Optimizing In-Pit Disposal of Problematic Waste Rock using Leaching Tests, Portable XRF, Block and Mass Transport Models

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OUTLINE

◆ CONTEXT
  ◆ Open Pit Mining of Uranium Deposits
  ◆ Decommissioning Strategy

◆ WASTE ROCK CHARACTERIZATION
  ◆ Arsenic : Laboratory testing
  ◆ Volumes : Block Models

◆ POST-DECOMMISSIONING
  ◆ Groundwater Flow and Mass Transport Conditions

◆ WASTE ROCK SEGREGATION DURING MINING
  ◆ Portable XRF

◆ CONCLUSION
Uranium Mine Locations in Saskatchewan, Canada
Sue Mining Area – McClean Lake Operation

Caribou

Sue C
Waste Rock Pile

Sue E
Waste Rock Pile

Sue E
Decommissioning Strategy

Clean Waste Rock – Above ground

In Pit Disposal of Problematic Waste Rock
Problematic Waste Rock vs Clean Waste Rock

◆ Mineralogical Context

◆ Uranium: oxide, silicate

◆ Arsenic, Nickel: variations within the system Ni-As-S-Fe (NiAs, NiAs₂, NiAsS, ...)

◆ Definition

◆ Problematic Waste Rock: material that contains between 250 mg/kg and ~ 850 mg/kg U, or has been identified as having acid generating potential, or contains greater than (75 to 250) mg/kg Arsenic

◆ Clean Waste Rock
  = Total Rock – Ore – Problematic Waste Rock
Waste Rock Characterization

◆ Objectives

◆ Source term definition for impact (mass transport) assessment models

◆ Methods

◆ Sequential leach tests => Leachable mass
◆ Column tests => Initial concentration (C0)
◆ Flow model => Flow through placed waste rock
◆ Assumption => Shape of source term function

Mass released

\[ = \int_{0}^{T_{\text{max}}} \text{Flow} \cdot C_0 \cdot \exp(-\beta \cdot t) \, dt \]
Waste Rock Characterization - Sequential Leach tests

- **Leachable Mass**
  - **Short Term =** Water leachable mass
  - **Longer Term =** Water + acid leach steps

- Water to Solid ratio of 20:1 (50 g / 1 L)
- Agitation
- Leach 1: de-ionized water for 48 hrs
- Leach 2: de-ionized water for 48 hrs
- Leach 3: weak Hydrochloric or Phosphoric acids for 72 hrs
**Water Leachable Concentrations vs Metal Content in the Waste Rock**

- As - Independent of age and degree of oxidation
- U, Ni - Highest water leachable concentrations associated with aged samples
Minimum volume (0.15 litres) sampled bi-weekly and submitted for chemical analysis.

Sample volume replaced.

Waste Rock

~ 20 kg

Water

~ 6L

N\textsubscript{2} Conditions

0.75m
**Initial Pore Water Concentrations vs Solid Content**

**Graph 1:**
- **Y-axis:** Pore Water (mg/L)
- **X-axis:** Time (wk)
- **Legend:**
  - As
  - Ni
  - U
- **Data:** Column A: As=1630 ug/g, Ni=780 ug/g, U=498 ug/g

**Graph 2:**
- **Y-axis:** Pore Water (mg/L)
- **X-axis:** Solid content (mg/kg)
- **Equation:** \( y = 0.001x^{1.6144} \)
- **R²:** 0.9124
- **Note:** Correlation independent of age of rock samples
**Problematic Waste Rock – Bloc Modelling**

- **Conservative Approach:** Assumptions that tend to maximize the amount of problematic waste rock

![Diagram of waste rock with concentration data](image)

**Maximum concentrations (10m x 10m x 3m)**

- **Bench elevation (masl)**
- **By/kg**
- **Uranium**
- **Arsenic**
- **Nickel**
Post Decommissioning – Ground Water Flow Conditions
Post Decommissioning - Particle Path Analysis
Post Decommissioning – Mass Transport

Typical Source Term Function

Mass released

\[ \int_{0}^{T_{\text{max}}} \text{Flow} \cdot C_{0} \cdot \exp(-\beta \cdot t) \, dt \]

Typical Breakthrough Curve

As Source Term - Waste Rock Pore Water Concentration

C0 (from column tests)

\[ \beta \]

As Concentration (ug/L)

Candy
Telephone
Collins Creek

Time (years)
Waste Rock Segregation

◆ OBJECTIVES
  - To Minimize the Volume of Problematic Waste Rock to be disposed in pit
  - To ensure that the Clean Waste Rock is Clean

◆ CONSTRAINTS
  - Field Conditions
  - Results in ~ 24 hours

◆ SELECTED APPROACH
  - Sampling of Blast Hole Cuttings
  - Traditional Approach – Radiometric Scanning for U
  - New Development - XRF technology for As detection
Waste Rock Segregation - Blast Pattern
Waste Rock Segregation - Sampling

Field Radiometric Scanning

Sampling for XRF Analysis
Waste Rock Segregation - XRF Analyser
Correlation Portable XRF - Laboratory

Sue A - Blast holes/Bench 406 - Systematic Comparison

Arsenic (mg/kg)

Samples #

Arsenic – Sue A Pit

mg/kg

Bench/composite
In-pit disposal of uranium mine rock in northern Saskatchewan is the primary strategy for mitigation of acid drainage from potentially reactive mine rock. However: Arsenic can be leached and subsequently transported in the groundwater flow system when the rock is submerged in water.
Assessment Stage: Conservative Approach to Develop Source Term, Flow and Mass Transport Scenarios

During Mining: Waste Rock Segregation based on XRF and Radiometric Scanning is a promising approach to optimize waste rock management