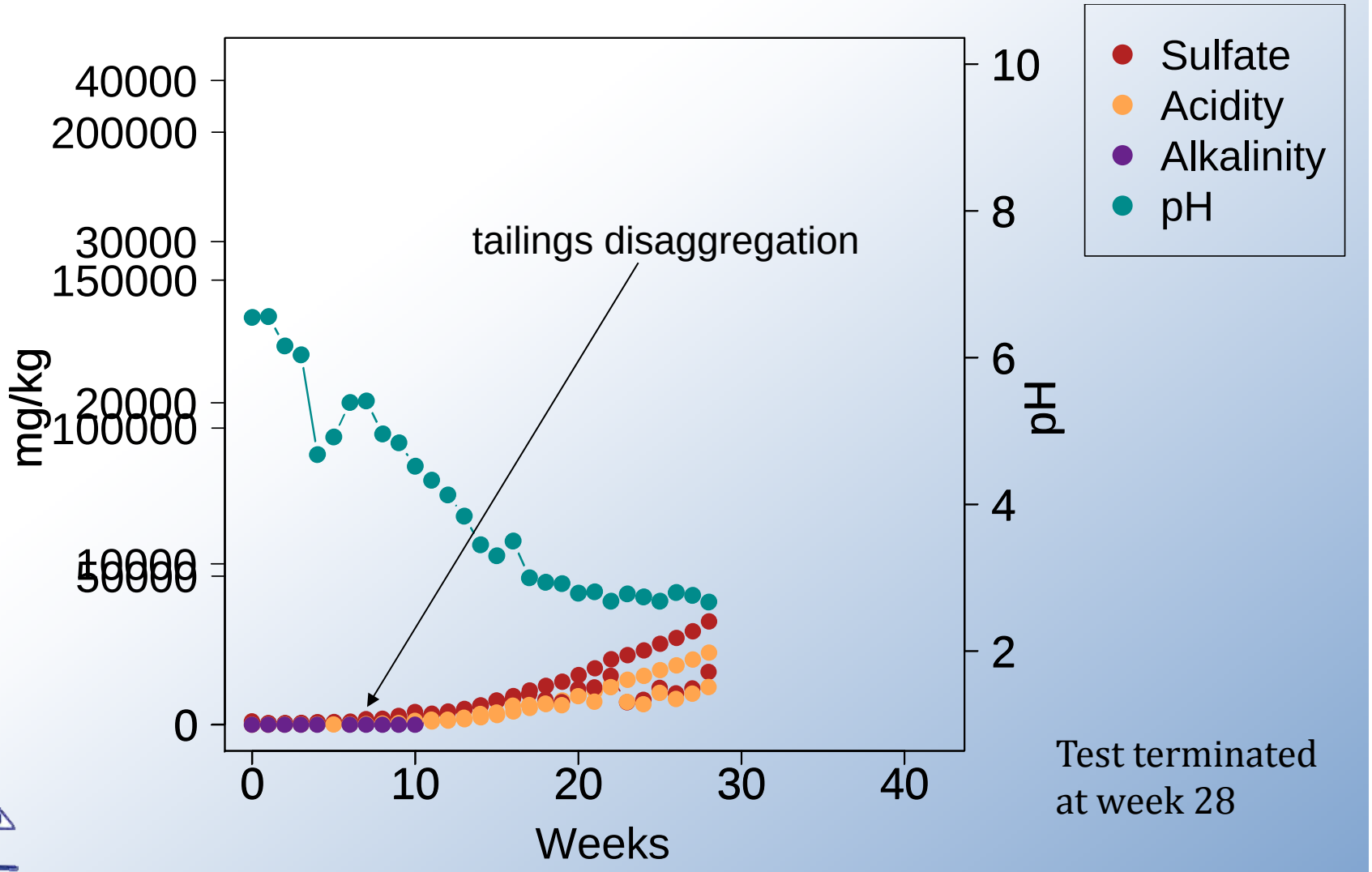
HCT of Paste Tailings: 4% Binders



Test terminated at week 28

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Details of Geochemical Tests

DIFFUSION TEST OF PASTE TAILINGS

Diffusion Test of Paste Tailings

- 11 day test, submerging cylinders in series of water baths (ASTM 1308)
- Subaqueous testing
  - limited oxygen exposure
- To predict capacity of paste backfilled into stopes to leach metals into groundwater

