Innovative approach to the development of a mine water remediation R&D portfolio

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Abstract

Rio Tinto recognises that its impact and responsibilities do not end with the cessation of its mining operations, but instead it should leave a positive legacy that delivers value to its shareholders, the environment and the community at large. To achieve this goal Rio Tinto built a mining-influenced water (MIW) remediation and valorization roadmap to guide the development of a diversified portfolio of research and development (R&D) initiatives now and into the future. To accelerate the identification of MIW R&D opportunities a novel crowdsourcing campaign was launched, which was successful in identifying 14 R&D initiatives with 27 research institutions across the globe.

Keywords: Crowdsourcing innovation, mining-influenced water, circular economy, research and development

Introduction

Mine closure is a growing concern for the global mining industry. Around the world, Rio Tinto has 97 active closed and legacy assets, with a further 20 sites planning to transition to closure in the next 10-15 years. Each of these sites represents a unique challenge with regards to the approach and technologies required to deliver the best possible outcome for the business and the receiving environment. Through the adoption of a circular economy mindset, many of these sites also present an opportunity for valorizing valuable metals and other materials from resources that are otherwise considered waste. In recognition of this challenge and by applying this mindset, Rio Tinto established a closure-focused R&D group with the aim of discovering and supporting the development of cutting-edge technologies that can significantly reduce the long-term impacts of mine asset closure, by not only treating wastes, but simultaneously valorizing these waste resources.

When considering the broad range of challenge themes related to mine closure – mineral and non-mineral wastes, earthmoving and landforming, mining-influenced water (MIW), restoring and repurposing, demolition, post-closure monitoring – innovative technologies may have a limited impact on improving outcomes for some of these challenge themes. Rio Tinto Closure R&D reviewed the needs, opportunities and the potential to deliver impactful technology development for each challenge theme. Sustainable MIW treatment was determined to be particularly suitable as an R&D focus theme. The reasons for this were:

- MIW treatment can play a significant role in minimising environmental impacts as well as potentially contributing to the circular economy by recovering resources, such as metals and water for reuse
- Water treatment processes are technology-based which fits with Rio Tinto Closure R&D's focus
- Experience from other industries (municipal and industrial wastewater treatment) have shown that significant step-changes in treatment capability and capacity can be achieved through innovative technology development and application

Based on the outcomes of this review, a decision was made to invest in a long-term, diversified R&D program focused on changing the dynamics of MIW treatment. In 2021, Rio Tinto commissioned the Sustainable Minerals Institute at The University of Queensland to undertake a foresight study for MIW treatment technology (Sustainable Minerals Institute, 2021). One of the key outcomes from this study was that the sheer number and diversity of technologies that could be applied to meet the challenge of MIW treatment was a limiting factor in the ability to assess and select the best available technologies (BAT) for Rio Tinto's needs. A novel approach to sourcing R&D projects was therefore required.

Roadmap development

To guide the development of mine closure focused R&D opportunities into the future, an MIW remediation and valorization R&D roadmap was established by Isle Utilities (Isle) in collaboration with Rio Tinto. The purpose of the roadmap was to provide inspiration and act as a platform to engage internal and external stakeholders and ultimately catalyse the development of new projects to achieve Rio Tinto Closure's goals. At the same time, the roadmap would be a structural element to guide discussions and for collating and organising the inputs received.

The roadmap included input from sites operated by Rio Tinto Closure regarding their current needs and expectations for future requirements. The roadmap defined the key areas of interest together with the goals and challenges expected over three horizons of time (NOW 1-3 years, NEW 3-5 years and NEXT 5-10 years), along with the drivers behind each area of interest. These areas of interest (AOIs) are listed in Figure 1.

The roadmap also identified existing technologies that have the potential to be transformational if deployed specifically for MIW treatment. These technologies were generally sourced from non-mining related applications and would require some development to meet the demands of MIW treatment or were technologies that were still at a very early technology readiness level (TRL) and had not been tested outside of the lab or even on real MIW.

Solution Identification

Following the development of the MIW R&D roadmap, Isle undertook a survey of the current global technology market capabilities for treatment and valorization of

SELECTIVE	Solutions that can target and **effectively remove targeted constituents for enhanced water recovery**, reduce residual wastes, and resource valorization (in a high-quality form) to generate new revenue streams and offset closure costs
SUSTAINABLE	Solutions with **low and/or renewable chemical and energy** use for increased supply chain resilience and minimal carbon footprint
VERSATILE	**Modular and scalable** solutions are those are innovatively designed and fabricated for reduced cost and manufacturing lead time, increased reusability and rapid scale-up, down or out
RESILIANT	Solutions that are **adaptable regardless of changing environmental regulations**, climate uncertainty and variable mine water quality and quantity enabling reliable treatment systems
AUTONOMOUS	**Passive water remediation solutions that can operate independently**, with minimal component replacement to improve treatment resilience, longevity, and staff safety at remote sites

Figure 1 *Five R&D opportunity areas, or areas of interest were developed as part of the technology roadmap.*

MIW. Several solutions were identified across the TRL spectrum, from concept through to pre-commercialisation. However, despite the number and diversity of solutions identified, few options were suitable for Rio Tinto's specific needs as identified in the roadmap.

