Appendix:
Remediation and Valorisation of Mining-Influenced Waters (MIW)

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Rio Tinto's MIW Areas of Interest (AoIs)

Rio Tinto are looking for solutions that address the mining-influenced water (MIW) remediation challenges faced during the closure of mining assets. Rio Tinto has articulated five Areas of Interest (AoIs) which guide the development of a diverse range of innovative solutions.

Rio Tinto's five R&D Areas of Interest are:

- **Selective** solutions that can target and efficiently remove constituents for enhanced water recovery, reduced residual wastes, and resource valorisation (in 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 that are innovatively designed and fabricated for reduced cost and manufacturing lead time, increased reusability and rapid scale up or down
- **Resilient** solutions which are adaptable regardless of changing environmental regulations, climate uncertainty and variable mine water quality and quantity enabling reliable treatment systems
- **Autonomous** and passive water remediation solutions that can operate independently, with minimal component replacement to improve treatment resilience, longevity, and staff safety at remote sites.

Campaign focus: Selective AoI

The focus of this crowdsourcing campaign is to identify selective solutions that can target and efficiently remove constituents for enhanced water recovery, reduced residual wastes, and the valorisation (recovery in high-quality form) of resources to generate new revenue streams and offset closure costs.

The goal of this AoI is to identify and implement treatment solutions that can achieve:

- Specific removal of contaminants known to adversely affect downstream treatment processes or impeding end uses or recovery approaches
- Selective separation of high value constituents (e.g., Cu, Ni, Co, Li, Zn, Mn and rare earth elements (REEs)) in the water and waste in a high-quality form that is readily commercialised
- Develop new revenue opportunities from the development of local opportunities such as the production of a fit-for-purpose water supply for communities, industries and agriculture

Why is this important?

Market opportunity

Raw materials form the basis of the global economy today and will do so in the future. They are fundamental and irreplaceable in driving change. Due to the nature of mining operations, valuable elements can still be found in the various waste streams, including MIW. To date, the focus has been on waste management to remain compliant to environmental regulations. For instance, water treatment plants (WTPs) are typically operated with the aim to achieve specific discharge limits.

While the techniques employed are fit for that purpose, they often treat contaminants in an unselective manner. When high levels of metal(loid)s and rare-earth elements are present, a shift towards selective removal can support the transition to a more circular economy and the creation of new revenue streams.

For example, a high concentration of a broad range of contaminants may be present in a mine site at high flow rates, meaning bulk separation of the contaminants may generate a considerable amount of sludge. Consequently, there is an opportunity to selectively remove contaminants of concern, as well as recover high value metals and reduce the waste generated at the site.

Resource Efficiency

Selectively removing contaminants of concern could help support new end uses and improve societal footprint. For instance, producing high-quality final effluent could help address water scarcity in some affected areas and selective removal of contaminants can also improve water recovery. A common example is that zero liquid discharge techniques are limited by TDS content in the water. Reducing this parameter prior to such treatment can help further improve its performance.

Ultimately, designing selective processes is closely related to the advancement of novel selective materials/technologies. Integrating innovative materials and processes can lead to reactive separations enhancing modularity and recovery.

For example, palladium may be detected in the water treatment sludge at a mine site, however, selective separation may be a challenge and require a rethink of current site processes and the development of novel separation techniques.

Policy and Regulatory Compliance

MIW are complex due to their temporal variability both in quantity and quality. Additional efforts might be required to address recalcitrant contaminants. The selective removal of certain contaminants is crucial as these can have acute toxicity at low concentrations. This precise targeting might be particularly relevant for sites where water discharges have a direct impact on the receiving environment.

It is common for operational permits to derive discharge limits based on mass flow (e.g., treatment required when mass flow exceeds the specified value). As such, WTPs could be optimised to target specific contaminants when it exceeds the discharge limits thereby further supporting optimised chemical usage and potential interventions.

Key solution performance criteria	Solutions in this area should be able to achieve at least one of the following: – Address recalcitrant contaminants of concern while maintaining performance regardless of seasonal variations; – Present novel and high-performance techniques for selective separation over state-of-the-art approaches across multiple pipe parity metrics relative to status quo techniques without significantly compromising other pipe parity metrics; – Adaptable and not using one-off sorbents/solutes for a niche application; and/or – Increase the value, quality and/or commercialisation value of removed constituents (i.e., integration with downstream processes).

Interconnectedness of solutions

The focus of this crowdsourcing campaign is identifying selective solutions, but it is understood that they will likely interconnect with the other AoIs. Some examples of this interconnectedness and the value it can bring to a solution are:

- Selective systems that can extract valuable reagents, metals, clean water, and separate salts are sustainable by virtue of their ability to recover usable materials that would have gone to waste and can in turn generate revenue to defray the cost of treatment.
- An autonomous selective treatment system that can be operated and monitored remotely requires minimal operator intervention and by its nature tends to be more sustainable as it will require low levels of chemical and energy inputs
- A modular and mobile or containerised selective treatment plant that can be deployed on a number of sites as needed makes more sustainable use of the materials and energy of construction and enables versatility in treatment unit operations across and between sites.

