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Australian Mine Waste Symposium Abstracts

Contents

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Abstracts

Theme 1 – Valorisation to sequestration

Turning what was once waste into a resource to reduce environmental footprint. In this theme, we explore the characteristics of mine waste and how these determine amenability to a range of alternative uses from critical metal recovery to CO_2 fixing.

Valorization of Ultramafic Mine Tailings for Greenhouse Gas Removal

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Abstract

The greenhouse gas carbon dioxide reacts spontaneously with ultramafic mine tailings to permanently store carbon in minerals through the process of mineral carbonation, a form of chemical weathering. In mineral carbonation, carbon dioxide is captured from the air above mine tailings and stored in minerals where it is isolated from the atmosphere over geological time scales. The total carbon sequestration capacity of ultramafic mine tailings greatly exceeds that of conventional mining and mineral processing, however background rates are much less and are controlled by gangue mineral content which in turn reflect hydrothermal alteration processes.

For some sites, passive rates of mineral carbonation approach about 10% of total mine greenhouse gas emissions with conventional mining processes. For these sites, optimization of mine tailings storage can increase rates of carbon mineralization to offset the hard to abate greenhouse gas emissions that remain after deployment of renewable electricity generation and decarbonation of motive power to offset, thus providing pathways to carbon neutral mining. To achieve carbon sequestration at a scale meaningful for global greenhouse gas emissions, the reactivity of ultramafic minerals must be increased. One pathway to increasing the capacity and rate of carbon mineralization is activation of ultramafic gangue minerals. This also expands the application of mineral carbonation to more mine sites with different gangue mineral content to further increase the global impact of mineral carbon.

Projections from bench top scale tests indicate that with activation large individual mines have the capacity to sequester carbon dioxide at a rate of 1E5 to 1E6 tonnes per year. This creates a future scenario in which mineral carbonation in mine waste enables carbon negative mining of the critical metals needed for the energy transition in electricity generation and in transportation. Metal mines of the future may not only supply the resources we need for the energy transition, but they may also play a significant role in achieving global climate goals through net reduction in the greenhouse gas content of Earth’s atmosphere.

Waste to Value: Addressing the Critical Metals Shortfall

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Abstracts

The requirements for strategic and critical metals are expected to increase dramatically as the world transitions to a low carbon economy. The current time to develop a mine from first exploration to metal production is approaching 15 years on average. This delay has the potential to create a gap in production that could be addressed by turning current waste inventories into resources. There are billions of tonnes of tailings that are on surface, well defined, easily accessible and contain the metal that society needs for the low carbon transition. Additionally, some of the tailings storage facilities may be a long-term environmental hazard.

By looking at the opportunity to recover critical, strategic, and precious metals from mine and smelter wastes, EnviroGold Global (NVRO) has developed a leach technology that is able to recover a range of metals from wastes. By being able to define the tailings / smelter waste as a resource, NVRO first addresses the location of the required metals within the complex mineralized matrix, evaluates a pre-concentration of the tailings to allow cost-effective processing, and then defines the mobilization steps for the metals and their subsequent recoveries.

The initial work was directed at the Hellyer mine tailings. Over a period of about three years, the NVRO developed a phased approach using a proprietary leach that increased gold and silver recoveries from 5% and 30% to 75% and 90+%, respectively. Following the successful pilot plant at the ALS Laboratory in Perth, the NVRO team is now working on eight different projects to recover value from the wastes. When successful, these projects will partially address the resource gap as the technology can then be applied globally. An additional benefit is a reduction in environmental liabilities and the opportunity for reduced closure and rehabilitation costs.

Geoenvironmental Characterisation of the King River Delta: A Combined Geophysical, Geochemical and Mineralogical Approach

Authors

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Abstract

The Mount Lyell Mining and Railway company, Queenstown, Tasmania, discharged nearly 95 Mt of tailings and 1.4 Mt of slag from its copper, gold and silver production into the Queen River from 1916 to 1994. As a result, approximately 87.4 Mt of tailings has accumulated at the King River Delta. This research presents a multidisciplinary approach to characterise tailings deposited at the King River Delta, combining geophysical, geochemical and mineralogical data.

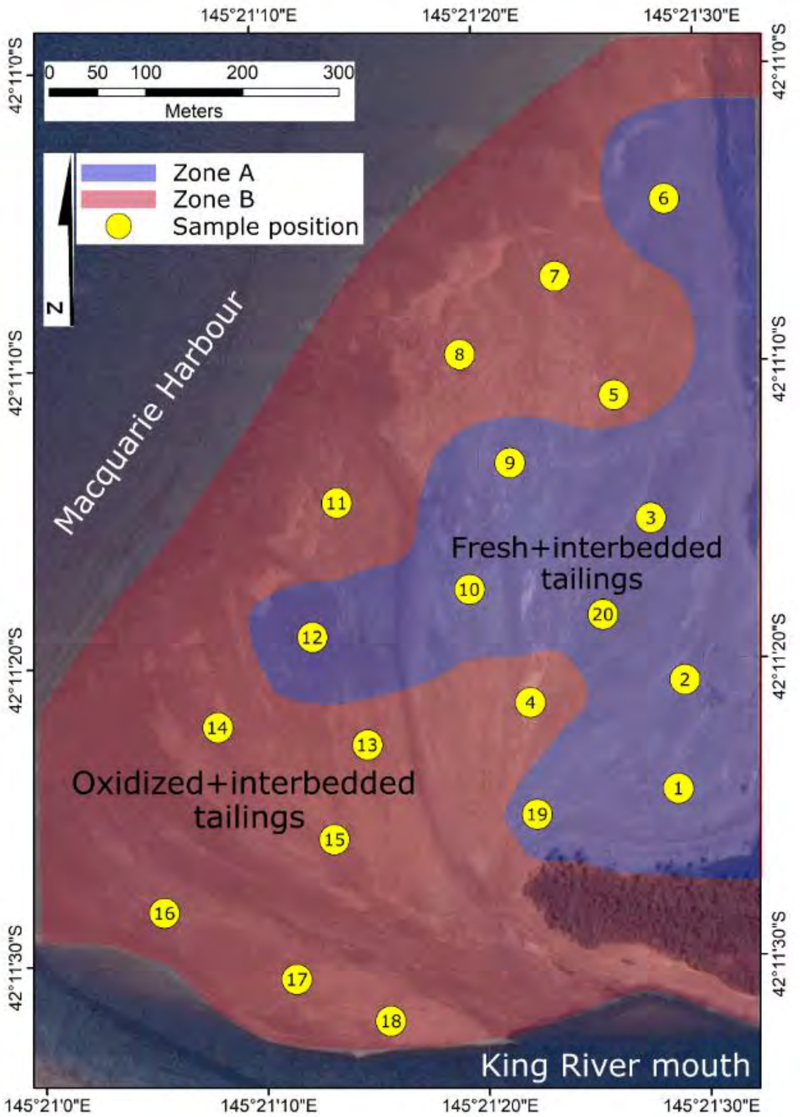
Tailings are composed of pyrite, chalcopyrite, muscovite, quartz, chlorite and secondary mineral and contain high concentrations of Fe (average~77,500 ppm), Cu (average~1,400 ppm) and trace elements such as Co (average~350 ppm). Prolonged exposure of tailings created an oxidized surface layer across the entire delta, extending up to 20 cm depth. This hard-pan is comprised of secondary iron oxide-hydroxides and sulphates which host an abundant variety of trace elements. Below this upper oxidized profile, two distinct zones were observed across the delta (Figure 1): i) zone A is the inner portion of the delta where unoxidized tailings are abundant; ii) zone B, next to the river mouth and harbour where hydrodynamics has contributed to the development of an oxidized profile. Pyrite concentration increases at depths below 20-30cm.