This survey made it clear that there is a wide range of technology development underway across the globe related to MIW treatment. Given the constraints on internal R&D team resources and the imperative for a sustainable R&D pipeline, traditional pathways of sourcing R&D projects were considered unfeasible and likely unable to deliver a strong pipeline of projects within 12 months. Therefore, a crowdsourcing campaign was designed to accelerate the identification of MIW R&D opportunities, improve Rio Tinto's innovation network within the field, while at the same time supporting a competitive comparative assessment of solutions to meet the requirements laid out in the MIW R&D roadmap.

Crowdsourcing Campaign

Rio Tinto has a strong tradition over the past 150 years of innovation in the mining industry. To support the sourcing of innovative solutions, Rio Tinto has an online innovation platform called the "Pioneer Portal" which many innovators around the globe were already familiar with. Therefore, as it became clear that an innovation crowdsourcing campaign was the preferred pathway to identify solutions for the MIW treatment R&D portfolio, Rio Tinto in collaboration with Isle decided to re-purpose the Pioneer Portal for the campaign. By changing the dynamics of technology identification through a direct crowdsourcing approach, the objectives were:

- To increase the number of technologies that Rio Tinto would have a direct relationship with
- Support a competitive, comparative assessment of the technologies to meet the requirements identified in the roadmap and translated into the crowdsource campaign

An important requirement posed in the challenge were the water quality and treatment objectives the technologies would need to address at Rio Tinto sites. A summary of the four MIW examples provided in the challenge is presented in Table 1.

The crowdsourcing campaign was launched in April 2022 and received 98 submissions after six weeks. This vastly exceeded the expectations and connected Rio Tinto with organisations that they would not otherwise have unearthed via traditional means of identifying and sourcing innovation. A two-phase assessment program was developed with the aim of ensuring that not only was the solution concept robust and there was a diverse range of technology types, but also that the MIW type and constituent recovery was relevant to Rio Tinto's sites. A summary of this selection process is outlined in Figure 2. As illustrated, the final 14 projects selected represent a range of technology readiness levels, target contaminants/metals in MIW and are based at sites around the globe that reflect the presence of Rio Tinto as a company.

The process for selecting the final 14 projects to be part of the MIW treatment R&D pipeline was rigorous. From the start of the process, a detailed set of assessment

Table 1 *Summary of MIW examples from Rio Tinto sites provided as part of the crowdsourcing campaign. More detailed water chemistry was provided through the Pioneer Portal*

Specification	Source	Contaminants of interest for recovery	Rio Tinto treatment objectives
AMD – high flow	Metalliferous mining site	Cu, Co, Zn, REEs, Ni, S	Recovery of target metals
AMD – low flow	Metalliferous mining site	Cu, Co, Zn, REEs, Ni, S	Recovery of target metals
Neutral MIW	Groundwater at mining site	As, B	Removal to meet environmental regulations. Valorization of B and potentially As
Alkaline leachate	Bauxite residue storage facility	V, Ga, REEs	Adjustment of pH and recovery of target metals

criteria were applied in the assessment of each project. The process relied on internal and external subject matter experts (SMEs) to provide diverse input based on experience in the mining and water treatment industries. An online collaborative software package (Sideways 6) was applied to allow a global team of SMEs to collaborate around this project. Throughout the process, feedback was provided to each shortlisted project with the responses provided forming part of the material being assessed by the SMEs. During the review period, the assessment team was able to connect several technology-adjacent projects with each other to create stronger collaborative projects.

When considering the outcomes from the challenge, analysing the TRL level of the projects selected provides an insight into how Rio Tinto has approached the development of this specific R&D pipeline. Fifty percent of the projects are TRL 4-6, the area between laboratory proof of concept (POC) and piloting/scaling. This is not surprising as weighting in the assessment gave credit to technologies that had a proof of concept in place but still fit the definition of an R&D project. Forty percent of the projects are early stage and represent high reward/high risk type projects that Rio Tinto felt could deliver game changing advances in selective treatment of MIW. The high TRL projects (7-8) represent technologies that are already commercially viable in other sectors, but where the adaptation of the technologies for MIW treatment requires investment in fundamental R&D to understand how they can be adapted to deliver the outcomes required by Rio Tinto.