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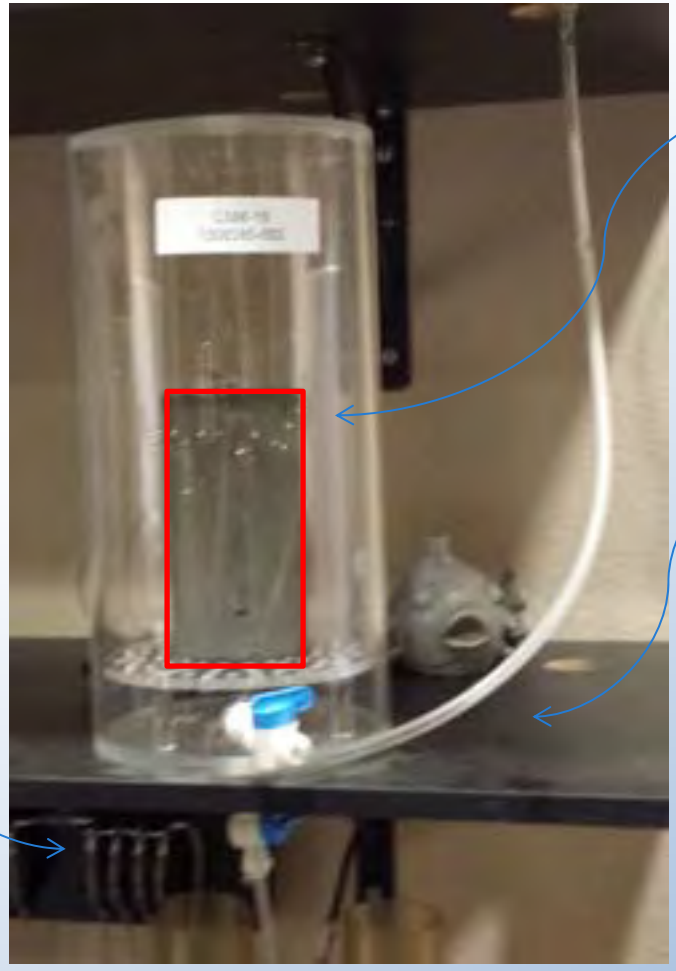
Diffusion Test Apparatus



Cylinder

Water outlet

Water drained at specified intervals

Water inlet:

Water Added after draining of previous pore volume

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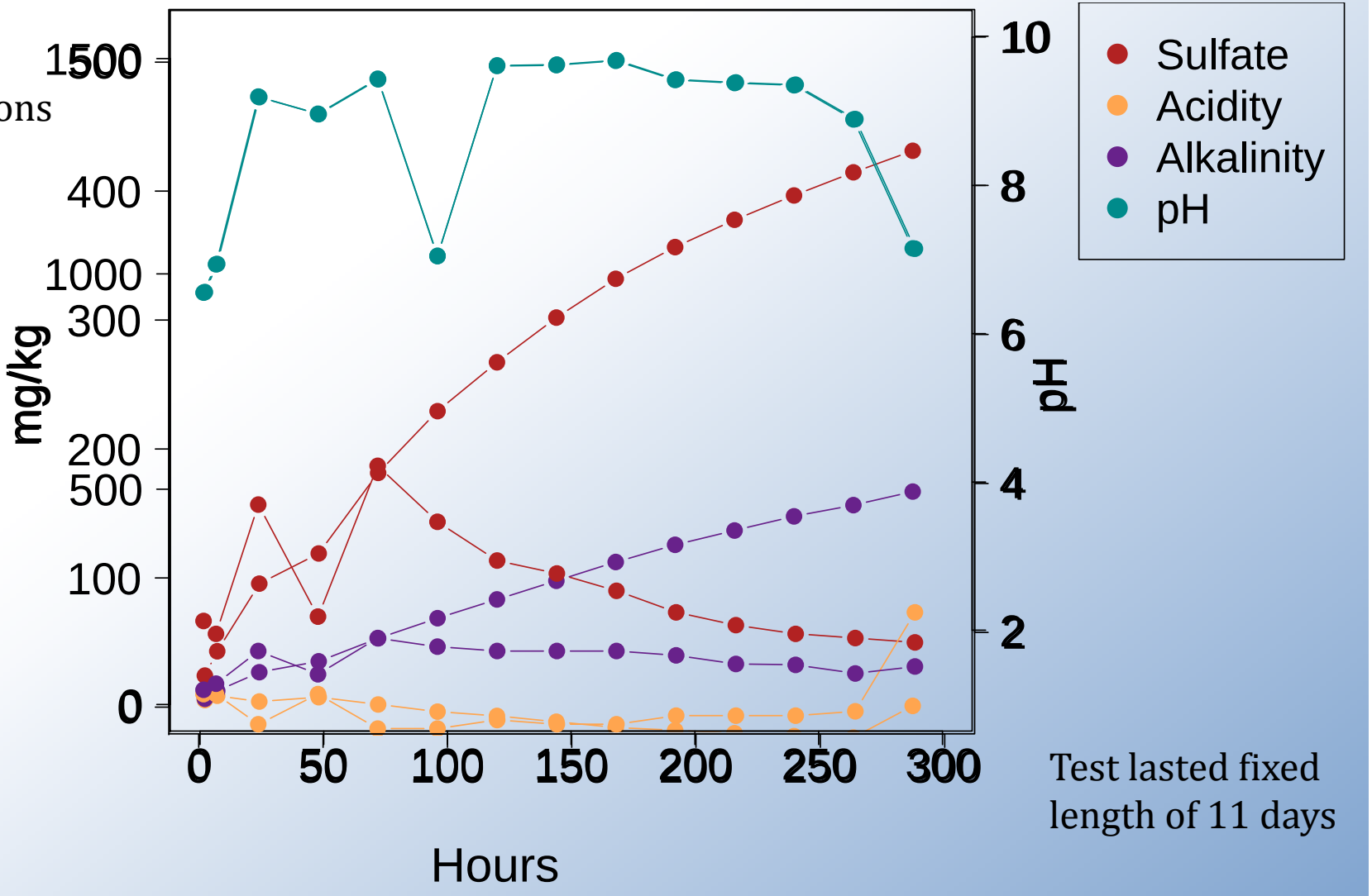
Diffusion Test of 4% Paste Tailings