Within the tailings, Co is predominantly hosted in pyrite while chalcopyrite is the main Cu-bearing mineral. Net acid generation (NAG) and paste pH tests indicated that tailings in the delta are acid forming. Pore water collected from delta ranges from pH 3-6 contains elevated concentrations of dissolved Fe, Cu, Co and Zn.

The internal structure of the delta is complex and consists of several interbedded layers, as inferred by geophysical surveys (i.e., seismic refraction and resistivity). Dry unconsolidated tailings are suggested between 0-2 m depth. Saturated unconsolidated tailings are indicated from 2-5 m depth. Salt-water intrusion is recognized at nearly 4 m and the transition into natural sediments/bedrock is expected at approximately 12 m. This corresponds to nearly 10Mt of tailings stored in the delta, which represents up to 4083 t of Co and approximately 45,439 t of Cu in tailings.

Concentrations of Co and Cu could imply a viable option for reprocessing of these sediments that would provide benefits from both an economic and environmental perspective.

Figure 1:
King River Delta showing tailings stored at the south lobe, the King River mouth, and Macquarie Harbour. Two different zones were detected in the delta. Zone A comprises tailings with little to no oxidation observed while Zone B contains tailings in advanced stages of oxidation.



Rare Earth Elements as Potential By-Products of Alumina Production from Bauxite Deposits in Samar, Philippines

Authors

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Abstract

The demand for rare earth elements (REE) has significantly increased in recent years due to the growth in global production of energy-economic technologies such as solar panels, wind turbines, and e-vehicles. This has also led to the aggressive exploration of more REE sources, especially those that can be extracted as waste products from the extraction of other metals. More recently, the potential of bauxite residue as an alternative source of REE has been investigated (Deady et al., 2016). Bauxite is the primary ore of aluminum, and the Bayer process reportedly increases the concentration of the REE in the bauxite “red mud” residue (Borra et al., 2015).

In the Philippines, Samar Island has the most abundant bauxite deposits, which are reported to contain significant amounts of REE (Gibaga et al., 2022). This study investigates the enrichment and extraction potential of REE from the bauxite deposits in Paranas, Samar. The Paranas bauxites have an Al2O3 content of ~45 weight %, with enrichment in Fe2O3, SiO2 and TiO2. The REEs are present in concentrations of up to 300 ppm. Mineralogical and geochemical characterization of the bauxites indicated gibbsite, boehmite, goethite, and hematite as the main minerals, with minor magnetite, lepidocrocite, rutile, and anatase. Initial leaching experiments using the Bayer process indicate that the REE preferentially concentrates in the bauxite residue. Sequential extraction will aid in determining the geochemical behavior of the REE in the deposit. The results of the study will not only provide valuable insights into the bauxite mineralization in Samar, but also provide inputs in the design of an economically efficient process to recover REE as by-products of alumina production from Philippine bauxite deposits.

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From “Earth” to “Earth” Principle and Technology to Tackle Global Tailings Challenges

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Abstract

Global economic development for improving livelihood has led to the rapid expansion of mining footprints to extract much needed metals and minerals, but leaving behind colossal volumes of tailings (i.e., polymineral residues) containing abundant pollutants, especially since 1990s. So far, billions of tons of tailings have been stockpiled in about 2000 tailings storage facilities worldwide 1, posing long lasting risks of environmental pollution and degrading / destroying community livelihood, due to land displacement and environmental pollution. Re-resourcing tailings for residual economic values may contribute to the reduction of global tailings inventory, but which is very limited (probably < 1% overall volumes). Building on disciplinary knowledge of pedogenesis, pedology, ecosystem ecology, it is advocated to apply the principle of “from earth to earth” to address this global challenge 2-4. This is to upcycle tailings derived from natural regolith profiles, into earth materials (e.g., eco-engineered soil, rocks), for reconstructing or eco-engineering new regolith profile and rehabilitating tailings landscapes with nonpolluting and sustainable ecosystems.

Through scaling up proofs of concept about engineered pedogenesis in tailings, this talk aims to illustrate the broad framework and technological pathways towards integrating this principle into tailings rehabilitation and closure in future. A series of examples will be drawn from recent research findings in long-term studies partnered with the mining industry. Field feasibility of this principle has been strongly evidenced by our success in developing Fe-ore tailings and bauxite residues into soil and soil systems which are capable of supporting long-term growth of native plant species and communities.

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Theme 2 – Mining and reprocessing pathways

What are the best practices to remine and reprocess wastes from the mining industry, and what are the best technologies required to effectively do so, considering energy and water usage, and with minimal footprint?

Creating value from Waste Rock Dumps with the use of Sorting Technology

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Abstract

Historically, waste dumps have been sidelined in mineral extraction due to processing cost constraints. Mt Carbine Tungsten Mine showcases the transformative application of XRT sorting technology. This technology has not only facilitated the efficient recovery of Tungsten at Mt Carbine but in other mineral applications, has also enabled the segregation of undesirable minerals such as Arsenopyrite, Pyrite, and Chalcopyrite. At Mt Carbine, this process results in a concentrate fraction that is merely 10% of the original mass.

The evolution of Sensor-based Sorting (“SBS”) technology, paralleling advancements in computer processing speeds, has significantly enhanced the detection of fine-grained particles and disseminated sulphides. This leap in technological capability has been validated in various case studies, including gold ore sorting.

The second phase of the value chain – the potential of using SBS waste, typically ranging from 8mm to 60mm, as quarry material. The research at Mt. Carbine demonstrates the feasibility of repurposing SBS waste for various construction materials, such as road base, concrete aggregates, rail ballast, gabion rock, and armour rock. This repurposing, however, requires adherence to criteria like chemical composition, shape, hardness, and sizing.

There is a need for future research and policy implications. Suggestions would be extensive testing of waste rock dumps across Queensland mines to evaluate their suitability for quarry use and inclusion in the Government's Strategic Resource areas. Additionally, there is an essential query regarding policy reforms: Should contractors employing mine waste in their projects receive preferential consideration in Government Tenders? This inquiry underscores the potential for integrating environmental sustainability with economic incentives in mining practices.

The presentation aims to highlight the potential for SBS in mining waste management, emphasizing the role in environmental sustainability and economic development. Mt Carbine serves as a model, illustrating the potential of recycling waste rock dumps into valuable resources.

Assessing phosphate Mine Tailings recovery potential through Spatial Modelling of Geochemical and Mineralogical Data

Authors

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Abstract

The reprocessing of phosphate mine tailings holds considerable potential in terms of sustainable resource utilization and effective management. These tailings have presented major challenges in terms of environmental and resource management, due to the depletion of mineral and water resources, the significant environmental impacts, the risks associated with storage facilities, and the carbon footprint.

This study introduces a novel approach to assess the residual value of phosphate and REEs contained in the tailings storage facilities (TSFs) through sampling, in-depth characterizations, and 3D modelling. These storage facilities contain 15,28 % of P2O5 on average. Comprehensive quantification of several parameters was performed for a set of thirteen exploration drill cores by in-depth chemical, physical, and mineralogical characterizations. Each parameter was assigned a specific weighting function applied to the entire dataset. Subsequently, these data were geo-referenced and combined to construct a 3D smart block model.

The results of this study emphasize the importance of combining and integrating advanced geostatistical, chemical, and metallurgical data to establish a detailed 3D smart block model of tailings storage facilities TSFs. This smart block model provides valuable insights into the distribution of phosphate and rare earth elements (REEs) and their deportment within the tailings, shedding light on the potential for phosphate recovery.

