Building Mine Rock Stockpiles to Enhance Operational and Closure Performance

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Introduction

- The mining sector worldwide is experiencing significant increases in closure costs.
- The most contentious and persistent issue is poor water quality (ML-ARD/AMD), during operation, closure and post closure.
- ML-ARD/AMD requires collection and treatment during operations and often in perpetuity.
- Range of mine site domains can be affected: waste rock dumps / mine rock stockpiles (MRS/WRD), tailings storage facilities, open cuts, underground voids.
- General breakdown of acid and metal pollution loading sources:
  - 60-80% waste rock (eg. Equity Silver Mine – 94%; Meints & Aziz, 2018)
  - 20-30% tailings
  - <20% other sources
- International Network for Acid Prevention (INAP, 2020) funded study to review, assess and summarise existing and improved MRS/WRD construction methods.
Conventional Mine Rock Stockpile Construction
Gas Transport and Oxygen Resupply Mechanisms in Conventional MRSs

- Oxygen supply to sulfidic mine rock is the key limiting factor for ML-ARD/AMD generation at most sites.
- Temperature differential (internal MRS and ambient) can lead to significant fluctuations in air flow through an MRS on a diurnal and seasonal basis.
- To manage ML-ARD/AMD risk, air flow mechanisms for MRSs should be considered.
Improved Construction Methods

- A total of 6 “improved” construction methods identified for assessment.
  - 4 “geotechnically-focussed” methods.
  - 2 “geochemically-focussed” methods (geochemical engineering).
- Geotechnically-focussed methods:
  - Lower lift heights.
  - Engineered layers.
  - Base-up, layered /compacted.
  - Encapsulation.
- Geochemically-focussed methods:
  - Oxygen consuming materials.
  - Sulfide passivation.
- Additional (evolving) methods also identified in INAP (2020).
Improved Construction Methods

- All methods aim to limit access of oxygen (not water) to sulfidic mine rock by either:
  - Regulating air entry;
  - Influencing pore gas oxygen concentrations; and/or
  - Coating sulfide grains to limit reaction with oxygen.

- All methods require:
  - Comprehensive and accurate geochemical characterisation;
  - ML-ARD/AMD risk classification system;
  - ML-ARD/AMD block model; and
  - Waste rock segregation and/or handling strategies.

- Potential benefits can be quantified based on lowering pollution (acid and metal) loads per tonne of mine rock placed (ie. improving site water quality).
Example: Base-up, Layered / Compacted

- Building an MRS from the base-up via paddock dumping in compacted, thin lifts, simultaneously retards air flow capacity and enhances carbonate and silicate neutralization, thereby improving site water quality.

- Construction method:
  - Base-up construction, even in undulating/steep terrain.
  - Paddock dumping and initial dozer compaction.
  - Final thickness of each flattened layer 1-3 metres.
  - Ongoing compaction to optimise permeability / air entry.
  - Water addition, if required.
  - Surface runoff control.
  - Site-specific field trials.
Example: Base-up, Layered / Compacted

Key benefits:

- Base-up construction avoids preferential pathways for air and water.
- Thin-lift configuration also limits preferential pathways.
- Compaction lowers potential for ML-ARD/AMD generation and discharge.
- Increased residence times enhance carbonate and silicate neutralisation.
- Stringent air entry control with strategic thinner layers (eg. < 1m).
- Water addition (for compaction) can further lower air entry.
- Lower reliance on cover systems.
- Lower risk of spontaneous combustion.
- Can be applied retrospectively to historic MRSs.
- Potential to improve geotechnical stability.
- Lower water treatment costs, improved water quality outcomes.
- Long term post-closure cost savings.

Case Studies

- Numerous sites where improved MRS construction methods are being applied.
- Published references / public domain examples:
  - Iron ore mine, Pilbara WA (lower lift heights + inter-lift layers)
  - Teck Coal Operations, Canada (engineered layers).
  - Golden Cross Mine, NZ (base-up, layered/compacted).
  - Ban Houayxai Gold Mine, Lao PDR (base-up, layered/compacted).
  - Kelian Gold Mine, Indonesia (base-up, layered/compacted).
  - Rosebery base metal mine, Tasmania (O₂ consuming materials + all of above).
  - Martha gold mine, NZ (base-up, layered/compacted).
  - Phu Kham copper-gold mine, Lao PDR (encapsulation + base-up, layered/compacted).
  - Martabe gold mine, Indonesia (TSF embankment encapsulation).
  - Grasberg copper-gold mine, Indonesia (sulfide passivation).
  - Brukunga pyrite mine, SA (sulfide passivation).
Conclusions

- Increasing evidence that ML-ARD/AMD management strategies solely focussed on cover systems and water collection/treatment can result in unrecognized and poorly funded closure liability.

- Improved MRS construction methods have been identified that build on recent industry experience (4 geotechnical; 2 geochemical).

- All improved methods aim to limit availability of oxygen to sulfidic waste rock, and thus reduce pollution generation, and ultimately improve seepage water quality.

- Some of these methods can be applied retrospectively at brownfield sites.

- Geochemical characterisation, classification and block modelling are essential.

- Suitability will be site-specific (climate, topography, texture, geochemistry, etc).

- Methods can be combined to further enhance water quality outcomes as compared to a single method.

- Numerous existing full-scale applications confirm benefits.
Next Steps

- Conduct an assessment to identify which of these improved methods could be applied to lowering pollution from your existing mine rock stockpiles.

- Consider implementing a trial to quantify the water quality / closure benefits of modifying / improving existing problematic mine rock stockpiles.

- Based on your site’s climate, topography, mine rock textures, and geochemistry, identify the optimum construction methods for your next new mine rock stockpile.

- Determine the costs of implementing the improved construction methods for existing or new MRS relative to conventional methods, and compare any increases with predicted costs savings during closure.
Resources

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References