Note, lower concentrations on Y-axis



Test lasted fixed length of 11 days

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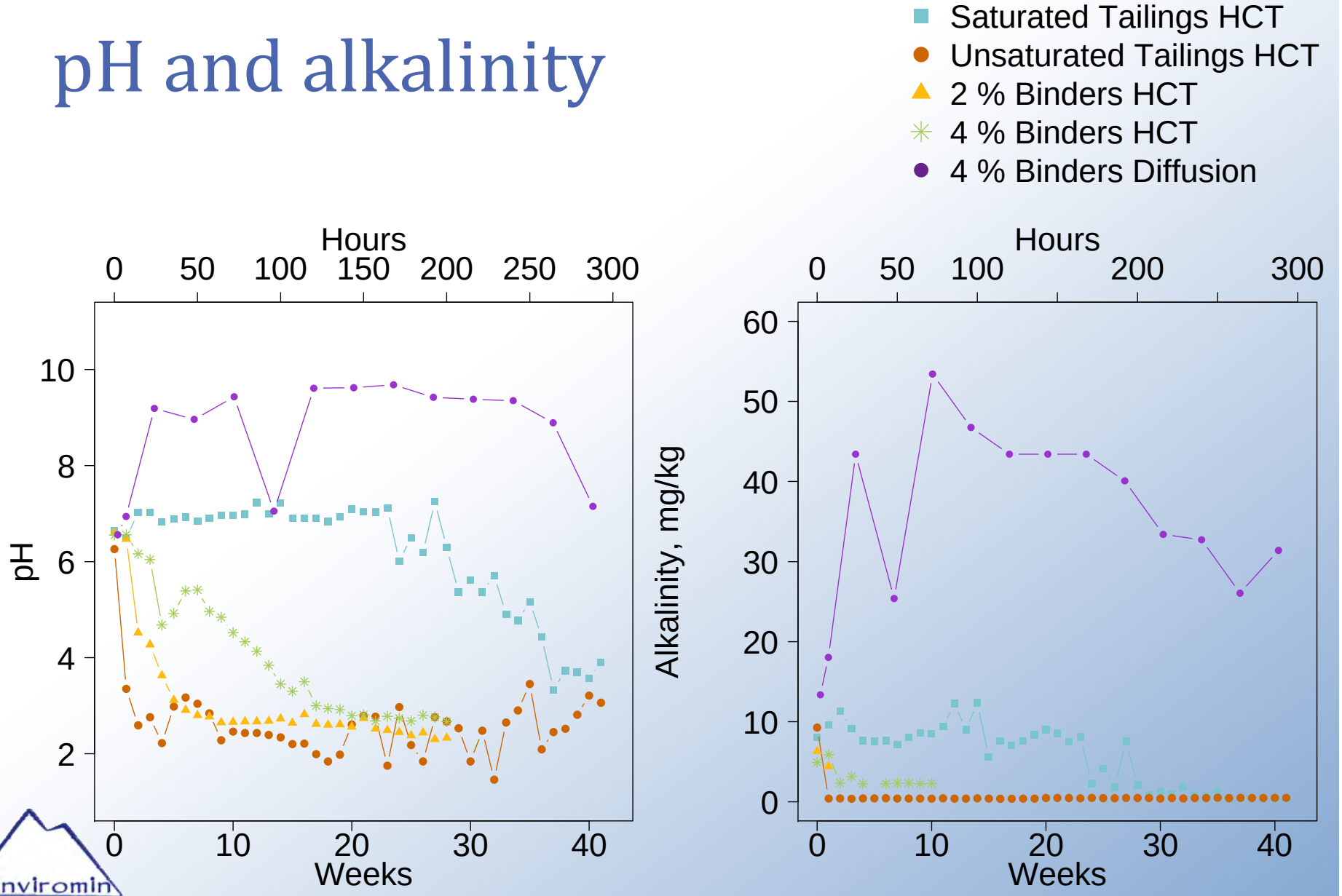
Details of Geochemical Tests