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The Geomicrobiology of Metal Extraction; next steps for Industrial Scalability

Authors

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Abstract

Geomicrobiology offers a suite of reaction pathways that could be used in metal extraction from mine residues to low-grade materials. These weathering reactions extend well beyond conventional copper bioleaching operations. Though conventional bioleaching systems can be anything but routine. The Princess Creek mine tailings in Tasmania, possessing chalcopyrite, sphalerite and cobaltiferous pyrite provided three targets for bioleaching. However, under bioleaching conditions and using synchrotron XFM, the copper and zinc became diffusely distributed throughout the sample and the minimal cobalt that initially dissolved, re-precipitated as part of the oxide solid.

In 'long-term', 400-day bioleaching studies of low-grade Salobo ore, iron oxidising bacteria were found to use varied mineral substrates to promote weathering: from conventional mineral substrates i.e., high grade bornite/chalcocite, to unconventional sources of energy, i.e., ferrous silicates and magnetite, promoting mineral weathering and copper extraction from Cu-sulphide inclusions by *Acidithiobacillus ferrooxidans*-mediated silicate dissolution.

The benefit of time in biological processes was exhibited in recent analysis of the Mary Kathleen mine tailing. After two rounds of mining, from 1956 to 1963 and from 1972 to 1984 the Mary Kathleen mine was decommissioned between 1982 and 1985 and left to weather. Possesses acid generating materials, i.e., pyrite and pyrrhotite, and significant Rare Earth Elements in allanite (Ca,Ce,La,Nd,Th)2(Fe2+,Fe3+,Ti)(Al, Fe3+)2Si3O12(OH), a main carrier of REE, and stillwellite ((Ce,La,Ca)BSiO5); weathering over decades has produced a novel, water soluble REE fraction under these arid, evaporative conditions.

Metal extraction can even include alkali earth elements. Weathering of mafic and ultramafic materials provides calcium and magnesium for microbially accelerated mineral carbonation. Pilot scale kimberlite bioweathering experiments, set up in Johannesburg, South Africa demonstrated that mineral carbonation can be accelerated under natural light and climate (rainfall) conditions, i.e., requiring limited resources. After as little as 15 months, cm-scale secondary carbonates formed, offsetting a 20% equivalent of mine emissions.

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The RIMM process: the potential for Mine Waste Valorisation and solving environmental issues on the Mine Sites

Authors

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Abstract

The resin in moist mix (RIMM) process[1], originally developed by InnovEco Australia and Oryxeio Ingenieria, represents an innovative approach to the cost-effective recovery of valuable metals from low-grade ores and fine minerals. Initially, the focus of this research was on copper, where nearly 100% of the acid-soluble copper was recovered from various minerals[2,3].

More recently, the RIMM process has found new applications in the recovery of battery metals and rare earth elements (REE) from mine waste[4]. The global mining industry generates millions of tons of mineral waste annually, with tailings being the most common waste type, amassing to over 280 billion metric tonnes worldwide. These tailings are estimated to contain valuable metals worth approximately US$3.4 trillion[5]. This provides an extraordinary opportunity as a source of base, precious, and critical metals.

Challenges in cost-effective tailings reprocessing stem from the low metal content and high content of fine fractions, posing significant environmental risks, such as seepage and the release of harmful compounds into surrounding ecosystems.

In an international collaborative effort supported by the Australia-India Strategic Research Fund (AISRF), the RIMM process has been applied to the recovery of copper, cobalt, and other critical minerals from various mine wastes (tailings, spent leach pads, waste water) in South Australia and Queensland. The results of these RIMM tests have been highly promising, showcasing substantial metal recovery, reduced consumption of reagents and water, and the potential for a smaller plant footprint.

This technology offers a pathway to overcome the barriers associated with tailings reprocessing, enabling the realisation of the immense value embedded in mineral waste while addressing critical environmental concerns.

The authors acknowledge A/Prof Anita Parbhakar-Fox and Dr Laura Jackson, MIWATCH Group, The University of Queensland, for providing mine waste samples for the tests.

Keywords: Mine Waste Valorisation, Resin in Moist Mix, RIMM Process, Tailings Reprocessing

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Copper Extraction Potential from Tailings and Waste Deposition in the CSA Mine, NSW, Australia

Authors

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Abstract

The CSA mine is one of the oldest copper mines in Australia with mining records since 1900s. It is located in the Outback NSW, 12 km from Cobar town. The ore is a world class chalcopyrite/cubanite bearing copper source embedded in chlorite-silicate gangue, with blended feed copper grades from 3 to 4% for processing. The ore is mined from ~1.9km underground stopes and shaft hoisted to surface into storage bins. The metallurgical circuit includes grinding, flotation, concentrate/tailing thickeners, and filters. Throughput varies from 100 to 220tph depending on mills configuration, with target P80 of 104µm. The flotation circuit generally achieves an overall copper recovery of 97% with copper grade of 26% in concentrates, and 0.10% copper in final tailings. The final tailings can be diverted to a paste fill plant to refill empty stopes in underground, or to the tailings dam for long-term storage. Also, waste fragmented rock from underground with low concentrations of copper can be hoisted to surface for storage around the tailings dam.

In recent years, the CSA mine has been producing an average of about 1M and 73K tonnes of tailings and waste, respectively. This study presents a general overview of the CSA mining, metallurgy, and tailings and waste deposition for potential extraction of copper in the future.

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Theme 3 – Barriers to success

With such an up and coming and new field, obstacles need to be overcome to reprocess and reuse mine waste in Australia.

From technology to the onshore infrastructure, resources to the policies, what are they and how do we take steps towards improving them?

Transforming Mine Waste Management: Overcoming Barriers to Circular Prosperity

Author

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Abstract

The management of mine waste in Australia is at a pivotal juncture, with the potential to significantly contribute to the circular economy. This keynote highlights the barriers and challenges that need to be addressed to unlock the full potential of mine waste in this context.

Historically, mine waste has been viewed as a problem rather than an opportunity. It has often been considered a necessary byproduct, leading to inefficiencies and missed opportunities for value creation. Shifting this perception is essential for harnessing the circular economy's potential.

Technical complexity represents another significant hurdle. The processes involved in recovering and repurposing waste materials require innovative solutions and a deep understanding of the mining sector's intricacies. Overcoming these technical challenges is critical for meaningful progress.

Transitioning to a circular economy involves more than just technical adjustments; it necessitates a systemic shift in how mining operations are conceived. This transformation extends to processes, supply chains, and business models, which can be challenging for established mining companies.

Moreover, the shift toward circularity encompasses political and social dimensions. Engaging with government representatives is crucial for policymakers to understand the environmental and economic benefits of embracing circular practices. Additionally, social acceptance is pivotal in overcoming resistance to change, especially when it involves repurposing mine waste innovatively.

In conclusion, addressing the technical, political, and social barriers collectively offers a unique opportunity to usher in a new era of mine waste valorisation within the circular economy. By doing so, we can envision a future where mine waste becomes a valuable resource rather than a burden, paving the way for a more sustainable and prosperous mining sector in Australia.

Finding value while managing risks of Mining Wastes

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Abstract

By creating wastes and disturbing land, water and vegetation, all of which have socio-cultural and ecosystem services values, mining is recognised as posing risks that must be managed. Mining industry risk assessment frameworks and risk management processes focus on reducing certain types of negative risks while often overlooking opportunities to create value, not only internally but also value that extends to other stakeholders and society at large. Yet identifying and bringing the value of mining wastes to fruition is essential to shifting a linear economy toward a circular economy.

