Mount Polley Tailings:
Updates on Geochemical Testing and Conceptual Model

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Presentation Overview

• Brief review of results from 2015

• Updates – kinetic testing and field sampling

• Geochemical Conceptual Model

• Implications for reclamation planning
Summary of 2015 Results

• A geochemical characterization program was started in September 2014 to help inform remediation and reclamation planning for “spilled tailings” (i.e. a mixture of tailings, natural soil and sediments and dam construction materials)

• Previous presentation and 2015 presentations provide more background information
2015 Summary: Initial Conceptual Model

- Developed geochemical conceptual model that indicated two deposition configurations needed to be assessed:
  - Tailings along the banks of Hazeltine Creek as these would be exposed to atmospheric oxygen and facilitate sulphide oxidation
  - Tailings that settled at the bottom of Polley and Quesnel Lake would inhibit sulfide oxidation but may facilitate dissolution of secondary oxide minerals
2015 Summary: Sampling

- 18 downstream transects ~ 500 m apart
- 68 subaerial samples
- 78 subaqueous samples
2015 Summary: Lab Testing

- Acid-base accounting
- Bulk composition (aqua regia ICP-MS, non-sulfide copper extraction)
- Mineralogical characterization – QEMSCAN, XRD, probe
- Sequential extractions
2015 Summary: Low ARD potential

NP_{wc} (kg CaCO_3/t) vs. AP (kg CaCO_3/t)

- Magnetite Sand
- Mix
- Grey Tailings
- Mill/Historical

1:1
- 1:2

Uncertain

PAG

non-PAG
2015 Summary: Low Element Leaching Potential

- Screening of all regulated elements found only copper and selenium above typical crustal rocks
- Selenium is not elevated compared to regional sediments
2016 Updates: Kinetic Testing and Field Sampling
Kinetic testing

Humidity cells
- 1 kg of material
- 500 mL of water
- Dilute (2 kg/L)

Column Tests
- 4 kg of material
- 400 mL of water (10 kg/L)
- Closer to mine site solids-water ratio
Field Sampling
Field Sampling

Excavated tailings and vegetation debris

Waste rock

Drainage ditch/pond

Hazeltine Creek

(location of POF-2 and looking north to HAC-10)
Laboratory Results
pH, Copper, and DOC Focus

• The following slides focus on pH, copper, and dissolved organic carbon (DOC) only

• This is because of questions around copper leaching brought forward by the BC MOE based on water quality results around the “Polley Flats”

• All regulated elements are being monitored in laboratory tests and field stations – to be reported subsequently
Kinetic Testing – Humidity Cell Results

- **pH**
  - Cycle (Weeks)
  - HC-1 (Magnetite sand)
  - HC-1D (Magnetite Sand)
  - HC-2 (Magnetite Sand)
  - HC-3 (Grey Tailings)
  - HC-4 (Grey Tailngs)
  - HC-5 (Magnetite Sand)
  - HC-6 (Grey Tailings)

- **Cu (mg/L)**
  - Cycle (Weeks)
  - HC-4
    - 300 mg/kg Cu
  - ~ 1,000 mg/kg Cu
Kinetic Testing – HC DOC Results

- HC-1 (Magnetite sand)
- HC-2 (Magnetite Sand)
- HC-3 (Grey Tailings)
- HC-4 (Grey Tailings)
- HC-5 (Magnetite Sand)
- HC-6 (Grey Tailings)

DOC (mg/L) vs. Cycle (weeks)
Kinetic Testing – HC DOC Results

HC-4

“spilled tailings”
Kinetic Testing – Column Results

COL-1 = 1200 mg/kg Cu
Kinetic Testing – HC + Column DOC Results

DOC (mg/L) vs Cycle (weeks)

- HC-4
- HC-1 (Magnetite Sand)
- HC-2 (Magnetite Sand)
- HC-3 (Grey Tailings)
- HC-5 (Magnetite Sand)
- HC-6 (Grey Tailings)

Column DOC (mg/L) vs Cycle (Weeks)

- Col-1 (Magnetite Sand)
- Col-2 (Magnetite Sand)
- Col-3 (Grey Tailings)

Similar DOC despite 5x less dilute
Field Results
Field Results: “Polley Flats” & Hazeltine Creek – pH and Copper

Upper Hazeltine reclamation activities

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Field Results: “Polley Flats” & Hazeltine Creek – DOC

Dissolved Organic Carbon (mg/L)

Date


Typical surface water

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Copper Geochemical Model
(aka what the heck is going on?)
Copper Geochemical Conceptual Model

• Subaerial tailings are exposed to the atmosphere and copper sulphides are oxidizing

• Neutral pH predicted based on an excess of carbonate buffering – this continues to be supported by monitoring data

• Variable copper leaching depending on sample and environment with carbon potentially impacting solubility
A. Oxidation of sulphides, diffusion of oxygen, potential oxygen diffusion limitations
B. Organic acids likely complex* with copper
C. Infiltration and transport of oxidation products, carbonate reaction, CO₂ released
D. Run-off to ditches
E. Till interface likely directs water laterally to become seepage or groundwater
F. Above sources may partially report to HAC or to groundwater
Copper solubility considerations

- Copper at neutral pH is relatively insoluble compared to acidic conditions.

Modified from Day and Rees (2009)
Copper solubility considerations

• First principles predicts relationship between copper and pH

![Graph showing solubility curves of copper with pH, including Malachite (S.I. = 0) and (S.I. = 0.5), Tenorite, and Cu(OH)2. The graph notes that curves were generated using PHREEQC and Mt Polley POF water.]
Copper solubility considerations

- POF and HAC copper concentrations appear to be only partially constrained

...BUT...
Copper Solubility and DOC Complexation

• The relatively high DOC (40 mg/L versus typical 10 mg/L) was likely complexing copper.

• Evaluated by Minnow Environmental using the Stockholm Humic Model (Gustafsson 2001).

• Results were that DOC is complexing between 93% and 99% of the copper in the field samples and HC-4.

• So, if we assume 95% complexation…..
Copper solubility considerations

Note: Copper concentrations assume 95% complexation with organic carbon
Importance of Copper DOC Complexation

- Copper that is complexed with DOC is less bioavailable than free or ionic copper

- Minnow Environmental are working with a biotic ligand model and HydroQual (v.2.2.3) to establish water chemistry specific guidelines for copper
Implications for Remediation and Reclamation
Remediation and Reclamation

• Ionic or “free” copper is likely well constrained by secondary minerals

• High DOC was found downstream of bogs and is not the “norm” in the “Polley Flats” or tailings pore water in general

• Establishment of vegetation on tailings is not expected to have a negative impact of water quality
Remediation and Reclamation

- Getting water off the tailings and making use of solubility control will likely reduce overall loadings
  - Less water but same concentration = less mass released
Acknowledgments

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Thanks for listening!