COMPARISON OF DATA

pH and alkalinity



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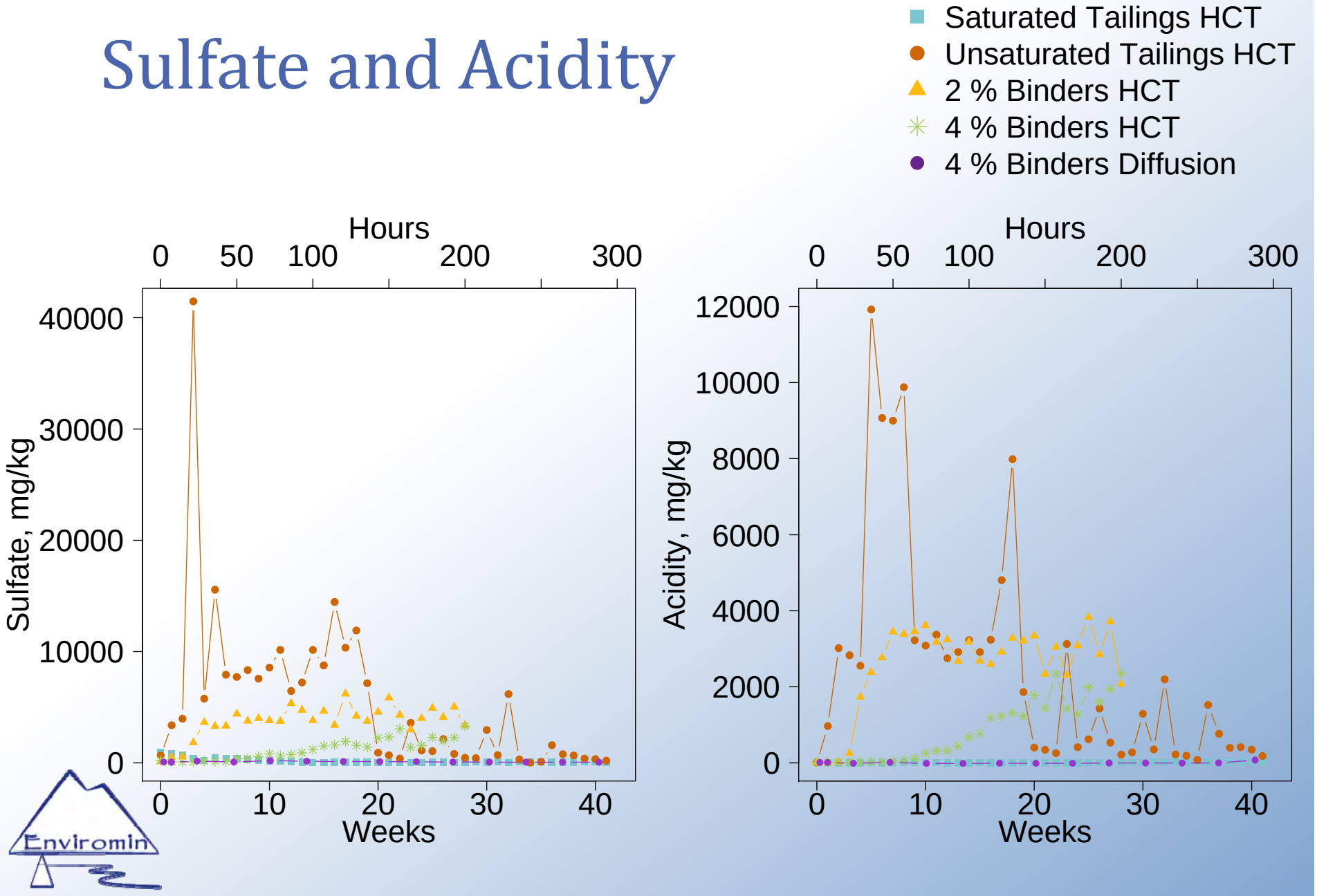
Sulfate and Acidity



