Waste Rock Pile Construction to Lower Closure and Relinquishment Costs

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INTRODUCTION

Acid and metalliferous drainage (AMD) is routinely derived from waste rock, tailings, pit wall rock, underground mine voids, heap leach pads, ore stockpiles, concentrate stockpiles and even slag piles. In many jurisdictions, there is an assumption that tailings materials represent the highest AMD risk. This is likely due to their highly sulfidic and ultra-fine grained nature, and the fact that they occur in large tonnage, partially unsaturated deposits. These characteristics are not unreasonably associated with reactive and therefore highly polluting mine waste materials. Interestingly, however, the high sulfide content and highly reactive nature of tailings achieves the rapid consumption of oxygen in tailings pore spaces. This oxygen depletion can limit or halt sulfide oxidation throughout much of the tailings pile. Oxygen can only be resupplied to the tailings via atmospheric exchange at the air-tailings interface. The grain size of most tailings materials limits this resupply to a diffusion related process that only affects the uppermost 100–2000 mm. Hence sulfide oxidation in tailings can be inherently self-limiting. Unfortunately, the same cannot be concluded for waste rock materials.

Using a unique site assessment strategy that focuses on quantifying acidity fluxes from various domains at a mine site, it has become increasingly evident that sulfidic waste rock produces the majority (typically 60–80 per cent) of the soluble acid and metalliferous pollution at most active and decommissioned sulfide-bearing mine sites. Whether sulfidic waste rock is disposed in engineered above ground facilities, backfilled into pits or even underground voids, it remains the primary source of pollutants for decades to centuries.

Conventional end-dumping waste rock practices result in angle-of-repose pathways for air and water, and these internal fabrics exacerbate sulfide oxidation (ie pollution generation) and discharge from waste rock materials. The primary aim of many cover systems is to retard the access of air and water to these conduits. Recent thinking is that more emphasis needs to be directed at strategic waste rock pile construction practices, and less reliance placed on thin soil cover systems to prevent AMD.

Waste rock pile construction approaches that minimise porosity and permeability but raise the retained moisture content and enhance water residence times have the potential to lower sulfide oxidation rates and thereby improve water quality outcomes. For example, innovative base-up, layered and compacted (BULC) waste rock piles have the potential to avoid or minimise the generation of AMD, supersede the need for treatment and facilitate successful closure and relinquishment across the mining sector (Figure 1).

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CONSTRUCTION METHOD

BULC waste rock pile construction employs geochemical engineering principles to overcome persistent AMD issues associated with conventional construction methods. Fundamental elements include:

• construction from the base, and progressing upwards, whether in flat, undulating or steep terrain
• commencing waste rock placement by paddock dumping, and initial dozer compaction to produce a uniform layers
• compaction to achieve a final thickness of each flattened layer of between one and three metres; thinner layers result in more effective compaction and oxygen exclusion
• ongoing compaction of each layer with dedicated, conventional compaction equipment to achieve optimum permeability reduction and to lower air entry
• water addition to facilitate optimum compaction if required
• construction of each thin, compacted lift to control surface run-off
• implementation of site specific field trials to quantify detailed construction criteria
• installation of pore gas and water quality monitoring equipment to confirm construction quality assurance / quality control and operational performance.

KEY BENEFITS

The key benefits of the BULC waste rock piles include:

• base-up construction avoids the production of preferential pathways for air and water, lowering AMD generation and acidity discharge
• thin-lift configurations create unstructured horizontal layers, thwarting the creation of preferential pathways, as well as enhancing the opportunity for effective compaction (porosity and permeability reduction)
• the compaction of thin layers is vital to lower the potential for air entry and AMD generation, as well as water discharge
lower water discharge rates translate to increased residence times for pore water in waste rock, thereby enhancing carbonate neutralisation reactions, and ensuring that silicate neutralisation reactions can play a far bigger role in managing AMD
• stringent air entry control can be achieved by the occasional, strategic construction of thinner layers with greater compaction (eg <1 m)
• water addition to optimise compaction can further lower air entry.

OTHER MANAGEMENT MEASURES
Thin layer construction techniques facilitate the incorporation of other AMD management measures into the design of BULC waste rock piles. For example:
• Multiple, very thin (eg 0.5 m), highly compacted waste rock layers can be distributed strategically through a PAF waste rock pile to sequentially reinforce water retention, retard oxygen entry, slow water migration and enhance silicate dissolution. This approach distributes the pollution control responsibility throughout the pile, rather than on a single layer or cover system.
• Thin layers of engineered oxygen consuming materials (ie sulfide-bearing waste rock mixed with an excess of carbonate) could be distributed strategically through a PAF waste rock pile to create multiple, internal oxygen exclusion barriers.
• Alkalinity generating layers (eg limestone, dolomite, caustic magnesia) could be strategically installed to operate as passive alkalinity addition layers, acid water neutralisation zones, as well as oxygen entry control zones if the carbonate is ultra-fine grained.
• The placement of highly reactive sulfidic waste in controlled thickness layers is a good method for dissipating heat and thereby lowering the risk of spontaneous combustion. In addition, this risk is dramatically minimised by the air entry control provided by BULC waste rock pile construction.

CONCLUSIONS
BULC waste rock piles permit waste rock masses to behave more like tailings deposits, where air entry control is routine, even prior to the installation of a cover system. BULC construction methods can improve the geotechnical stability of waste rock storages, but a focus on surface water control and run-off is necessary.

BULC waste rock piles can be designed and constructed directly at greenfields sites, but could also be employed at sites with legacy AMD issues. For example, encapsulating PAF waste rock piles with BULC waste rock shells could provide effective pollution control from new and legacy materials.

The initial cost of BULC piles may be higher than end-dumping procedures at some sites, but these are predicted to be far outweighed by the savings in lower AMD management and water treatment costs, as well as closure and relinquishment expenses.