Choosing Management and Remediation Systems

Dave Trumm
Rowan Buxton
Rachel Rait

Mine drainage framework
• Management and remediation in the Framework  
  Dave Trumm
• Mine waste management techniques  
  Rowan Buxton
• Water treatment for AMD  
  Dave Trumm
• Arsenic Treatment  
  Rachel Rait
Proceed (with ongoing monitoring)

How do we reduce impact to an 'acceptable' level?

No

What is the level of potential impact?

Yes

Proposed operations

Normal operations

What is the potential for a detrimental ecological impact?

Operational Management

Remediation during operation

Decision-making step

Is this an 'acceptable' level of impact for this system?

Proceed (with ongoing monitoring)
Ecological impacts deemed unacceptable and water quality targets are identified

- It is up to mine operators to decide how to meet targets

Framework provides - Toolbox

- Options for mine operators to meet targets
- Method to select options
- Confidence to stakeholders that mine operators have ability to meet targets
Overall Goal

Reduce impacts to acceptable levels

Mine waste management techniques can prevent or minimise unacceptable mine drainage
Overall Goal

Reduce impacts to acceptable levels

Mine waste management techniques can prevent or minimise unacceptable mine drainage

Water treatment systems can remediate impacted water
Overall Goal

Reduce impacts to acceptable levels

- Mine waste management techniques can prevent or minimise unacceptable mine drainage

- Water treatment systems can remEDIATE impacted water

- Framework provides methodology to select most appropriate option
Mine Waste Management

Minimising water quality impacts
Goals

• Prevent or reduce the amount of water entering the mine area

• Prevent or reduce the contact of water or oxygen with acid-forming materials

• Neutralise or reduce the concentration of contaminants present in mine drainage
Factors influencing mine drainage

- Landform & climate
- Mine type & history
- Arrangement & composition of strata
- Waste volume & proportions
- Grain size, porosity & flow paths
- Flow volume & rate

↓

Mine planning & management options
Pre-mining analysis

Rock geochemistry and water quality

- Non Acid Forming (NAF)
  - Turbidity
  - Trace metals

- Potentially Acid Forming (PAF)
  - AMD
Water Management (NAF)
Water Management (NAF)

- Surface water diversion
- Sediment collection

- Regrading
- Surface roughening
- Rapid revegetation
Potentially Acid Forming
## Mine Waste Management

<table>
<thead>
<tr>
<th>Approach</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avoidance</td>
<td>Total or partial reduction in excavation or exposure of problematic materials can limit or prevent sulphide oxidation and metal release</td>
</tr>
<tr>
<td>Neutralisation</td>
<td>Addition of alkaline material to offset acidity; inhibition of iron-oxidizing bacteria that catalyse acid generation</td>
</tr>
</tbody>
</table>
Mine Waste Management

• Isolation

Techniques to separate problem materials from oxygen & water - the vectors of acid formation/transportation
Proportion of acid materials
Grain size/ Porosity/ Fracturing
Flows
Water Table/ Fluctuation

Arrangement of acid materials

Avoidance or Isolation

Avoidance Practical

Isolation Possible

AMD formation

Sufficient acid neutralising material available

Neutralisation

AMD neutralised

Remediation required
Sufficient acid neutralising material available

Prevented

Isolation not possible

In discrete strata

Avoidance Practical

Avoidance or Isolation

High

Low

No oxidation

Oxidation

Prevented

Not prevented

AMD formation

Proportion of acid materials
Grain size/ Porosity/ Fracturing Flows Water Table/ Fluctuation

Arrangement of acid materials

Avoidance or Isolation

Neutralisation

AMD neutralised

Remediation required

No oxidation

Oxidation

Prevented

Not prevented

Sufficient acid neutralising material available

Yes

No

Yes

No
Isolation Strategies

- Dewatering
- Cover design
- Inundation
- Seals

Special handling
- Cover materials
- Barriers
Neutralisation Strategies

- Alkaline addition
- Blending
  - Mixing
  - Layering
- Bactericides
- Anionic surfactants
AMD Treatment
Low pH
High metal concentrations

Treatment = add neutralising agent to raise pH
Due to low solubility at high pH, metals precipitate
Active Treatment

- Continuous dosing with base (lime, caustic soda, soda ash)
- Regular operation and maintenance
- Reliable and effective but costly

*Generally* more common at operational mine sites

- Limited space for remediation
- Drainage chemistry & flow rate changes
- Power and people
Limestone Dosing to Mangatini
(SE Environmental Team)

Temporary until 100 year plant constructed
50 tonne capacity (1-2 days supply)
Air cannons to fluidise limestone

Lime slurry discharge
Passive Treatment

- No continuous dosing with chemicals
- Takes advantage of naturally occurring chemical and biological processes
- Not “walk away” solution
- Less costly in the long term

Generally more common at abandoned mine sites
- More space for remediation
- Stable drainage chemistry & flow rate
- No power or people
Treatment Selection in the Framework

• Collect data
  – pH, acidity, Fe, Al, Mn, TSS, DO, flow rate
  – Active mine site?, power?, available land area

• Use flow charts to identify potential solutions
  – Active vs Passive Treatment
  – Active Treatment Options
  – Passive Treatment Options

