Strategies for Managing Chemically Reactive Mineral Waste at Rio Tinto Iron Ore Mines

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Abstract

Effective mineral waste management during mining and process activities is critical for protecting the environment and reducing liabilities and long-term risks. Upfront proactive management of chemically reactive mineral waste can be challenging as the consequences of actions may not be fully understood and may involve immediate extra resources and expense. Conversely, the lack of proactive management can result in high ongoing cost, environmental degradation, and regulator intervention.

The awareness of mineral waste risks is important for empowering those that work with chemically reactive mineral waste to make informed decisions. Rio Tinto Iron Ore's corporate HSE&C standards, management plans and assurance process provide guidance on the strategies and expectations for those that work with chemically reactive mineral waste at the Western Australia Pilbara operations.

Keywords: AMD, ARD, Management Plans, Geochemical Characterisation, Pilbara, Case Studies

Introduction

Chemically reactive mineral waste may prevent the re-establishment of vegetation, contaminate surface and groundwater leading to environmental degradation, as well as pose direct exposure (health) risks. Unless managed appropriately, chemically reactive mineral waste may have the potential to generate Acid and Metalliferous Drainage (AMD), salinity, neutral mine drainage or spontaneous combustion.

Potentially Acid Forming (PAF) material is managed at some of Rio Tinto Iron Ore's (Rio Tinto's) Pilbara mining operations within Western Australia. Fig. 1 provides an indication of the PAF tonnages at each operation on a year by year basis. Significantly more ore (330 Mt in 2017) is mined than PAF waste material (4 Mt in 2017). Although chemically reactive waste represents a small percentage (≈1%) of the waste generated by most of Rio Tinto's Pilbara open cut operations, it can contribute to waste-related environmental, health, reputational and financial risks. Therefore, significant effort is devoted to proactively identifying chemically reactive waste materials, assessing risk, developing management strategies, increasing awareness and providing assurance that the systems are working. This approach is what Rio Tinto undertakes as an internal requirement, which is independent of, but is consistent with, external regulatory requirements and/or national and international guidelines and standards (DITR 2007; INAP 2018).

PAF material can exist in unoxidised Mount McRae Shale, sulfidic banded iron formation and detrital (lignite and siderite) waste rock. Extensive sulfur analysis (Fig. 2) is undertaken on drill hole data which is combined with acid base accounting data (Fig. 3) and assessed in AMD risk assessments (Green and Borden 2011). If necessary, findings from the AMD risk assessment are translated into the development of management strategies, plans and safe work practices.

Management Plans and Strategies

Rio Tinto has six environmental standards with the Chemically Reactive Mineral Waste Management standard representing the most relevant for the management of PAF waste. It applies to the full mine life cycle from exploration through to post-closure, providing expectations for planning, implementation and operation, and performance monitoring.

