Setting ARD Management Criteria For Mine Wastes with Low Sulfide and Negligible Carbonate Content

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Outline

• Project setting
• Observations from long term kinetic testwork
• Hypothesis for trends in leachate pH
• Experimental design
• Results
• Application to setting management criteria
Acknowledgements

Minnesota Department of Natural Resources – Lands and Minerals (MDNR LAM)
Setting

- Duluth Complex – a gabbroic layered intrusion.
- Containing copper and nickel sulfide deposits.
- PolyMet Mining Corp’s NorthMet Project – proposed open pit mine.
Observations from Long Term Kinetic Testwork by MNDNR

Total S – 0.2%, Negligible Carbonate

Observations from Long Term Kinetic Testwork by MNDNR

Total S – 0.4% to 0.6%, Negligible Carbonate

18 years

Hypothesis for Trends in Leachate pH

• Conventional acid neutralization by carbonates (pH buffered in neutral range):

• Acid generation:

\[
\text{FeS}_2 + \frac{15}{4} \text{O}_2 + \frac{7}{2} \text{H}_2\text{O} \rightarrow \text{Fe(OH)}_3 + 2\text{SO}_4^{2-} + 4\text{H}^+
\]

• Acid Neutralization by Carbonates

\[
4\text{CaCO}_3 + 4\text{H}^+ \rightarrow 4\text{Ca}^{2+} + 4\text{HCO}_3^-
\]
Hypothesis for Trends in Leachate pH

• Acid neutralization by alumino-silicates (pH buffered 4 to 5):

• Acid generation:

\[ \text{FeS}_2 + \frac{15}{4} \text{O}_2 + \frac{7}{2} \text{H}_2 \text{O} \rightarrow \text{Fe(OH)}_3 + 2\text{SO}_4^{2-} + 4\text{H}^+ \]

• Acid neutralization by alumino-silicates:

\[ \text{CaAl}_2\text{Si}_2\text{O}_8 + 8\text{H}^+ \rightarrow \text{Ca}^{2+} + 2\text{Al}^{3+} + 2\text{SiO}_2 + 4\text{H}_2\text{O} \]

\[ \text{Al}^{3+} + 3\text{H}_2\text{O} \rightarrow \text{Al(OH)}_3 + 3\text{H}^+ \]
Hypothesis for Trends in Leachate pH

• Acid neutralization by bicarbonate from silicate weathering:

$$\text{CaAl}_2\text{Si}_2\text{O}_8 + 2\text{H}_2\text{O} + 2\text{H}_2\text{CO}_3^0 \rightarrow \text{Ca}^{2+} + 2\text{Al(OH)}_3 + 2\text{SiO}_2 + 2\text{HCO}_3^-$$

• Resulting bicarbonate is dissolved alkalinity that can participate in acid buffering.
Hypothesis for Trends in Leachate pH

• Long term non-acidic pH can be sustained when alkalinity generation from weathering of silicates exceeds acid generation from sulfide oxidation.

• Acidic leachate occurs when acid generation exceeds alkalinity from silicate weathering.
Experimental Design

• Evaluate silicate weathering
  – Humidity cells on rock samples containing negligible sulfide.
  – Consider variation in silicate mineralogy.

• Correlate acid generation rates with sulfide content
  – Humidity cells representing a range of sulfide contents.

• Supporting mineralogy.
Results

Waste Rock - S≤0.05% - Concentrations
NorthMet Project

Sulfide S ≤ 0.05%

P H

10
9
8
7
6
5
4
3

9 years

Cycles [weeks]
Results

• For samples with less than 0.05% sulfide:
  – The testing period was sufficient to deplete very low levels of original carbonate minerals.
  – Leachate chemistry (Ca, Na, Mg, Si, pH, $\text{HCO}_3^-$) can be explained by weathering of plagioclase feldspar and olivine at $\text{pCO}_2 = 10^{-3.4}$.
  – Base level alkalinity generation rate range of 2.1 to 5.3 mgCaCO$_3$/kg/week
Results

• Sulfate release is strongly correlated with sulfide content.

• Distinctive relationships depending on copper and iron sulfide content:
  – Higher oxidation rates when copper sulfide dominates.
Application to Setting Management Criteria

• Used base level alkalinity generation rate and correlations to define sulfur thresholds for acid generation:
  – >0.12% (higher levels of copper sulfide).
  – >0.31% (lower levels of copper sulfide).

• Consistent with MDNR long term testwork
  – No acid generation for sulfur of about 0.2%.
  – Acid generation if sulfur is 0.4%.
Conclusions

• Weathering of large reservoir of reactive silicates offsets acid generation at low sulfide contents.

• Acid generation criteria can be based on sulfide content rather than conventional acid-base accounting.