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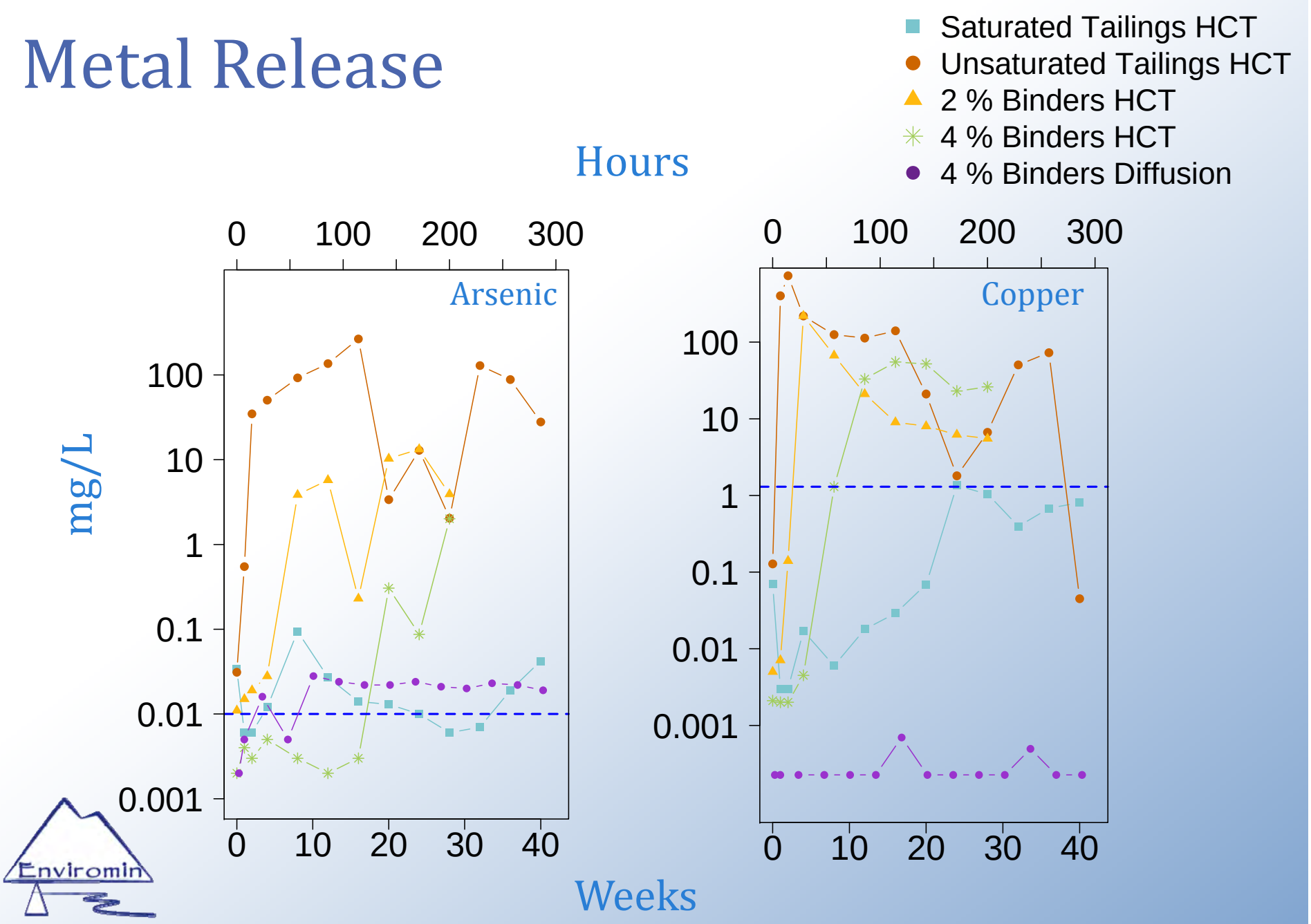
Metal Release