A Mineral Waste Management Plan (MWMP) is applicable for every Pilbara

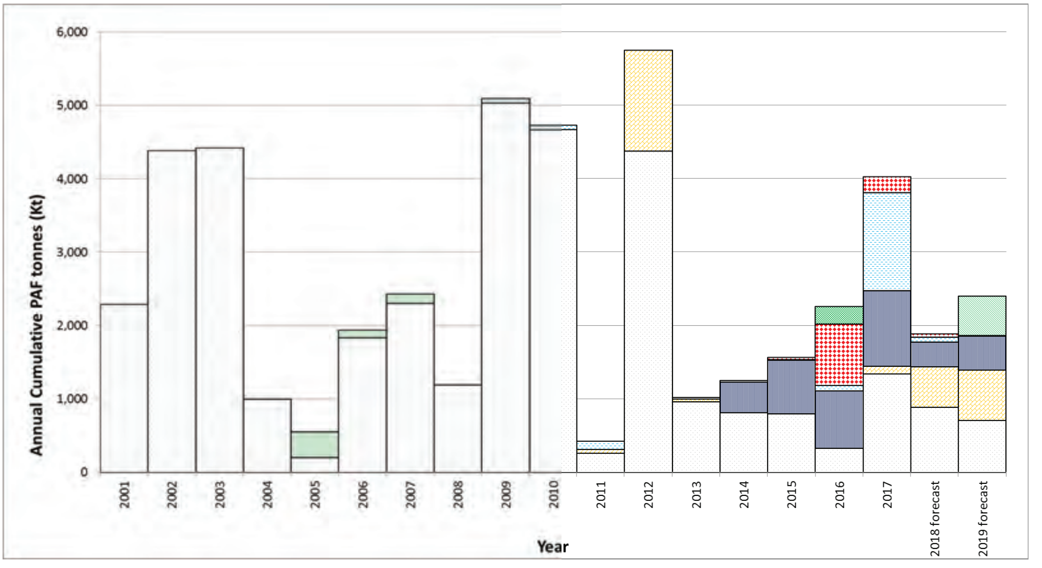
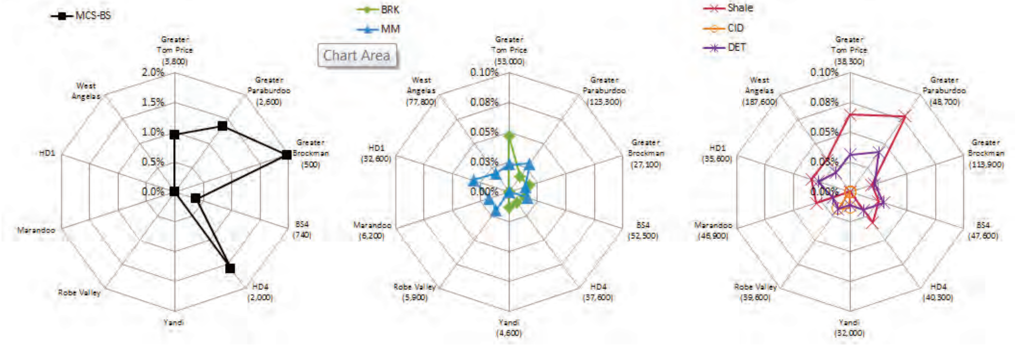


Figure 1 *Indication of yearly PAF tonnages mined at different sites. The different colours and patterns represent different mine sites.*



MCS-BS = Unoxidised Black Mount McRae Shale; BRK = Brockman Iron Formation; MM = Marra Mamba Iron Formation; DET = Detrital; CID = Channel Iron Deposits

Figure 2 *Average total sulfur content of drill hole waste samples from Rio Tinto mine sites (both in pit and out of pit). The number of samples analysed are represented next to the site names.*

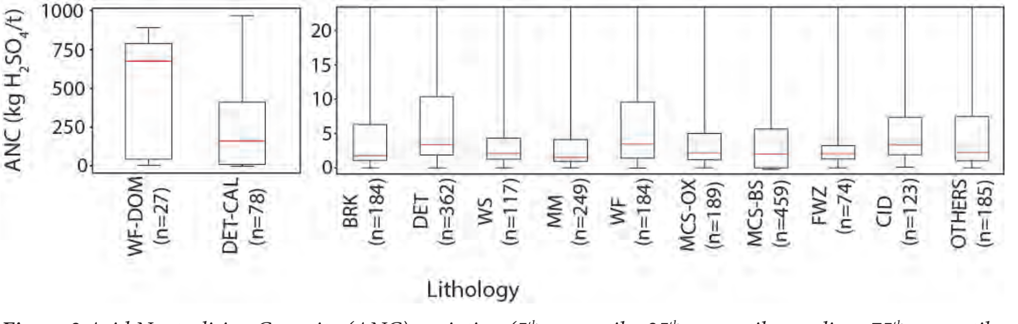


Figure 3 *Acid Neutralising Capacity (ANC) variation (5th percentile, 25th percentile, median, 75th percentile and 95th percentile) in different lithologies (showing the number of samples analysed).*

development project and mining area. The plan describes the actions to be taken during resource drilling, order of magnitude, pre-feasibility and, feasibility studies and mine development.

The MWMP requires the completion of an AMD risk assessment, and if the project is assessed as posing a significant AMD risk, then the Spontaneous Combustion and ARD (SCARD) Management Plan will be implemented. The SCARD plan describes the actions to be taken by long-term planning, site planning, geology, survey, operational planning, blasting, hauling, hydrogeology, environment, health and safety and the mineral waste management team to reduce AMD-related risks at the site. It captures guidance for: dump designs; rehabilitation and closure; and contingency planning.

Easily accessible hyper-links are included in the SCARD plan to relevant technical reports and reference material. Safe work practices, acid water management plans and health guidance notes that are specific to individual operations have also been developed.

