Geochemical Assessment of Mineral Waste through the Mine Life Cycle

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Abstract

Although chemically reactive waste represents a small percentage of the waste generated by many mining operations, it creates many of the waste related environmental, health, reputation and financial risks for mining companies. Geochemical assessments throughout the mine life cycle are essential and four case studies spanning from Exploration through to Closure are presented in this paper. These case studies demonstrate the need for upfront baseline characterisation, the potential to avoid geochemically reactive material through appropriate risk assessment, the need to validate dump designs and the importance of quality control during construction of covers over reactive waste dumps.

Keywords: acid and metalliferous drainage, mineral waste, exploration, case studies, Pilbara, mine closure

Introduction

Mineral waste is composed of rocks or unconsolidated sediments that are disturbed or exposed by mining. Mineral waste can also be composed of mineral residue generated by the processing of ore. The environmental exposure hazards of reactive mineral waste or Acid and Metalliferous Drainage (AMD) whose innate physical, chemical or biological properties could now or in the future pose harm are a major risk to many mining operations. Reactive mineral waste can cause harm by: degrading contact water quality causing human health or ecological impacts; posing a direct exposure risk to plants, animals and humans that live on, ingest or grow in the waste (preventing vegetation from re-establishing); and degrading air quality by dust or gas emissions.

Geochemical characterisation of waste material is an essential tool that mine sites utilise in many ways including avoidance, dump design, monitoring, treatment and closure geochemical predictive modelling. Significant progress has been made to develop characterisation methodologies to predict AMD and subsequently to develop management and treatment techniques (*INAP 2009*). Yet despite this progress, management of AMD presents major challenges in many mine operations around the world and accounts for a major part of day today and closure related expenses.

Upfront and continual accurate geochemical assessments can ultimately:

Ensure accurate valuation of projects, acquisitions, and expansions by characterising the waste material and assimilative environment to assess the true long-term costs of mineral waste management.

Reduce operational costs over the long term by minimising the mass of reactive mineral waste that must be exposed, 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.

Account for the value of mineral waste management strategies to support the implementation of other strategies related to biodiversity and water.

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.

Geochemical characterisation during the entire mine life cycle from Exploration through to Closure will be broadly discussed using case studies from Rio Tinto Iron Ore's (RTIO's) Pilbara mine sites, located 1,200 km North of Perth in Western Australia. The discussion is not exhaustive and the amount of geochemical characterisation will vary depending on the commodity, mining and processing techniques. An upfront risk assessment that is reviewed for any new expansions is critical in dictating the level of geochemical assessment required (*Green and Borden 2011*).

Methods

Broadly four stages of the mine life cycle are discussed in this paper however in reality there are significantly more phases within each stage. RTIO use management plans to detail and standardise the geochemical test work required throughout the mine life cycle by a variety of groups within the business. Within these management plans are a series of guidance documents that provide information on assessment triggers, modelling expectations, characterisation expectations, typical geology, hyperlinks to previous reports, standard dump designs, contingency plans and rehabilitation guidance.

Results and Discussion

Exploration

The exploration phase for a deposit can vary from a number of small to very large programs. The extent of geochemical characterisation obviously needs to be flexible depending on the size of the program and the availability of existing data. The extent of characterisation necessary should be determined from an early geochemical risk assessment (*Green and Borden 2011*). Often the focus of a drill programs is on the ore however it is also important to ensure sufficient waste that surrounds the ore body is geochemically characterised. Geochemical characterisation work during the exploration phase can include:

- Developing a conceptual understanding of AMD risk: Identify if more work is necessary and if sufficient waste has been drilled to understand the risk. Extra holes may need to be drilled to reflect waste

characteristics and understand material in the groundwater cone of depression.
- Routine geochemical analysis: including distinction of oxidised versus unoxidised, sulfur and trace metals assays.
- Detailed geochemical characterisation: focused characterisation on high risk lithologies and including typical static acid base accounting, kinetic and mineralogy test work.
- Identify synergies and experience elsewhere: using both internal and publically available data.
- Identify if sulfidic (or metalliferous) lithologies can be isolated: and consider this in geological models.
- Monitor background water quality: at least two years of data to represent seasonal variability in both surface and groundwater.

Case study: Importance of baseline water quality assessments

Since the start of monitoring elevated sulfate concentrations (up to 5,400 mg/L) have been measured in some groundwater bores surrounding the sulfide containing Marra Mamba waste dump at Tom Price mine site. The pH is neutral and metal concentrations are generally low. Whilst 13 years of data has been collected, unfortunately the monitoring bores were not installed before construction began of the dump. Therefore baseline information for the site is unavailable.