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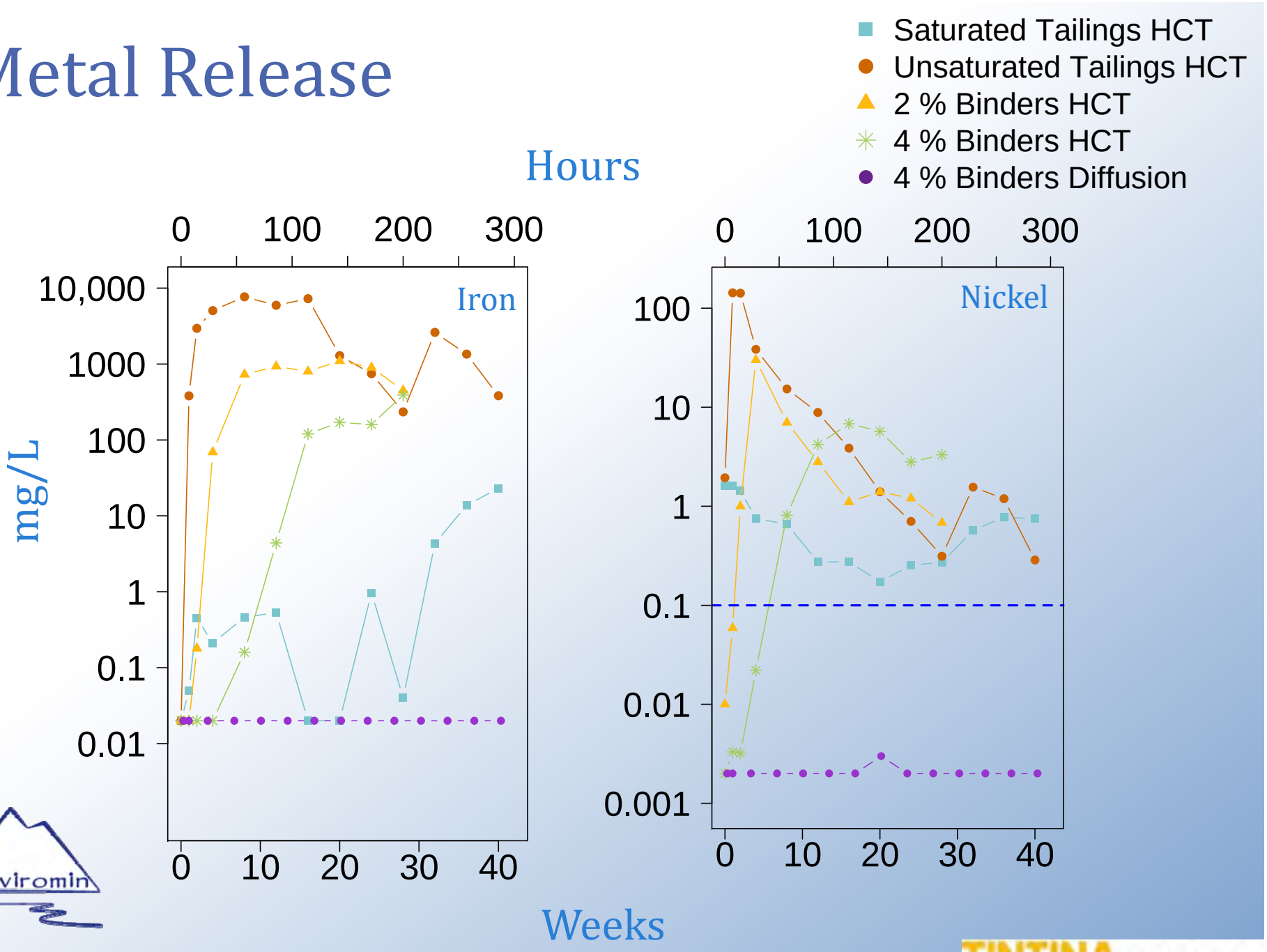