Maintaining an opportunity focus on sustainability is challenging (Evans et al, 2007). Commonly adopted mining risk frameworks direct practitioner attention to types of risks that materialise suddenly in unwanted events, thus obscuring what I name insidious risks that develop slowly and are not as obvious as sudden accidents or events. Even the organisational risk management literature is dominated by sudden risks 'to life and limb' in extreme contexts (Cliff et al, 2017; Hällgren et al, 2018) overlooking slow developing risk, value and opportunity.

To address this oversight, I studied the practice (Hardy et al, 2020; Schatzki, 2013) of insidious risk management (IRM). Two extreme cases were complemented by a third case of routine IRM at an open cut coal mine. I found that attentive or 'leading practice' IRM minimises residual risk while seeking value and opportunity while the blinkered practice creates and worsens insidious risk over time missing opportunities and culminating in crises. The intermediate IRM practice fluctuated according to regulatory interest. A key difference between these cases was that only attentive IRM seeks out value and opportunity, even without government stipulations.

I present the organising activities common to each way enabling organisations to recognise the trajectory of their IRM practice and showing implications for industry risk management and regulatory reforms.

Acknowledgements: PhD Advisors Professor Jörgen Sandberg and Dr Jo-Anne Everingham

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Overcoming barriers to Mine Waste Valorization through Biotechnology

Author

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Abstract

Globally, mining and mineral processing generate in the order of 100 billion tons of solid waste per year. The industry also generates various liquid effluents and mine drainage that can cause detrimental environmental impacts if poorly managed. Examples of mining and metallurgical wastes include waste rock, tailings, slags, sludges and ashes (Kaksonen and Petersen, 2023). Until now, the management of these wastes has largely been based on linear economy thinking (Kinnunen and Kaksonen, 2019).

With declining ore grades, the valorization of mining and metallurgical wastes is essential to mitigate the shortage of resources and to drive the industry towards sustainability and a circular economy. Although many mining and metallurgical wastes still retain valuable elements, the grades are often considered as sub-economic for traditional pyro- and/or hydrometallurgical processing.

Biomining has proven to be profitable for processing some low-grade and complex minerals. It may also offer potential for extracting value from mine waste streams that would not otherwise be exploited, and thus extending the mine life. Bioprocessing can also remove impurities from solid and liquid waste streams, making the wastes more amenable for final disposal, thereby reducing risks to humans and the environment (Kaksonen and Petersen, 2023).

This presentation will review various biomining applications and technical options for recovering resources from solid and liquid mining and metallurgical wastes. Examples include bioleaching processes for extracting metals from mineral wastes (Kaksonen et al. 2020), biorecovery of metals, selenium and sulfur from acid mine drainage (Yan et al. 2022) and bioelectrochemical recovery of caustic from organic wastes generated in alumina refineries during bauxite processing (Cheng et al. 2023). The integration of bioprocesses with physical-chemical unit operations and possible challenges in the bioprocessing of wastes will also be discussed, along with key considerations required to overcome the barriers for waste valorization.

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Addressing Mine Legacy Issues for Reprocessing Gold Tailings – A Case Study

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Abstract

This paper presents the barriers to success in the start-up of a reprocessing operation for gold tailings as a means of rehabilitating a non-operating mine site.

Reprocessing operations at the site will comprise of reclaiming hydraulically placed tailings; reprocessing to extract remaining gold; tailings filtration; and placement and compaction within the existing TSF footprint. The improved geotechnical characteristics of the filtered tailings will facilitate construction of the cover system and post mine land use. The project is currently in the construction phase, scheduled to commence reprocessing of tailings in early 2024.

Over the past 2 years, various engineering investigations, construction works, and environmental assessments have been undertaken to improve site safety, meet current regulatory requirements and best practice standards and guidelines, and obtain approval for remining operations from the regulator. Specifically, the following has been undertaken:

- Geotechnical investigations and modelling undertaken for the purpose of remining identified that minimum factors of safety were not achieved for the TSF. As a result, a buttress to the existing TSF embankment was designed and constructed.
- Dewatering of the TSF supernatant pond to facilitate remining activities and decrease the risk of overtopping prior to remining. Various dewatering methods were employed to reduce the approximately 400ML of water in the supernatant storage pond.
- Geochemical characterisation of tailings, as required by the regulator and to inform closure planning.
- Closure design, comprising landform and cover system design.

Some of these legacy issues were unforeseen and were identified during the design phase, with works undertaken leading to delays in the commencement of mining activities. Notwithstanding, improvements to the site has reduced environmental and societal risks and addressed regulatory compliance.

Mount Morgan Mine – Challenges to Remining the Historic Mine Wastes

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Abstract

The Mount Morgan Mine in Central Queensland is historically significant as one of the oldest and richest mines in Australia. Mining commenced in 1882 and by the end of hard rock mining in 1981, approximately 262t of gold, 37t of silver and 387,000t of copper were mined from underground and open cut operations.

Between 1982 and 1990, over 27 million tonnes of historic tailings were reclaimed with the reprocessed tailings discharged into the former open cut pit. An estimated 12 million tonnes of historic tailings were left behind. After all mining ceased in 1990, the Queensland Government accepted responsibility for managing the significant ongoing environmental and heritage legacies while facilitating company interest in evaluating the economic potential of remnant resources.

Since 1993, several companies have evaluated the technical feasibility and economic viability of remining the historic mine tailings and waste dumps to recover gold, copper, and pyrite. Currently, Heritage Minerals Pty Ltd (Heritage Minerals) has completed a feasibility study indicating the viability of a tailings reprocessing project and are moving towards a project start with plans to commence mining in 2024.

Why has it taken so long for mining to recommence at Mount Morgan? The answer is complex with issues relating to the capability of proponent companies, project viability, environmental challenges, legislative and regulatory application to the mine site, joint mine site management, technical constraints, community expectation and corporate/investor expectations.

This presentation will explore each of these issues and with the view of hindsight, discuss what lessons have been learnt and how these lessons could be applied to the utilization of mine wastes at other locations.

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Abstracts

Theme 4 – The future landscape

Integrating valorisation of mine waste in the Australian mining industry DNA is crucial for the country's circular economy principle. What does this future look like and how can each stakeholder contribute to achieving this aim?

The Future Landscape: Good is the new Cool

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Abstract

Societal expectations around resource management are shifting and there is a growing consciousness about the impact of the products and services we consume. A trend that started with a small subset of society aiming to reduce their personal footprint on the planet is building into a mainstream thematic - ‘good’ is the new cool. For the final keynote address at the 2024 Australian Mine Waste Symposium, I will explore how this trend has developed and where it is impacting our personal and business decisions, including in the mining industry.

What we purchase represents part of our identity, and demonstrating purpose driven purchases is increasingly popular. As companies align to a triple bottom line version of success there is a growing role for the valorisation of mine waste as an alternative to primary extraction of materials. One that considers social and environmental sustainability in addition to financial outcomes.

What do we mean by ‘good’ and is it commercially viable or a form of virtue signaling? What can be learnt from early adopters who are leading the way on circular economy principles that will help drive investment decisions for turning waste into valuable source materials? Take inspiration from what is already possible with a range of real-world examples from clothing to food, electronics to construction, travel, and home waste management.

Implementation of these principles on a wider scale will require engagement and support from direct and indirect participants of a value chain, not just company shareholders. Explore the various stakeholder groups and the role where each can lead in embracing good as the new cool. Increasing awareness of the lifecycle impact of our purchasing decisions may be the key to systemic change on what and how we produce our future consumables.

Extracting predictive environmental indices for Queensland's ore deposits derived from HyLogger spectroscopic logging and Minalyzer XRF drill core scanning

Author

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Abstract

The forecasting and management of future mine waste remains one of the main challenges for the mining industry. These materials commonly contain pyrite (FeS2), which, under surficial conditions, may oxidise to produce acid rock drainage (ARD) and metal leaching (ML). With the ARD predicted at early stages, an early environmental risk can be identified. Resources and strategies can be incorporated into mine planning, allowing better closure outcomes with innovative storage facility designs. Additionally, possible reuse of these materials and potential buyers can be determined.