Awareness

In addition to site-specific and role-specific training, a general interactive mineral waste training module has been created. The online module provides an engaging approach to self-learning which differs to typical classroom or PowerPoint-type training, and includes case studies and a final interactive assessment. It has been completed 360 times since its rollout in September 2014, primarily by geologists, hydrogeologists and mine planners.

Geographic Information System (GIS) layers have been created for each Rio Tinto operation in the Pilbara that displays:

- AMD risk ratings for pits, including details of lithologies and estimated life of mine PAF tonnages;
- AMD risk ratings for PAF waste dumps, including historically recorded tonnages; and
- PAF pit wall exposures mapping and surface areas relative to catchment areas.

The storage of this information within Rio Tinto's GIS database means this information is readily available for mine planners and other groups that work with mineral waste. This enables informed decisions on rehabilitation, pit backfill and monitoring.

Assurance

Business Conformance Audits (BCAs) are undertaken at all Rio Tinto operations (typically every two years). They assess compliance with the Rio Tinto HSE&C standards (including the Chemically Reactive Mineral Waste Management standard). Auditors external to the operation assess the risks and identify findings for the mine site to implement and track. In addition, the Chemically Reactive Mineral Waste Management standard requires a review of PAF management across a site every four years if the risks are significant. These reviews are undertaken by mineral waste experts that are external to the site and the scope covers the characterisation programs, management strategies, disposal facilities, monitoring and closure plans. The findings are actioned and tracked by each site, and communicated or transferred to other sites in the Pilbara, if relevant.

Case Study 1: Dedicated PAF Study for an Operating Mine

Whilst PAF waste management is a component of many studies, particularly prior to mining, a detailed and dedicated PAF study to inform an existing operation on optimal PAF management is relatively unique. Such a study was undertaken in 2016 for a mine that began mining low tonnages of PAF waste in 2009. Questions were raised on the optimal long-term storage location for this PAF waste (i.e., above the water table or below the water table, in-pit or external). The pit represents a flow-through system that will be backfilled above the water table at closure.

Rio Tinto progressed a dedicated PAF study to assess options. A study manager was assigned, and a team was formed which included representatives from mine operations, business analysis, mine planning, hydrogeology, hydrology, mineral waste management, environment, closure, risk and sustainable development. A management Steering Committee was formed consisting of general managers and managers to review findings and make the final decision. The focus of the study was to identify the optimum storage location for chemically reactive mineral waste to meet both environmental and company objectives.

The study was undertaken over eight months and included:

- Mine designs, option analysis and fatal flaw analysis;
- Hydrogeological and geochemical modelling;
- Geochemical and eco-toxicological testing;
- Closure, legal and environmental approval considerations;
- Mineral waste strategy and constructability reviews; and
- Risk register and decision framework development.

The outcomes of this study meant that Rio Tinto was able to make an informed decision on the future PAF waste storage location based on risk and other business considerations. The strategy developed by the study team had management support and a waste management strategy was developed that is unique within Rio Tinto. This study is an example of developing an upfront informed management strategy to support an effective life of mine plan, rather than placing the material in a sub-optimal location.

Case Study 2: Avoidance of PAF material

During the study phase for three Rio Tinto mine sites, investigations were undertaken to determine the amount of PAF material within proposed pit shells. This included an evaluation of uncertainty due to gaps in drilling data and the potential for any inaccuracies in the geological modelling.

Based on the risk assessment process (Green and Borden 2011) and the confirmation of PAF material exposed on the proposed pit walls, the mine plans for each development project were revised to avoid or minimise exposing PAF material. This reduced the likelihood that acidic pit lakes would need to be managed in perpetuity.

Conclusions

Mining and ore processing unavoidably generates large volumes of mineral waste which may have long-term environmental impacts. Appropriate identification and management of chemically reactive mineral waste can:

- **Ensure accurate valuation of projects, acquisitions, and expansions** by characterising the waste material and assimilative environment to identify and assess the true long-term costs of mineral waste management.
- **Reduce operational costs** over the long-term by minimising the volume of reactive mineral waste that must be selectively managed, and by implementing upfront management of mineral waste rather than management of impacts once they have already occurred.
- **Reduce closure costs** by designing waste disposal facilities with a consideration of rehabilitation requirements.
- **Reduce environmental and health risk** and improve outcomes by on-going monitoring of mineral waste repositories and receiving environments.
- **Enhance business reputation** through better stakeholder relationships that take into account community expectations of the management of mineral waste and by minimising the intensity and duration of mineral waste disposal impacts.

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