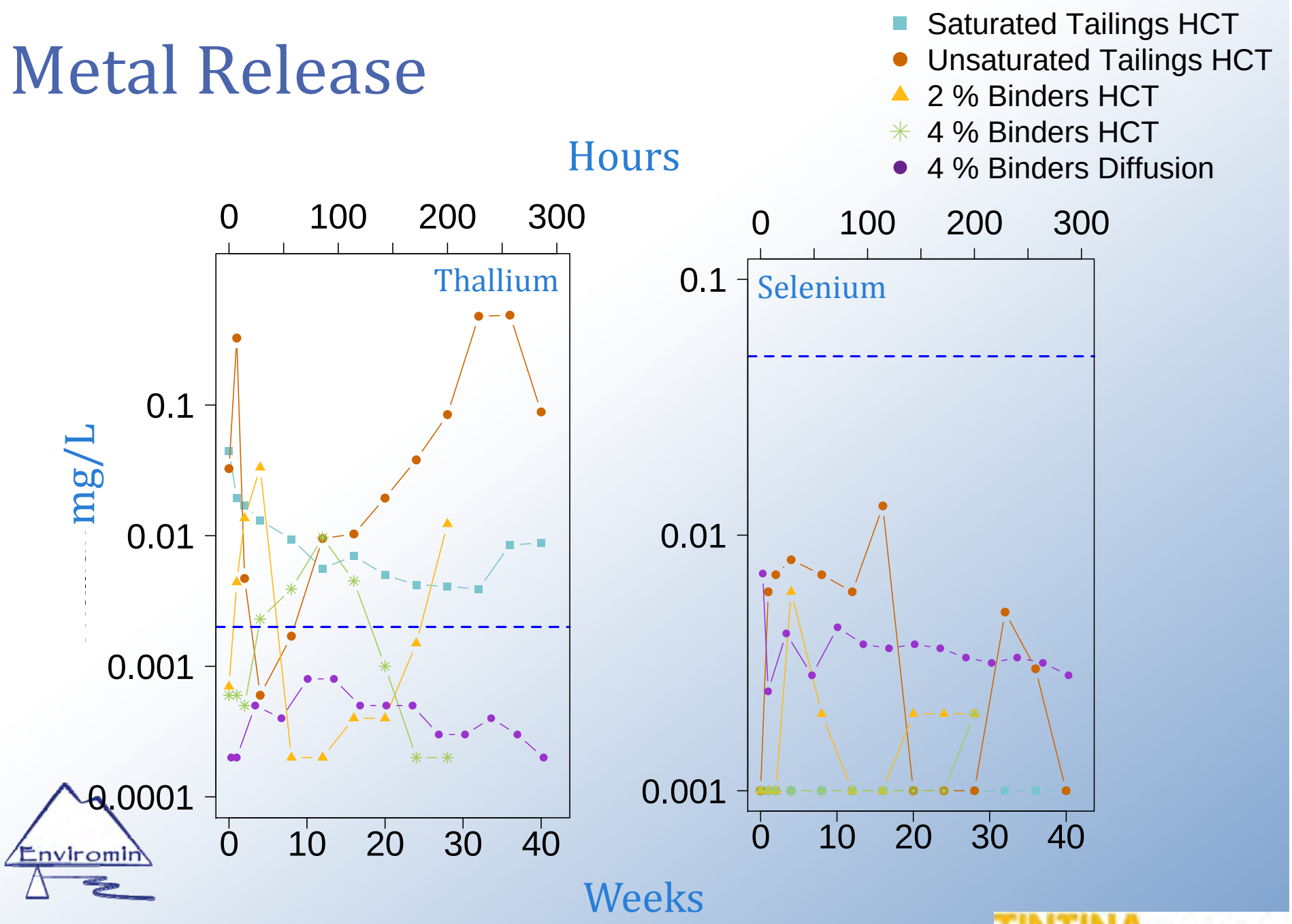
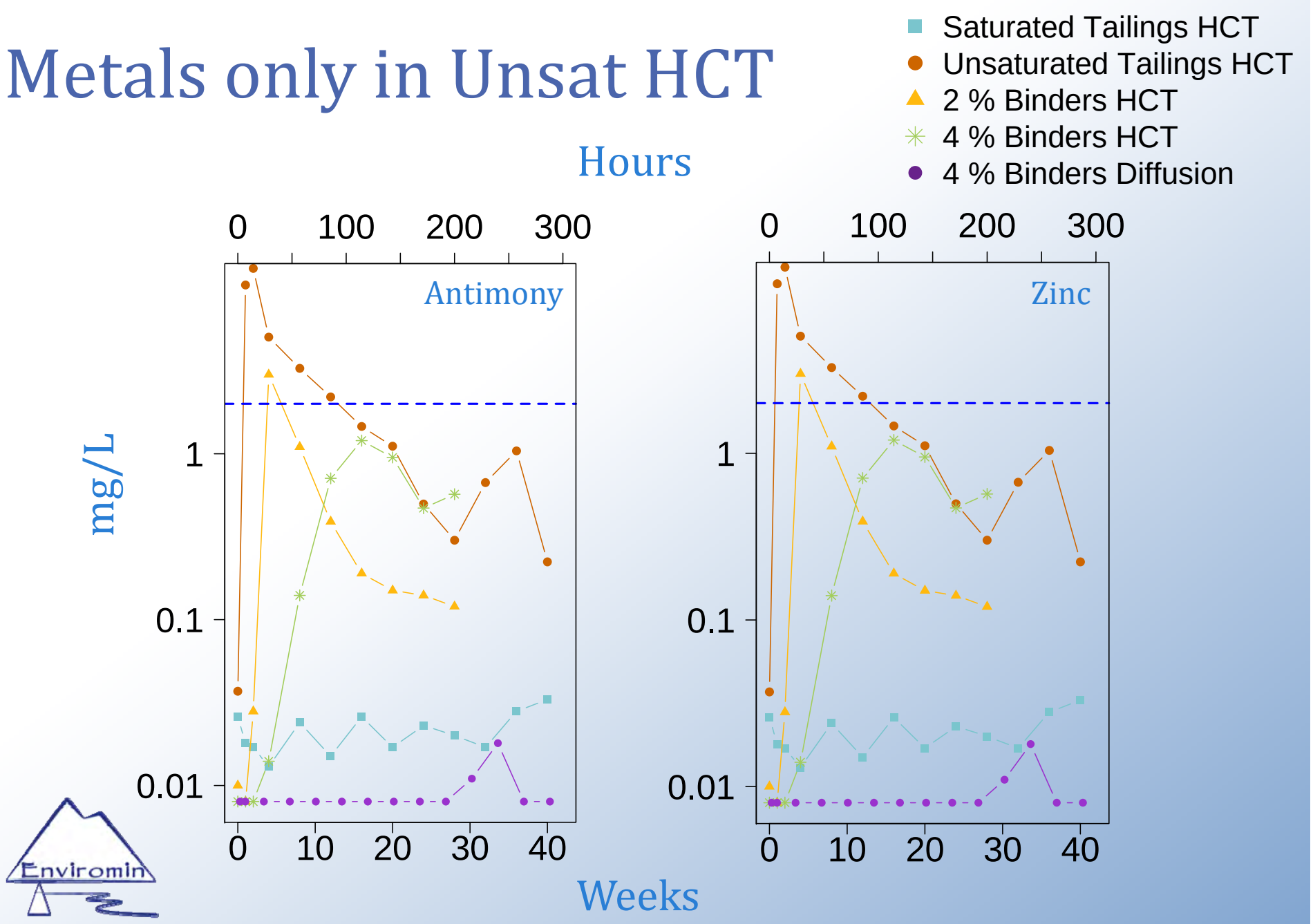
Metal Release