In recognition that the objective of this challenge is to create and populate a sustainable and productive R&D pipeline, a key requirement is to understand the technical risks in each project and how this portfolio wide risk can be managed effectively. The approach taken was to map out the technology "family" of each project. As illustrated in Figure 3, there is a wide spread of technologies being addressed as part of the MIW R&D pipeline, with no one technology family dominating. This approach should ensure a balanced outcome from the R&D pipeline, with a toolbox of options being developed and made available to Rio Tinto, rather than a single technology. Technology taxonomies and other R&D management approaches were applied to ensure that each component of interest in the example MIWs was being addressed and a broad range of technologies were part of the pipeline.

Discussion and Conclusion

The entire process from the launch of the Sustainable MIW Treatment Crowdsource

Figure 2 *Summary of the MIW crowdsourcing campaign process*

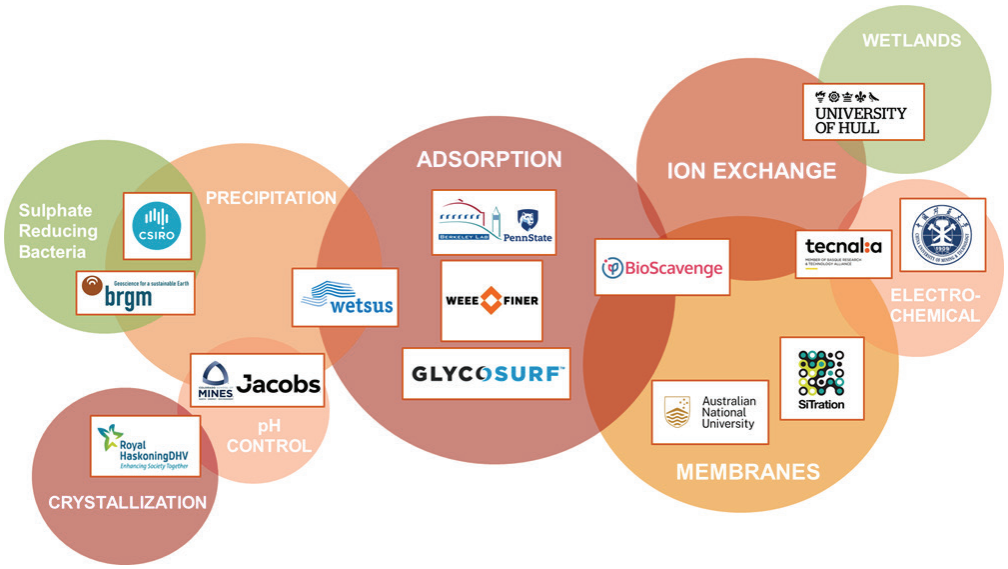

Figure 3 *Technology map of the 14 selected technology providers and the approach being taken in the projects submitted to the crowdsourcing campaign.*

Challenge to the selection of 14 projects to enter project agreement negotiations lasted seven months. Compared to traditional approaches of sourcing R&D in Rio Tinto, this represents a significant reduction in time and increase in number and quality of projects entering the R&D pipeline. Another benefit of the crowdsourcing approach has been that several promising technologies that did not meet the requirements for the MIW treatment challenge have been connected with other business units within Rio Tinto – for example technologies related to battery mineral recovery. These outcomes have demonstrated that despite taking an untried, broad and high-risk approach to sourcing innovation for a focused specialised topic area such as selective MIW treatment, the outcome has been very successful with Rio Tinto attaining its objective of populating a sustainable R&D pipeline for innovative MIW treatment technologies in a cost and time efficient way. The success of this challenge has inspired other functions and product groups within Rio Tinto to pursue a similar approach.

A key learning from this novel process is that having a clear objective, detailed preparation (in the roadmap development), strong stakeholder engagement and a clear set of criteria for assessing the projects that are submitted will provide strong outcomes that meet the expectations of the sponsoring R&D group. Marketing is also key in order to reach the broadest possible audience. In respect to this, professional social media channels such as LinkedIn provided an opportunity to reach a global yet relevant audience for the crowdsourcing campaign.

An unexpected positive outcome from the process has been the development of a connectivity map between many of the submitted projects, allowing synergistic partnerships to deliver stronger outcomes and further the scope of progress during the project delivery phase. This process has resulted in 14 projects being selected with 27 participating entities from across the globe. This unique approach is expected to deliver positive outcomes for the MIW R&D pipeline at Rio Tinto over the next 2-5 years and the methodology has already been replicated in another program to

develop next-generation in-situ and remote sensing technology solutions. Rio Tinto's goal to have a toolbox of technically strong and commercially viable technologies to meet the long-term challenges related to selective MIW treatment now has a greater chance of success after the positive outcomes of this novel R&D crowdsource campaign.

This example clearly demonstrates the value that a well-designed and executed R&D crowdsourcing campaign can be adapted to fit the needs of the end-user (in this case, Rio Tinto) and has significant potential to be applied across the mining industry to meet fundamental technology challenges and deliver significant value to the end-users.

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