Estimating Solute Release from Mining Operations

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BACKGROUND

• NEW MINE CHANGES LANDSCAPE
  – Physical
  – Geochemical

• NEW MINING CONCERN
  Water quality impacts
Some Pits Serve as Municipal Water Supply
Other Pits Don’t
BACKGROUND

TO ADDRESS CONCERN

• NEED PRIOR TO OPERATION
  Estimates of solute release from source terms

• ESTIMATES USED
  – Impact assessment
  – Mitigation design
  – Financial assurance
**Source**
- Pit, tunnel, waste piles, tailings piles, storage areas, mechanical shops, labs

**Pathway**
- Water, surface or groundwater
- Air - dust, precipitation
- Soil, directly or indirectly
- Biota

**Receptors**
- People
- Animals
- Invertebrates
- Vegetation

From Carol Russell
BACKGROUND

• MINE WASTES OF CONCERN
  – Mine
  – Waste Rock
  – Tailings
  – Metallurgical wastes
  – Other
BACKGROUND

• WATER QUALITY CONCERNS
  – Acidic drainage
  – Neutral drainage with heavy metals
  – Neutral drainage with sulfate
  – Process related solutes
OBJECTIVE: ESTIMATE SOLUTE RELEASE FROM MINE WASTES

GENERAL APPROACH

1. Determine baseline conditions
2. Impose mine plan
3. Mine waste geochemical characterization
   3.1. Existing information
   3.2. Conduct tests (some peripheral information)
4. Develop model to estimate release
1. BASELINE CONDITIONS

- Water quality
- Hydrology
  - Surface
  - Ground water
- Soils
- Glacial overburden
- Bedrock
- Climate (Precipitation, Temperature)
- Topography
- Other
2. IMPOSE MINE PLAN

2.1. Conventional economic components

- Mine → → Ore

- Mineral Processing → → Concentrate

- Metallurgy → → Refined product
2. IMPOSE MINE PLAN

2.2. Environmental components

– Mine → →
  • Mine walls and floor
  • Waste rock

– Mineral processing → → Tailings (coarse, fine)

– Metallurgy → →
  • Slag
  • Hydrometallurgical wastes
2. IMPOSE MINE PLAN

2.2. Environmental components

Waste Rock Information for Modeling

• Rock units present

• Mass of rock units

• Compositional variation of rock units
2. Impose Mine Plan

2.2. Environmental Components

• Drill core data for waste rock
  – Logging (e.g. rock types, visual examination)
  – Chemical analysis
  – Mineralogy/Petrology

• Mineral processing pilot tests

• Metallurgical processing pilot tests
2. IMPOSE MINE PLAN

2.3. Mine Waste Management

• Water treatment

• Covers
  – Soil + Vegetation
  – Clay
  – Geotextiles

• Subaqueous
3. Geochemical Characterization

3.1. Existing information: Rock → Water

- Baseline water quality
- Soil signatures
- Vegetative signatures
- Geological description
- Geoenvironmental model
  - Solute release related to rock composition
  - Solute release related to mining and processing
3. Geochemical Characterization

3.1. Existing information

- Drill core data for waste rock
- Mineral processing pilot tests
  - Tailings composition
  - Water quality
  - Release rates
- Metallurgical processing pilot tests
3. Geochemical Characterization

3.2. Conduct tests

• Why?
  – Better understand rock → water quality

• On what?
  – Drill core
  – Tailings from mineral processing tests
  – Wastes from metallurgical tests
3. Geochemical Characterization

3.2. Conduct tests

Drainage quality = f(solid-phase characteristics)

- Solid-phase characterization
  - Chemical analysis (What’s here? How much?)
  - Mineralogical/petrological analysis (How occurs?)
  - Metal partitioning (How readily released?)
  - Static tests (acid and neutralization potentials)
    - (See White et al. 1999)
Duluth Complex drill core

Core is 2” in diameter (vertical dimension in photo).
Pyrite included in +2000 µm rock particle
Partially exposed pyrite in 75-150 μm particle
Liberated pyrite in 75-150 size fraction
Framboidal Pyrite is Bumpy and has High Area/Unit Mass
3. Geochemical Characterization

3.2. Conduct tests

• Short-term dissolution tests (soluble salts)
• Kinetic tests (long-term dissolution tests)
  – Soluble salts, other mineral dissolution
3.2. Conduct tests

ASTM 5744 kinetic testing of waste rock

Provide rates for modeling solute release in field

Test representative samples.
ASTM 5744

Mine Waste Dissolution Test Method

• Provides detailed description of protocol
  – Provide guidance for new practitioners
  – Promote method consistency
  – Increase reproducibility of results

• See Bucknam et al. 2009 for changes
ASTM 5744 Protocol

• 1 kg sample used for testing

• Waste rock particle diameter < 6.25 mm

• Characterize sample
  – Particle size distribution
  – Chemistry
  – Mineralogy
ASTM Humidity Cell
ASTM 5744 Protocol

• React with air, humidity in cell for 1 week
• Rinse on seventh day (500 or 1000 mL)
• Analyze drainage for
  – pH
  – Acidity, alkalinity
  – Sulfate
  – Other solutes
Determine SO₄ release rates for Archean Greenstone, 1.22% S
Average sulfate rates: $\mu$mol(kg•wk)$^{-1}$

![Graph showing average sulfate rates](image)
4. Modeling Lab to Field?
4. Modeling lab to field
~1000 t Duluth Complex Test Piles
4. Modeling lab to field
~60-ton test piles & barrel tests
4. Lab to Field Modeling: A general description.

- Practical modeling to inform mine waste management decisions
- Focus on waste rock
- Interface of geochemistry and regulation
- Don’t have all answers
Conceptual view of waste rock pile (Gard Guide).
Conceptual Model

Mine plan interaction with the environment? What affects quantity and quality of drainage?

Baseline condition

Mine waste facility description for mine plan

Scientific principles

Data generated by project (including kinetic test data)

Existing Data

Assumptions
Quantitative description of model

Develop computational machinery

Determine quantitative input ranges

WR pile mass
WR composition
Input water
Reaction conditions
Reaction rates (kinetic tests)
Output
Release Rates

Sensitivity

Uncertainty

Probability distribution
Baseline conditions

Conceptual Model

Quantitative description

Output

Probability

Mine Plan
Guidance (see NRC 2007)

- Transparency (balance simplicity < > rigor)
- Computational checks on calculations (e.g. vs. simplifications, other models, empirical data)
- Conceptual model scientifically sound
- Algorithms accurately reflect conceptual model
- Inputs and assumptions sound
- Sensitivity (important inputs)
- Uncertainty (probabilistic reflection of output)
Summary

• Prior to mining, predict mine drainage quality, solute release rates

• Need site conditions, mine plan

• Characterization/prediction program based on above
Summary

• Kinetic tests yield solute release rates
• Modeling required to apply laboratory results to field
  – Mine plan superimposed on existing conditions
  – Conceptual model based on science
  – Transparent
  – Sensitivity analysis
  – Output expressed as probability
References and Helpful Publications


References and Helpful Publications

http://www.csp2.org/reports/Framework%20for%20Responsible%20Mining%20Executive%20Summary.pdf


http://www.iied.org/pubs/pdfs/9084IIED.pdf