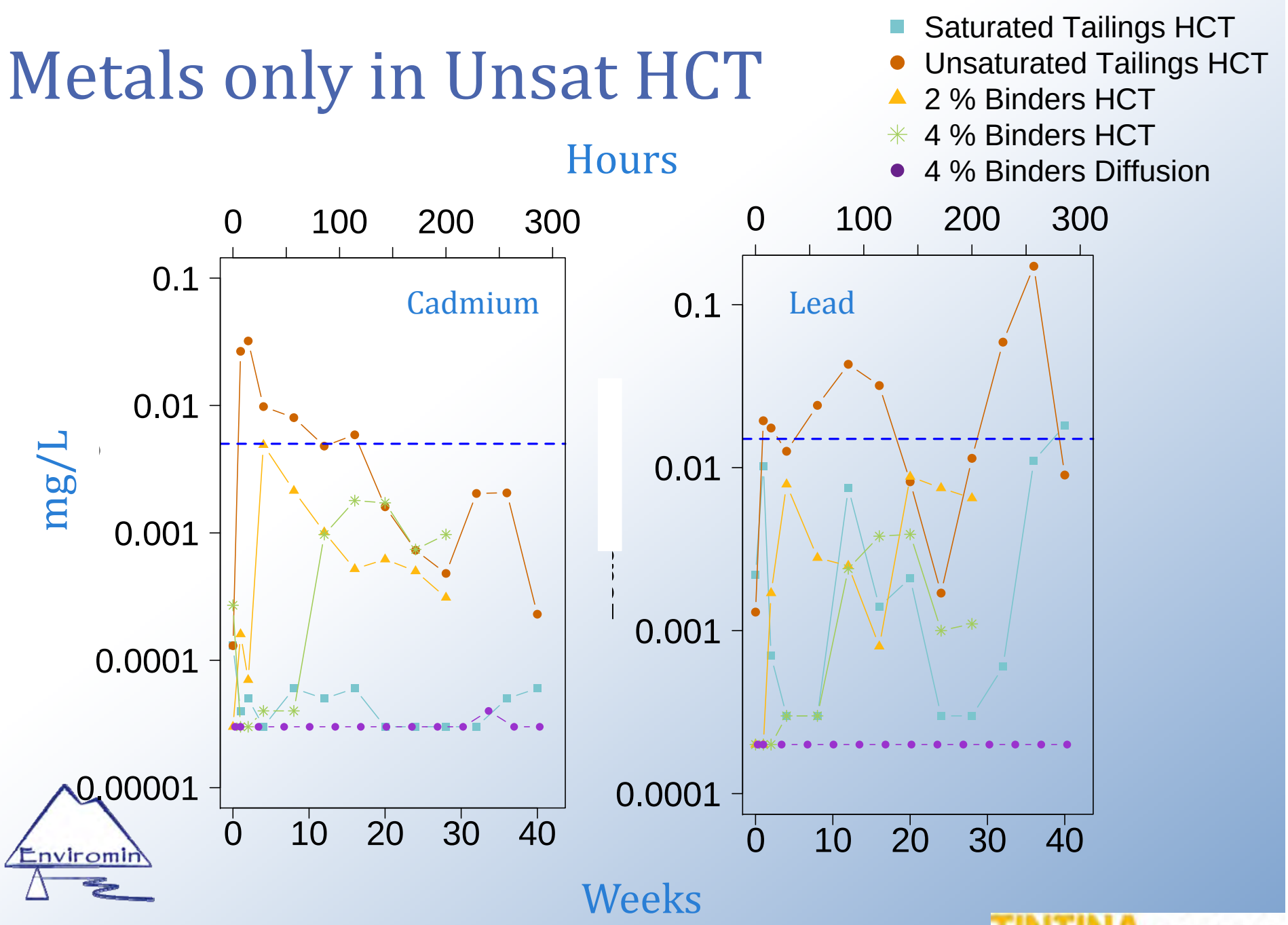
Metal Release



Metals only in Unsat HCT



Metals only in Unsat HCT



Acidity Varied

- Tintina BBC Project tailings are acidic
- Subaerial weathering produces significant acidity, sulfate, and metals
- Subaqueous placement worked well in reducing acidity, sulfate and metals, but ultimately depleted alkalinity
- Subaerially weathered paste tailings reactivity is
  - Significantly lower than non-amended tailings.
  - Surface area directly influences lag time and solute release rate.
  - Initial oxidation lag, sulfate and acidity release are low
    - up to 4 weeks in 2% and 8 weeks in 4%
- Subaqueous leaching of paste tailings - very low rates of acidity, sulfate or metals production.

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Metals

- Metal release in all treatments, to varying degrees,
  - greatest for unsaturated non-amended tails
  - least for the saturated cemented paste tailings.
- Several metals were not detected above GW standards, ie: Se.
- Of the detected metals, As, Cu, Fe, Ni, and Tl were elevated in HCT leac concentrations decreased with increasing paste amendment.
    - 4% < 2% < 0% binder
- The metals Sb, Cd, Pb and Zn were only detected above Montana DEQ groundwater standards in the unsaturated test of conventional tailings

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Implications

- Subaqueous placement of conventional flotation tailings reduces oxidation more than subaerial placement
- Cemented paste reduces tailings reactivity when weathered subaerially (HCT), but this affect diminishes with disaggregation
- Subaqueous placement of cemented paste tailings greatly reduces sulfide oxidation and metal release
  - Due to low transmissivity (k= 10^{-8} cm/s)

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Conclusions

- Underground
  - Concurrent backfill limits native rock oxidation in filled stopes
  - Saturated pastes (at closure) further limitacidity, sulfate, and metal release.
  - Low transmissivity limits groundwater interaction, which flows around and not through the fill.
  - Water collected in sump for treatment in operations.
- Surface CTF
  - Non-flowable mass
  - No water stored on facility
  - Water reports to sump for treatment
  - Initial lag in weathering limits solute release prior to placement of next lift
  - Options for adjustment of binder operationally

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Thank you…

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