The Queensland State Government have collected a range of high-resolution data from numerous ore systems across the state, including HyLogger (NIR-SWIR-LWIR hyperspectral mineralogy) and Minalyze (linescan XRF). Using the relative percentage abundance of acid-neutralizing minerals (e.g., carbonates), the 'HyLogger Geoenvironmental Index' (Hy-GI) was calculated across a total of eleven drill cores from Baal Gammon (N = 3), Ernest Henry (N = 4), Mount Isa (N = 2) and Wolfram Camp (N = 2). The Hy-GI was then plotted against total sulphur (S %) concentration to produce a bivariate classification plot for the ARD relative prediction. The results allow a systematic downhole mapping of ARD/ANC potential and discrimination between three main domains: 1) potential acid forming (PAF); 2) not acid forming (NAF); and 3) High PAF and high acid neutralising capacity (ANC).

The following steps include validating selected samples for mineralogy and wet chemical determination of ANC/net acid generation (NAG). The results will be compared with the Hy-GI vs S % classification, allowing its calibration and the creation of an ARD domaining model when compared with other geological features of each deposit. With this, a routine workflow by which the Hy-GI and S can be readily extracted from these datasets is expected to be developed, enabling an early risk prediction and domaining for potential ARD.

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Manufacturing Building Blocks using Mining Waste

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Abstract

Building materials such as blocks and paving can be made from many forms of waste, including mining waste. Where a mine is close to a local community, or local infrastructure, and the materials are not acid forming, there is a high possibility of developing suitable products for local use.

The tonnages required for use as building products are relatively low compared to the output of a mine. However, if the products are tailored to local use, there is a significant and visible benefit to the nearby community in the form of practical and useful products, and local employment.

Recent research work will be presented on manufacture of building blocks from four tailings streams, from The Pilbara, Southern WA, Victoria and Vietnam. These waste streams show a variety of results, and serve to indicate the many issues that need to be addressed when researching materials for building. Product certification testing such as leaching of toxic elements and compressive strength will be discussed, as well as the development of aging tests for long term stability.

Practical considerations for manufacturing will be given, including machinery design, product types, tonnes produced, costs, buildings, labour, and other aspects relating to the development of a circular economy based on manufacturing building products. A list of factors will be given for increased chance of success for the manufacturing building products from mine waste. This list can be used to assist companies to decide whether to investigate making building products from various waste streams.

Tailings Valorisation – Drivers for Commercial Viability

Author

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Abstract

As the green transition drives demands for base metals and critical minerals, waste volumes generated will increase, highlighting the importance of alternate approaches to management of this waste to minimise impacts on ecosystems and communities. Reducing, reprocessing, and repurposing are three approaches can be integrated as part of an overall comprehensive tailings management strategy. The key is a logistical, technical, environmental, and economic evaluation of a union of all these elements for successful, implementable outcomes. This paper is focused on reducing the impact of mining waste that will be generated by primary mining or handled through secondary processing. In particular, tailings dewatering, reprocessing, and re-use are considered.

Options for dewatering the final tailings to produce a drier tailings stream are proven and offer several environmental and long-range financial benefits, such as significantly lower tailings storage footprint, liability and risk, yet are associated with a high upfront capital and operating costs. Currently, proposals to reprocess fresh or historical tailings (to recover residual value of the original elements or chase recovery of a by-product not originally targeted) are generating commercial interest. Reprocessing does not typically materially reduce final waste volumes, but it does allow alternate treatment of tailings once handled, such as storage in disused open pits, rather than dams, for increased stability. In addition, options for a 'circular economy' solution to tailings may be made viable from cashflow generated from reprocessing, but these uses are highly dependent on the waste characteristics.

This paper provides an overview of some applicable technologies and highlights projects that have delivered innovative tailings minimisation plans across multiple commodities and regions. At many locations, these approaches have faced challenges to commercial viability on a stand-alone basis. The authors propose that an analysis of the logistical, technical, environmental and economic interdependence of a combined tailings reduction, reprocessing, and repurposing solution be considered, to support evaluation of commercial viability.

Managing Mining Legacies: A New Global Standard

Authors

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Abstract

Globally there are innumerable negative mining legacies but only a few nations and fewer sites gaining the attention they require to reverse harm to communities and environments (Kretschmann, Goerke-Mallet, & Melchers, 2020; Laurencont, 2014; Unger, Lechner, Kenway, Glenn, & Walton, 2015; Worrall, Neil, Brereton, & Mulligan, 2009). The need to ensure transparency of the supply chain of mineral extraction requires sustainable development to be demonstrated through the whole life cycle of a mine. This includes the management of legacy mines by finding further raw material value in mining wastes and transforming negative legacies to positive post-mining uses.

Despite an array of guidelines for managing mine closure and mining legacies globally, a standard for managing mining legacies did not exist. Hence ISO initiated a process to develop one and under the leadership of the first author and core writing team (co-authors) the standard was developed with a global working group of experts from the Global North and South.

The Managing Mining Legacies standard was published in October 2023 in two parts. Part 1 outlines what must be carried out to comply with the standard while Part 2 is a Technical Report that provides guidance via illustrative case studies and a bibliography. The Standard integrates the 17 UN Sustainable Development Goals (SDGs) to show how its application will work toward reducing inequalities, restoring peace, justice & strong institutions while returning life to degraded land and water. The Standard applies to all stakeholders with an interest in managing mining legacies and this includes finding value in mining wastes concurrent with, and supporting, the process of reclamation. The standard is structured around;

- governance and leadership,
- stakeholder participation
- management planning,
- implementation, and
- stewardship, performance and reporting.

The adoption of this standard is an integral part of ensuring transparency of the full life cycle of mining and a shift toward a more circular economy for mining waste, particularly timely as society strives to meet the critical raw material demands for a green energy transition.

Acknowledgements: all members of ISO TC82/SC7WG3

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Poster presentations

Theme 1 – Valorisation to sequestration

Parallel extraction of hydrogen from olivine-bearing mining tailings and ex-situ sequestration of CO2 minerals

Author

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Abstract

Sequential hydrothermal alteration studies were carried out on olivine-containing mine tailings to study the creation of hydrogen and the sequestration of carbon dioxide (CO2) as two potential methods of valorization. This work's originality allows two processes to be investigated simultaneously while highlighting their differences. This work is original in that it investigates the differences between two processes simultaneously. In three distinct sets of P/T conditions—375 K/20 MPa, 487 K/25 MPa, and 536 K/25 MPa—we reacted powdered mine tailings with CO2-saturated water. After the reaction lasted for 20 days, CO2 was trapped in all of the tests as Fe-bearing magnesite, or (Ca,Fe)CO3. In order to capture 350.5 g of CO2 per kilogram of mine tailings, the maximum carbonation output of 64.6 weight percent of the product was reached at 487 K and 25 MPa. By oxidizing Fe2+ in olivine, hydrogen gas has been produced. At 487 K/25 MPa, or 1.34 g of H2 per kg of mine tailings, the greatest amount of hydrogen (H2) had been produced.

This approach combines carbon capture and storage (CCS) with clean hydrogen production and utilizes waste heat from other industrial processes. It has the potential to significantly reduce emissions and contribute to New Caledonia's clean energy and climate goals. Additionally, this approach could serve as a model for similar projects in other regions looking to address carbon emissions and produce clean energy on a large scale.

Mine Waste as a possible source of Strategic and Critical Raw Materials: Advancing the Knowledge for some Case Studies in Italy.