Technology Readiness Level (TRL) definitions

Technology Readiness Levels		Description	Supporting Information
1	Basic principles observed and reported	Scientific research begins translation to applied R&D. Paper studies of published peer reviewed papers.	Published research identifies the principles that underlie this technology.
2	Technology concept and/or application formulated	Invention begins, practical application is identified but is speculative, no experimental proof or detailed analysis is available to support the conjecture.	Publications or other references that outline the application being considered and that provide analysis to support the concept.
3	Analytical and experimental critical function and/or characteristic proof of concept	Active R&D initiated (physical validation in laboratory)	Results of laboratory tests performed to measure parameters of interest and comparison to analytical predictions. Confirm technology concept has firm scientific underpinning. References to who, where, and when these tests and comparisons were performed.
4	Technology component validation in laboratory environment	Basic technological components are integrated to establish they will work together.	System concepts that have been considered and results from bench scale testing of the technology. References to who did this work and when. Details of how the bench scale technology and test results differ from the expected goals. For process technologies, the typical capacity of a bench-scale plant can be between 0.001 to 0.01% the one required for a commercial-size implementation.
5	Components/technology validation in relevant environment	Technology tested in a large bench scale laboratory environment using real world fluids, data or setpoints (more realistic simulation)	Results from testing technology are integrated with other supporting elements in a simulated operational environment. How does the “relevant environment” differ from the expected operational environment? How do the test results compare with expectations? What problems, if any, were encountered? Were the technology components refined to match the expected system goals more nearly?
6	Prototype demonstration in a relevant environment	Prototype evaluation in a simulated laboratory operational environment	Results from laboratory testing of a prototype system that is near the desired configuration in terms of performance, weight, and volume. How did the test environment differ from the operational environment? Who performed the tests? How did the test compare with expectations? What problems, if any, were encountered? What are/were the plans, options, or actions to resolve problems before moving to the next level? For process technologies, the typical capacity of a pilot plant can be between 0.01 to 1% the one required for a commercial-size implementation.

Technology Readiness Levels		Description	Supporting Information
7	Prototype demonstration in an operational environment	Whole system prototype evaluation in actual operational environment (on a water, wastewater or network site)	Results from testing a prototype system in an operational environment. Who performed the tests? How did the test compare with expectations? What problems, if any, were encountered? What are/were the plans, options, or actions to resolve problems before moving to the next level?
8	Actual technology completed and qualified through test and demonstration	Final phase of technology development; validation of technical performance and compliance with design specifications (Initial commercial trials)	Results of testing the system in its final configuration under the expected range of environmental conditions in which it will be expected to operate. Assessment of whether it will meet its operational requirements. What problems, if any, were encountered? What are/were the plans, options, or actions to resolve problems before finalizing the design? For process technologies, the typical capacity of a demonstration plant can be between 1% to 10% the one required for a commercial-size implementation.
9	Actual technology proven through successful operations	Actual commercial application of the technology in its final form and under real world conditions (Commercial trials).	Operational commissioning reports.

Target use cases

Influent data	Site #1: **AMD Case 1**	Site #2: **AMD Case 2**	Site 3: **Alkaline Seepage**	Site 4: **Neutral with high As + B + TDS**
Average flow (m^3/h)	250	2500	10 - 50	50
pH	2.5 - 3.5		10 - 13	7 - 8
Al (mg/L)	500 - 2500	250 - 500	25 - 100	
As (mg/L)	0.05 - 5		0.05 - 5	10 -20
B (mg/L)				1000 - 5000
Ba (mg/L)	0.05 - 1.5			
Ca (mg/L)	100 - 400			
Cd (mg/L)	0.02 - 0.04			
Ce (mg/l)	2			
Cl (mg/L)	150 - 1000			
Co (mg/l)	10 - 20	5 - 10		
Cr (mg/L)	0.01 - 0.1			
Cu (mg/L)	200 - 650	50 - 200	1 - 5	
Dy (mg/l)	2			
Er (mg/l)	1			
Eu (mg/l)	0.5			
F (mg/L)	1 - 10	1 - 10	10 - 50	
Fe (mg/L)	50 - 100	10 - 50	25 - 100	
Ga (mg/L)			1 - 5	
Gd (mg/l)	0.5			
Ho (mg/l)	0.5			
K (mg/L)	10 - 40			
La (mg/l)	0.75			
Mg (mg/L)	1500 - 6000	1000 - 1500		
Mn (mg/L)	150 - 250	75 - 150	50 - 200	
Mo (mg/L)			1 - 5	
Na (mg/L)	50 - 100			
Nd (mg/l)	2.5			
Ni (mg/L)	1 - 25			
Pb (mg/L)	0.001 - 0.05			

Influent data	Site #1: **AMD Case 1**	Site #2: **AMD Case 2**	Site 3: **Alkaline Seepage**	Site 4: **Neutral with high As + B + TDS**
Pr (mg/l)	0.35			
Sc (mg/l)	0.5			
Se (mg/l)	0.1			
Se (mg/L)	0.02 - 1		0.02 - 1	
Si (mg/L)	15 - 60			
Sm (mg/l)	1			
Tb (mg/l)	0.3			
V (mg/L)	0.05 - 5		0.05 - 5	
Y (mg/l)	10			
Yb (mg/l)	1			
Zn (mg/L)	10- 100			
TDS (mg/L)	10000 - 25000	5000 - 10000		10000 - 50000
TSS (mg/L)	100 - 200			
SO_4 (mg/L)	10000 - 30000	5000 - 10000	500 - 5000	

Indicative effluent discharge requirements	Site #1: **AMD Case 1**	Site #2: **AMD Case 2**	Site 3: **Alkaline Seepage**	Site 4: **Neutral with high As + B + TDS**
pH	6.5 - 8.0			
TSS (mg/L)	25			
Fe (µg/L)	750			
Al (µg/L)	100			
B (µg/L)	1000			
Cu (µg/L)	25			
Cd (µg/L)	1			
Ga (µg/L)	1.5			
Zn (µg/L)	200			
Mg (µg/L)	50			
Pb (µg/L)	25			
Ni (µg/L)	25			
As (µg/L)	50			
Se (µg/L)	50			
SO_4 (mg/L)	250			