HASTINGS
Technology Metals Limited

APPENDIX 5

Hastings Technology Metals Limited
Yangibana Rare Earths Project

RESEARCH FRAMEWORK

12 December 2018

A number of potential issues have been raised by Department of Water and Environmental Regulation (DWER; as per the background description in each section below) due to the nature of the resource being mined and processed. However, research in this area has not been specific to the semi-arid environment of the Project area and is often laboratory based. The following research framework developed in consultation with DWER aims to reduce the level of uncertainty in this area and further inform potential risks associated with mining and processing of Rare Earth Elements:

1. Heavy metal characterisation
2. Characterisation of the hyporheic environment
3. Metals uptake by flora on rehabilitated landforms

1.0 Heavy metal characterisation

Background

Some mine rock materials that have low sulfide contents have the potential to leach significant amounts of harmful chemical constituents to the environment, particularly of metals and metalloids that form stable oxyanions in water (MEND, 2004)[1]. There is a risk that this could occur at the Yangibana deposits because of the unusual characteristics host-rocks in these deposits. A review of carbonatite-hosted rare-earth deposits undertaken by the US EPA (US EPA, 2012)[2] indicated that a range of metals and metalloids have the potential to be released under neutral to alkaline conditions from waste rocks (neutral mine drainage) including zinc, cadmium, antimony, arsenic, selenium, uranium and vanadium.

The leaching tests that have been undertaken to-date on rocks from the Yangibana deposits are designed to assess the leaching potential of partially weathered wastes near the surface of a waste-rock or tailings landform that are exposed to rainfall. They are "single scenario" tests that do not consider the potential for chemical constituents to become mobilised if wastes are exposed to different geochemical conditions such as being covered by a soil profile after mine closure.

Additional test procedures would be required to assess the leaching potential of mine-wastes in other exposure scenarios such as the use of test procedures in the US EPA Leaching Environmental

[1] MEND, 2004. Review of Water Quality Issues in Neutral pH Drainage: Examples and Emerging Priorities for the Mining Industry in Canada. MEND Report No 10.1 which is available from web site http://mend-nedem.org/mend-report/review-of-water-quality-issues-in-neutral-ph-drainage-examples-and-emerging-priorities-for-the-mining-industry-in-canada/.

[2] US EPA, 2012. Rare Earth Elements: A Review of Production, Processing, Recycling and Associated Environmental Issues. US EPA Report EPA 600/R-12/572. The report is available from web site www.epa.gov.

Assessment Framework (LEAF) suite of tests coupled with geochemical modelling using the ORCHESTRA model (US EPA, 2017[3]).

Objective 1:

Determine the mobilisation and release of toxic chemicals under a range of pH values

Initial scope of work:

1. Review of the soluble metals associated with the waste and tailings characterisation to-date
2. Collection of tailings from TSF 1 and 2 during operations and under steady state conditions
3. Verification of TSF characterisation conducted to-date using tailings generated during operations
4. Define the pH range of tailings under operations scenarios and closure scenarios
5. Conduct laboratory testing of the tailings under a full range of pH values (using the US EPA leaf test 1313 or similar)
6. Conduct geochemical modelling

Potential next steps:

Based on the outcomes from the initial scope of work, the potential next steps include:

- Develop mitigation plan should scope of work highlight risk of impact to surrounding environment
- Conduct further laboratory testing

Timeframe:

The initial scope of work will be conducted within one year of operations generating tailings under steady state conditions.

[3] US EPA, 2017. Leaching Environmental Assessment Framework (LEAF) How-to Guide: Understanding the LEAF Approach and How and When to Use It. US EPA technical report that is available from web site https://www.epa.gov/sites/production/files/2017-11/documents/leaf_how_to_guide.pdf.