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Abstract

Recent European policies are designed to stimulate the growth of domestic production of Strategic Raw Materials (SRMs) and Critical Raw Materials (CRMs). These regulations actively support the recovery of mining waste to obtain CRMs, along with their core objectives (1). Waste rocks and mining dumps could contain relevant quantities of valuable minerals that were overlooked in past industrial operations (2). Despite Italy having an important mining industry during the 1900s, today there are no active base metals mines. Primary production centres around industrial minerals and ornamental stones (3). As of 2022, there were more than 500 abandoned mine waste sites documented in the Italian National Storage Facilities registry (4). Nevertheless, the information reported on these databases is typically too vague for action definitions and more detailed information is needed from other sources (5). We are currently developing a multi-step approach for selected case studies to bridge the existing information gap. This approach merges publicly available information from governmental sources, scientific literature, and field information aiming at individuating and characterizing the tailings or mine waste bodies. Further site information is also implemented in a Geographical Information System (GIS) model using processed open-source satellite images or remote sensing data. This tool is used to preliminary plan on-field sampling and characterization campaigns in order to collect representative samples that will undergo lab-scale mineral processing tests for mineral recovery estimation. Collected information suggests that SRMs or CRMs could potentially be found within some of the waste volumes considered. Upon successful validation of this multi-step approach on a restricted set of cases, the methodology may be extended to a broader context encompassing several mine waste facilities in Italy. Enhanced knowledge of mining dump sites might improve strategies for CRMs recovery and environmental restoration.

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Arsenic Distribution, Speciation and Mobility in Loddon River Legacy Deposits

Authors

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Abstract

Many river catchments in Victoria were intensively mined during the Gold Rush (1851 – 1914), leading to wide-scale deposition of mine tailings and changes in river and floodplain geomorphology (1). The geochemistry of these tailing deposits was examined, focusing on the Loddon River, one of the most impacted after the Gold Rush.

Our work has identified the presence of an arsenic-rich ‘plume’ in the tailing deposits overlying the original (i.e. pre-mining) floodplain surface in some of these rivers. Subsurface arsenic concentrations (> 500 mg/kg), exceeding the high level (70 mg/kg) interim sediment quality guidelines (ISQG) for Australian and New Zealand (2), indicate that As may pose a potential hazard to surrounding aquatic ecosystems.

The combination of sequential extraction, electron microprobe and XAS analyses was employed to understand the nature and the potential mobility of the As contamination within the tailings deposited in river banks along the Loddon River. Tailing deposits from Tullaroop Creek, a tributary of the Loddon River, were further examined to determine the conditions under which arsenic contained in these sediments may become more mobile. Specifically, a column experiment simulating reducing and oxidizing conditions was performed with the sediments to study the behavior of arsenic and its interactions with iron, under wetting and drying conditions.

As these As-contaminated sediments are located on floodplains upstream of major reservoirs, this work will assist in the future management and understanding of the environmental risk presented by these tailings to surrounding aquatic ecosystems. Importantly, this work highlights how the risk associated with historical gold mining in Victoria may have been underestimated, especially given only surface concentrations are usually considered. This warrants further attention, to investigate the potential toxicity and mobility of this largely forgotten 100-year-old contamination plume.

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How X-ray Absorption Spectroscopy can help to assess the resource potential of mine wastes

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Abstract

Assessing the resource potential of mine wastes requires a good understanding of the geochemistry and mineralogy of the trace metals within. Bulk geochemistry (e.g. XRF) can tell us which valuable metals are present and how abundant they are, while mineralogy (XRD) can tell us which crystalline mineral phases make up the rock, but often, these pieces of evidence alone are not sufficient to understand which minerals a metal is hosted within. This is particularly true in cases where poorly crystalline or amorphous phases can host valuable metals, or when trace metal concentrations are low (e.g. 10's ppm).

X-ray absorption spectroscopy (XAS) directly measures the oxidation state of an element of interest, and its mineralogical speciation. This technique can be used to quantitatively determine that 20% of Cu in a mine tailings sample is present as Cu+ in cuprite, 20% in bornite, and 60% as Cu2+ associated with Fe-oxyhydroxide phases, for example. Since oxidation state and mineral speciation typically control an element's mobility, toxicity, and recoverability, this technique provides critical information that can often only be inferred by other datasets.

In this presentation, examples show how XAS can help us to understand trace metal chemistry in mine wastes with relevance to their resource potential. A weathering profile through tailings will track the fate of nickel and sulfur undergoing oxidation and passive mineral carbonation reactions. Old assumptions will be overturned when nickel is discovered to be hosted in concentrated alloy grains in legacy tailings where it was previously assumed to diffusely substitute in silicate minerals. Lastly, a new capability at the Australian Synchrotron – a crystal spectrometer, is described, which will expand our current capabilities to include high resolution measurements (HERFD) for enhanced element speciation between similar phases, and cobalt speciation in iron-rich materials which is currently a challenge for XRF based measurements.

AMICS: Novel Automated Mineralogy System

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Abstract

Advanced Mineral Analysis and Characterisation System (AMICS) is based on energy dispersive X-ray spectroscopy utilised in a scanning electron microscope (SEM-EDS). A specially designed software coordinates the sample positioning inside the microscope chamber, EDS spectra acquisition and analysis, phase identification, and results visualisation in the form of maps, graphs and tables ready for reporting. Characterisation can be conducted automatically for up to 28 mounted samples with or without coating. Although, many options exist for an experience researcher to influence the analysis process: (i) extract a spectrum for each acquisition point and determine chemical composition at this point, (ii) visualise mineral maps for each phase or a group of phases to characterise their interactions, (iii) determine the particle geometry- chemistry relationship, (iv) conduct statistical analysis of EDS spectra, define presence of solute elements, and visualise distribution of particles with a particular chemical composition.

All these approaches can be used to fully analyse the sample chemistry or facilitate the following study of the sample with other analytical techniques, such as XRF, EPMA or ICPMS. The combination of modern instrumentation with dedicated software allows high resolution analysis of fine particles (down to 1 micron). Characterisation of fine mineral bodies is critical in studies of pre-processed materials such as mine tailings, fine grained waste, or clays. Therefore, application of AMICS is growing in geology, mining, and mineral processing.

This presentation will outline the system capabilities and showcase recent results from a number of projects, in particular, (i) identification of commercially valuable metallic elements in mine tailings and clays, (ii) mineral phase balance in rocks, soils and dust, (iii) characterisation of laboratory synthesised oxide nano-particles.