Sulfate is known to be naturally elevated within the screened lithology of the monitoring bores and sulfidic material was encountered during bore construction. Whilst modelling has shown that the sulfate source is likely natural, it would have been simpler and more conclusive if monitoring was undertaken early in the dump construction to prove this. This case study demonstrated the importance of installing monitoring bores early to characterise background water chemistry prior to the dumping of sulfidic material.

Study

- The study phase of a project involves the evaluation of how the deposit will be mined and includes metallurgical assessments, planning and geological modelling amongst numerous other considerations to make the mine operational. Some important geochemical considerations during this phase include:
- AMD Risk assessment: determining the high risk lithologies using drill hole information, material tonnages in the pit shell and assessment of detailed geochemical test work (*Green and Borden 2011*).
- Ecological risk assessments: assessing the risks and pathways to potential receptors.
- Develop management plans: including dump design, pit void management, responsibilities and avoidance strategies.
- Metallurgical assessment of tailings: potential geochemical assessment of tails if there are pilot scale studies.
- Hydrology and hydrogeology studies: assessing the risk of geochemically reactive material in the groundwater cone of depression, assessing

bunding options to reduce AMD volumes and risk based pit lake predictions.

Case study: Avoidance of geochemical risks through early risk assessment identification

At Koodaideri there is potential for sulfide exposures within one of the pit shells and directly underlying mineralisation. Drilling indicated that no sulfidic black shale was expected within the pit shell, however there is still some uncertainty due to gaps in the drilling data and potential for inaccuracies in the geological modelling.

Based on the risk assessment and the identification of black shale potentially in the pit wall, the mine plan is being redone to avoid or minimise exposing the black shale. This will reduce the likelihood of an acidic pit lake that will need to be managed indefinitely, and will also speed up and increase the likelihood of government approval for the project.

Operations

During the mine operation it is important to continually geochemically assess material as the pit shell deepens or if new material is mined. Other geochemical considerations during this phase of the mine life are:

Validate management options: potentially include cover trials and monitoring, continually refine pit lake predictions and assess dump behaviour.

- Continually review management and closure plans.
- Communication and training.
- Monitor water quality around high risk dumps and pits.
- Acid water treatment.

Case study: Validating dump designs

Carbonaceous and sulfidic black shale which has the potential to combust is mined at several mine operations in the Pilbara. Dump designs for the material with the greatest risk of combustion consist of an inert layer between the reactive layers to dissipate the heat. During mine operations it is important to validate the design to ensure the dump is behaving as expected. Several reactive waste dumps have been drilled and geochemically characterised. Some of the results from this work include:

- Oxygen is supplied by diffusion and there is no evidence of convection.
- Oxygen may be supplied by diffusion from below the black shale layer as well as above.
- Significance amounts of black shale are not generating AMD due to oxygen supply limitations.
- The maximum temperature was 36°C so it is clear there is no combustion of black shale in the dump.

Closure

Once the operation has stopped production of ore there can be a substantial amount of work involved to close the mine. Ideally closure should be planned during the study phase and this can reduce rehandling of material and potential negative environmental and financial surprises. In some cases AMD treatment and monitoring can be ongoing indefinitely. Important geochemical considerations for mine closure include:

- Water quality monitoring.
- Rehabilitation and remediation.
- Validation of modelling with monitoring data and refining models as necessary.

Case study: Importance of quality control during final landform construction

During an inspection of the store and release cover construction for a sulfidic waste dump at Tom Price mine site it was noticed that large boulders were being used within the cover. Obviously large boulders could promote preferential flow in the cover and would not support the necessary function of the cover. In this case study, the cover had to be reconstructed using properly graded material and with an improved quality control program.

Conclusions

Four case studies of geochemical assessments during exploration, the study phase, mining operations and closure are presented within this paper. These case studies demonstrate the practical application of geochemical test work.

During the exploration phase the importance of upfront geochemical baseline assessment is demonstrated. It becomes difficult to set appropriate water quality discharge triggers without this information and modelling may be necessary to assess any impacts from reactive mineral waste. During the study phase the importance of AMD risk assessments is highlighted. Upfront planning around geochemical risks can ultimately save both negative environmental and financial outcomes. During the mine operations it is important to validate assumptions and ensure the waste dump designs are functioning as planned. This can reduce the potential for rehandling or potential long term treatment of poor water quality. It is important that final landform structures are built as designed. If the construction is not quality controlled then the system will not behave as expected and remediation or rehandling may be necessary.

References

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