• Review supporting information in tables, graphs
AMD

High Suspended Solids

Settling Ponds / Clarifiers

Mn > 100 mg/L

Flow > 1 L/s

Fe > 20 mg/L

Sodium Carbonate

Calcium Hydroxide or Calcium Oxide or Calcium Carbonate

Water Treated

Ammonia Gas or Sodium Hydroxide
<table>
<thead>
<tr>
<th>AMD</th>
<th>High Suspended Solids</th>
<th>Setting Ponds / Clarifiers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max pH</td>
<td>Effic</td>
<td>Vol</td>
</tr>
<tr>
<td>Soda ash or sodium carbonate (Na₂CO₃)</td>
<td>11.6</td>
<td>95 - 100 (powder) 60 (briquettes)</td>
</tr>
<tr>
<td>90 - 95</td>
<td>0.74</td>
<td>0.17</td>
</tr>
<tr>
<td>90</td>
<td>0.56</td>
<td>0.11</td>
</tr>
<tr>
<td>100</td>
<td>0.34</td>
<td>0.60</td>
</tr>
<tr>
<td>100</td>
<td>0.80 (solid)</td>
<td>1</td>
</tr>
<tr>
<td>90 - 95</td>
<td>0.40 or 0.58</td>
<td>0.22</td>
</tr>
<tr>
<td>90 - 90</td>
<td>1</td>
<td>0.04</td>
</tr>
</tbody>
</table>

**Key Chemicals:***

- **Calcium Hydroxide**
- **Calcium Oxide**
- **Calcium Carbonate**
AMD

High Suspended Solids
Flow > 1 L/s
Mn > 100 mg/L
Fe > 20 mg/L

Sodium Carbonate
Ammonia Gas or Sodium Hydroxide
Calcium Hydroxide or Calcium Oxide

Water Treated
Settling Ponds / Clarifiers

Low Flow / Low Acidity

Moderate Flow / Moderate Acidity

High Flow / High Acidity

Na₂CO₃
NH₃
NaOH
Ca(OH)₂
AMD

High Suspended Solids

Settling Ponds / Clarifiers

Mn > 100 mg/L

Flow > 1 L/s

N

Fe > 20 mg/L

Y

Sodium Carbonate

Calcium Hydroxide or Calcium Oxide or Calcium Carbonate

Ammonia Gas or Sodium Hydroxide

Mechanical Aeration or Chemical Oxidation

Water Treated

Mechanical Aeration or Chemical Oxidation

Flocculants / Coagulants

Mechanical Mixing

Flow > 20 L/s

N

Flow > 5 L/s

N

Flow > 20 L/s

Y
Limited Land Area

Settling Ponds

Clarifiers

Sludge Dewatering and Disposal

Water Treated
Sites with Existing AMD

- Chemistry and flow rate data real
- Use same selection flow charts
- Conduct laboratory experiments / small-scale field trials
Arsenic Treatment
• Waste rock management
  – Similar techniques are used as coal PAF
  – Selection based on cost and site characteristics

• Removal of arsenic through
  – Oxidation
  – Coagulation/filtration
  – Adsorption
  – Ion exchange
  – Membrane/reverse osmosis
  – Biological
Oxidation

Often pre-treatment
As(III) to As(V)

- Air oxidation
  - By stirring
  - Cascade
  - Air injection
- Chemical oxidation
  - Ozone, bleach, Mn Oxide, hydrogen peroxide, permanganate
Mine Drainage

Low flows < 50L/s

Large space for ponds and dams

Concentration of arsenic < 20 mg/L

Active treatment

Passive treatment
<table>
<thead>
<tr>
<th>Technique</th>
<th>Media</th>
<th>Relative cost</th>
<th>Factors to consider</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adsorption</td>
<td>iron-rich AMD sludge coated aggregate</td>
<td>low</td>
<td>Availability of AMD sludge</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Chemistry of AMD sludge sludge</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cost of preparing aggregate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sludge disposal requirements</td>
</tr>
<tr>
<td>Adsorption</td>
<td>iron grit and sand</td>
<td>low</td>
<td>Cost and availability of iron grit</td>
</tr>
<tr>
<td>Adsorption</td>
<td>Fe sulphate and calcite</td>
<td>High</td>
<td>Cost of chemicals</td>
</tr>
<tr>
<td>Coagulation precipitation</td>
<td>Iron oxide/hydroxide</td>
<td>High</td>
<td>Cost of chemicals</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sludge disposal requirements</td>
</tr>
</tbody>
</table>
Example of operating active system
Globe Progress Mine
Oxidation tank

Iron chloride addition
Oxidation Tank

Precipitation Tank
Passive systems

- System include:
  - Ponds
  - Wetlands
  - Dams
  - media-manganese oxide coated sand, zero valent iron, iron oxide coated sand...
Constructed wetland

AQUA-mat® basins
Basins with algae
Filters
Discharge
Sedimentation basin
Conclusion

• Waste rock management and remediation options have been presented together with selection criteria

• Provides a first cut for selection. Site specific characteristics will determine refinement of technologies

• Small scale tests may be required to optimize system for the site.