Indium Cycling and Mobility in Mine Waste and Acid Mine Drainage Environments

Authors

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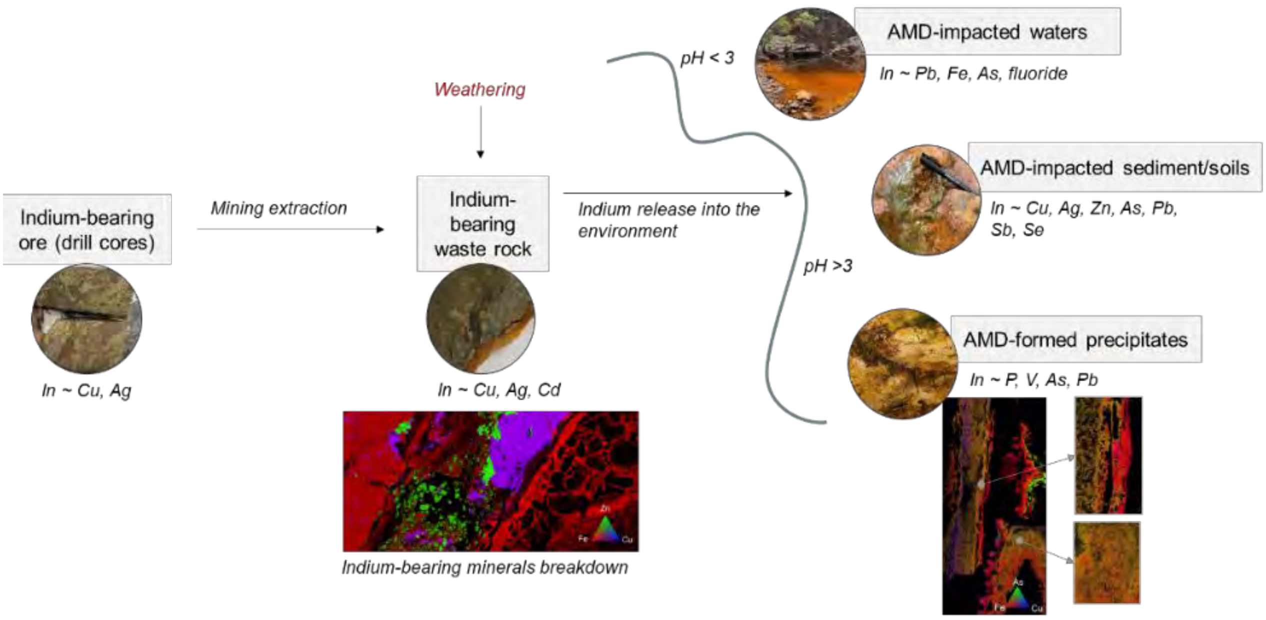
Abstract

Indium (In) is vital for transitioning to a low-carbon economy. However, a knowledge gap exists in understanding indium cycling in mine waste environments. Addressing this gap is crucial for refining extraction methods and environmental mitigation [1-2]. Indium is recognised as a critical element in Australia and has been identified in Queensland's mine waste [3-5].

This study aims to uncover the mechanisms behind the cycling and mobilisation of In in two geological mine waste environments: Mt. Morgan (Au-Cu VHMS) and Baal Gammon (Sn granite-related) in Queensland, as an essential first-step toward designing a remining process.

Preliminary findings show that Baal Gammon's waste rock samples contain up to 356 ppm In, correlated with Cu, Ag, and Cd. Indium-bearing minerals include stannite-kësterite, sphalerite, and chalcopyrite (1,000s of ppm In). Nanoscale In-rich features were observed at sphalerite grain boundaries (>100,000 ppm In). XFM-synchrotron experiments revealed In-rich precipitates intergrowth with microorganisms, containing up to 175 ppm In and correlated with P, V, As, and Pb. The concentration of In in AMD is up to 73 µg/L In at pH < 3 and correlates with fluoride, Pb, Fe, and As. In contrast, Mt. Morgan's waste rock exhibits a maximum of 3.53 ppm In, with sphalerite and chalcopyrite as In-bearing minerals (100s of ppm). Precipitates contain up to 1.58 ppm In, correlated with V. In AMD, concentration reach 5 µg/L In at pH < 3 and correlates with fluoride, chloride, As, Pb, and Fe.

The findings emphasise significant In enrichment in Sn-related mine waste and fundamental pH impacts on In mobility. Based on these findings, for In recovery, recommendations include selective flotation followed by leaching, highlighting As, Pb, and V removal and a stepwise Fe precipitation process. Moreover, the presence of microorganisms in In-rich precipitates suggests the potential of biogeochemical processes in In cycling and biomining opportunities.



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A Conceptual Geochemical Model of Mary Kathleen Tailings Storage Facility in view of Risk Assessment and Element Recovery

Authors

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Abstract

The abandoned Mary Kathleen uranium mine can be one of the possible sources of rare earth elements (REE) in Australia. Approximately 7 million tonnes of tailings in this mine contain about 3% REE. However, radioactive substances from uranium and thorium, and potentially toxic elements are also present.

Considering possible reprocessing and potential environmental issues, a conceptual geochemical model was developed through mineralogical and geochemical characterisation of tailings samples, and assessment of potential mobility of elements and radionuclides through natural weathering processes. The tailings contain abundant andradite, with lesser amounts of albite and clinochlore. Based on the spatial distribution of uranium oxide and rare earth oxides, two zones were confirmed in the tailings storage facility (TSF). Accumulation at depth was observed for Ra-226 and Pb-210 with a downgradient distribution pattern inside the TSF. The column leaching study showed both shallow and deeper tailings can be acid generating, eventually releasing sulfate and metals. The tailings' neutralising capacity was mostly provided by the dissolution of silicates. Five-step sequential extraction (Schultz et al., 1998) found REE to be mainly in the residual fraction but were released over time. Pyrite oxidation may result in mobilisation of uranium and thorium, including via secondary reactions. The important geochemical processes in the TSF controlling seepage water chemistry include 1) oxidation of pyrite and dissolution of sulfates releasing sulfuric acid, plus any residual acidity; 2) dissolution of silicates and carbonates which contribute to neutralization; 3) exchange reactions between calcium and sodium especially near the surface; and adsorption-desorption of metal ions such as Pb on the surface of fine tailings, particularly the clay fraction; and 4) precipitation of secondary phases such as gypsum.

The results in this study will assist in predicting residual risk associated with the existing tailings and the potential risk in any new tailings produced through reprocessing.

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Recycling Mine Waste: Opportunities for Mount Gunson

Authors

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Abstract

Our millennia-old dependency on Earth's resources is evolving as we transition to net zero. The demand for critical minerals has escalated dramatically, however, their uneven distribution poses challenges exacerbated by geopolitical instabilities.

Australia's Critical Mineral Strategy aims to leverage substantial untapped mineral deposits, establishing the country as a "renewable energy superpower" and committing to sustainable resource practices. Extraction and reprocessing of historic primary mine waste is a method of mineral recycling currently gaining traction.

The focus of this study is Mount Gunson, an inactive copper project in South Australia. I aim to characterise the tailings by defining their copper and cobalt mineralisation and estimating the relevant mineral concentrations to predict economic viability, with an emphasis on the method's contribution to closing the critical mineral resource loop.

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Towards a case for the Economic Feasibility of Concurrent Mineral Carbonation and Metal Recovery

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Abstract

Critical metal recovery concurrent with mineral carbonation may provide an avenue to incentivise carbon sequestration in tailings. In order to stimulate investment into developing such processes, the case for profitability, or at least economic viability, must be made. A simple case study from the Mt Goode deposit (Western Australia) is presented. Estimates of total potential revenue from non-sulfide nickel & cobalt, and total CO2 storage potential based on magnesium carbonation, are provided. These are used to estimate the maximum permissible emissions intensity if the Mt Goode operations were to reach CO2 neutrality under different carbonation and metal recovery rate scenarios. The results are then discussed in the context of whether emissions from the Mt Goode operations could be abated in an economically viable manner.

in silico Discovery of Critical Mineral Binding Proteins for Mining Applications

Authors

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Abstract

Due to sustainability concerns in the mining industry, there is growing interest surrounding the utilisation of proteins that selectively and with high affinity bind critical minerals such as cobalt, vanadium and rare earth elements. The interactions between critical minerals and the biological world is extensive, with minerals playing primary biochemical and metabolic roles in organisms across all three domains of life. In recent years there has been a rapid rise in research surrounding the exploitation of microbe-metal interactions for mining. The 'EF-hand motif' is a conserved protein region that forms a helix-loop-helix topology resembling the fore-finger and thumb of the human hand[1]. Only a few EF hand-containing proteins that bind specific metal ions are currently known, exemplified by the La(III)-binding Lanmodulin[2] and Ca(II)-binding Calmodulin[3]. **Metagenomic analysis of microbial samples from environments such as mining sites may lead to the discovery of novel biochelators suitable for targeted mineral extraction, which can be characterised in silico via molecular dynamics.**

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Mine waste sampling and characterisation in Western Australia

Authors

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Abstract

Western Australia (WA) hosts around 11,000 abandoned mine sites, some with associated environmental risks. In 2010, total rehabilitation and closure costs for mines operating under the WA Mining Act 1978 was estimated at ~AUD $6 billion. With a changing climate, alternative mine closure and waste management strategies may be needed but can only be developed based on a robust understanding of the physical, chemical and mineralogical properties of mine waste.