2.0 Characterisation of the hyporheic environment

Background:

Sensitive receptors of potential concern are fauna in hyporheic zones beneath nearby ephemeral creeks. There is potential for impacts of groundwater contaminated by leachate from mine wastes on the hyporheic zone in the network of creeks that surround the mine site. Although these water courses are ephemeral in nature, it is possible that sands and gravels beneath creek beds contain a hyporheic fauna (stygofauna) that has the potential to be affected by mine discharges. Although this fauna is likely to be fairly depauperate by comparison with the fauna in calcrete bodies lower in the catchment, measures should be taken to limit the potential impacts of mine discharges on the hyporheic zone of local creeks which are potentially located very near the proposed mine-waste landforms.

Objective 2:

Determine the composition and characterisation of the hyporheic environment within the drainage channels in the immediate vicinity of the Tailings Storage Facilities.

Initial scope of work:

Engage study (by a university student) to characterise the ecology of the drainage channels in the immediate vicinity of the TSF 1 and 2 including:

1. Define the hyporheic environment of the drainage channels (depth, moisture content in soil, salinity, pH, chemical ecology).
2. Characterise the invertebrate species composition and species richness in the hyporheic environment.

Potential next steps:

Based on the outcomes from the initial scope of work, the potential next steps include:

- Conduct ecotoxicology study
- Develop monitoring program including trigger levels
- Identify contingency actions should trigger levels be exceeded

Timeframe:

The initial scope of work will be conducted during the operations phase.

3.0 Metals Uptake by Flora on Rehabilitated Landforms

Background:

A second potential group of environmental receptors are vegetation and soil fauna that will be established on mine-waste landforms after mining ceases at the Yangibana deposits. The ore and host rocks at the Yangibana site contain elevated concentrations of phosphorus in a region which is otherwise often deficient in this nutrient, and it is likely that soil fungi, bacteria and plant roots in soils on waste landforms after mine-closure will access this phosphorus by exuding organic acids to attack phosphate-containing minerals in the wastes (Gad, 2007)[4]. This organic acid attack can also release metals into soil pore-water where they can be taken up by soil fauna and vegetation. Even the highly resistant mineral monazite can be attacked by soil fungi to cause the leaching of rare earth elements (Corbett et al., 2017)[5]. Metals that are released into soil pore-water through leaching by organic acids in soils can then enter local food-webs.

Objective 3:

Determine the uptake of soluble metals in the soil-plant continuum of rehabilitated landforms.

Initial scope of work:

1. Determine elevated soluble metals in waste rock and tailings material for rehabilitation
2. Identify flora species to be used on rehabilitated areas and potential indicator species
3. Engage research student to conduct laboratory-based assessment of uptake of soluble metals by indicator species
4. Determine the potential for fungi, bacteria and plant roots to release organic acids and influence the solubility of metals in the waste materials (i.e. waste rock and tailings from TSF 1 and 2)
5. Determine effects if bioaccumulation occurs in indicator species

Potential next steps:

Based on the outcomes from the initial scope of work, the potential next steps include:

- Assess in situ uptake of soluble metals by indicator species on rehabilitated landforms
- Determine availability of soluble metals on landforms at closure
- Assess potential of animal ingestion of elevated metals concentrations in plant material
- Conduct a 'Final Land Use' study as a component of closure planning to assess thresholds of metal concentrations in water and soils taking account ANZECC guidelines (and other thresholds).

Timeframe:

The initial scope of work will be conducted within the first five years of operations.

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[4] Gad, G.M., 2007. Geomycology: biogeochemical transformations of rocks, minerals, metals and radionuclides by fungi, bioweathering and bioremediation. Mycological Research, 111, 3-49. The paper is available from web site http://dzumenvis.nic.in/Microbes%20and%20Radionuclide%20Pollution/pdf/Geomycology%20biogeochemical%20transformations.pdf.

[5] Corbett, M.K., Eksteen, J.J., Niu, X-Z., Croue, J-P. and Watkin, E.L., 2017. Interaction of phosphate solubilising microorganisms with natural rare-earth phosphate minerals: a study utilising Western Australian monazite. Bioprocess and Biosystems Engineering, 40, 929-942.