With this in mind, there is estimated to be around 700 tailings storage facilities (TSF) with the potential to host critical minerals in WA. In addition to this, there are over 100 TSFs which may be amenable for carbon sequestration through mineral carbonation, and a further ~ 1,000 abandoned TSFs with unknown potential. As part of collaborative projects with the Geological Survey of Western Australia (GSWA, "Mine Waste Sampling and Characterisation in Western Australia") and Geoscience Australia (GA, "Exploring for the Future – National Mine Waste Assessment Program"), mine wastes at three sites across WA have been sampled, with an additional site planned for early 2024. The mine waste sites selected for sampling originate from ores containing major commodities mined in WA, including gold, nickel, and copper as well as diamonds. The sampled mine waste will be examined using an integrated geochemistry-mineralogy test-work program (termed 'Stream 1'), with a focus on determining critical metal tenor.

The data obtained will provide a first-pass insight into the potential for remining waste in WA particularly for critical metal recovery, as well as the potential for carbon sequestration. The potential recovery of critical minerals from mine waste in WA will help to achieve the aim set-out in the Australian Government's Critical Minerals Strategy to be a "globally significant producer of raw and processed critical minerals" by 2030.

Critical Mineral Assessment of Mine Waste from the Northern Territory, Australia

Authors

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Abstract

Critical minerals are fundamental to modern technology and the global economy, and therefore present an important economic opportunity for the Northern Territory (NT). As of 2023, the Department of Industry, Science and Resources from the Australian Government defines 30 minerals of interest (e.g., Co, In, Mn, Sb, rare earth elements), some of which are also targeted by the NT Government. In addition to geological ore deposits, mining waste materials (e.g., tailings, waste rocks) may also host critical metals. Geochemical characterisation of mining by-products, therefore, is indispensable to assess critical metal endowment and to evaluate the possibility of recovery of such strategic elements. The Sustainable Minerals Institute of The University of Queensland (SMI/UQ) currently has multiple collaborative projects with Geoscience Australia (GA) and state and territory geological surveys, such as the Northern Territory Geological Survey (NTGS), to investigate the chemical and mineral composition of mine waste.

In the present study, seven mine sites across the NT were sampled in 2022 and 2023, including Mt Bonnie, Iron Blow, Brocks Creek, Mt Todd, Peko, TC8 and Cosmo. Preliminary results show that mine waste products from the NT are overall endowed in Ag, As, Au, Bi, Pb, Sb, Se and Te. For instance, Sb contents are up to 5,110 and 4,930 ppm in Mt Bonnie and Iron Blow mine waste, respectively. Some sites are also particularly enriched in other critical metals, such as Co in Peko mine waste (<2,870 ppm Co). Importantly, mineral characterisation (XRD, MLA, SEM and LA-ICP-MS) of mine waste provides information regarding the deportment mode of critical metals. For example, laser analysis of Mt Bonnie and Brocks Creek mine waste suggests that Sb is predominantly hosted within Fe oxide and pyrite, respectively. Next phases of this study include geochemical analysis of Cosmo mine waste, and mineral characterisation of Mt Todd, Peko and TsC8 samples. This research marks the first step towards exploring the potential for recovering critical metals from NT mine waste.

Critical metal potential of South Australia's mine waste

Authors

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Abstract

According to its Critical Minerals Strategy of 2022, Australia aims to turn into the "global critical minerals powerhouse" by 2030 by becoming an integral part of the international critical minerals supply chain (DISER, 2022). The Geological Survey of South Australia (GSSA) has identified there is potential to explore for critical metals in mine waste materials across the state forming part of this new supply chain.

The initial phase of this research focused on the identification of mine waste with potential to host economic accumulations of critical metals in South Australia. For this desktop study a ranking criteria was created using five key inputs based on data available from the Mines and mineral deposits (MinDep) database, accessed via the South Australian Resources Industry Gateway (SARIG). The criteria included, i) mine status; ii) known commodity; iii) associated commodity; iv) discovery year and, v) mine waste feature/s. The ranking was used to identify abandoned/historic mine sites with a high probability of containing critical metals in the mine waste.

The results of the desktop study indicate that South Australian mine waste is fertile in metals including Co, Cu, Ni, REEs and Au (particularly within the Adelaide Rift Complex, Gawler Craton, Nackara Arc, Kanmantoo Group and Willyama Supergroup). The Middleback Ranges was recognised as a potential host for Mn, with notable enrichment likely in waste materials. The ranking also indicated the potential for bismuth in several sites (Gawler Craton and Nackara Arc).

The second phase of this research involves integrated characterisation of the chemistry and mineralogy of mine waste from the sites identified in phase one. Two sites have been sampled (Brukunga and Mount Gunson), with two sites to be sampled in early 2024.

Identifying Resources of Critical Metals in Queensland's Mine Waste – the 'MIWATCH' approach

Authors

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Abstract

Since 2019, exploration for critical metals and minerals has focused on studying Queensland's mine waste in a 5-year program led by the Sustainable Minerals Institute (MIWATCH). Whilst the original scope of this project focused on identifying new deposits of Co, it has since expanded to identify additional critical metal resources including In, REE, W, Ga, Ge and others listed on the QLD Governments new economy minerals list. A range of mine waste materials (n= 30) have been sampled across the state including tailings, waste rock, spent heap leach, slag, coal ash and metallurgical residues. These samples have been analysed using an integrated 'Stream 1' chemistry-mineralogy-mineral chemistry program with some distinct trends observed.

In Queensland's North West minerals province, a distinct signature of Co rich mine waste has observed in tailings, waste rock and heap leach materials sampled from the Capricorn Copper, Mt Oxide, Pindora, Mt Cuthbert Rocklands, Osborne, Selwyn and Great Australia mine sites. At these sites, with the exception of Mt Oxide Pindora and Mt Cuthbert, pyrite is the primary host of Co and is contained within the lattice. Based on these observations, recovery of Co has focused on mineral separation by sulphide flotation and metal recovery using (bio)leaching and roasting methods in collaboration with groups including Cobalt Blue and JOGMEC. At Mt Oxide, Pindora and Mt Cuthbert, Co was identified as present within oxide materials, and as such its extraction tested using leaching methodologies. For example, at Pindora, in collaboration with Innoveco, > 70% recovery of Co and Cu was extracted using their proprietary technology. Also within the North West Minerals Province new opportunities for REE recovery from Mary Kathleen tailings in addition to Pindora and Phosphate Hill have been explored, with metallurgical testing (in collaboration with groups across UQ) to extract Ce and La trialled on the prior with new hydrometallurgical approaches developed.

In Queensland's North East minerals province, elevated In and W have been identified in waste sampled at Baal Gammon, Jumna, Collingwood and Wolfram Camp mines. Whilst more towards Central Queensland, whilst not critical, Au has been identified in mine waste associated with Mt Morgan and Mt Chalmers. In South East Queensland, coal ash residues at Tarong and Swanbank have comparatively endowed REEs. This study has highlighted there is significant potential for (critical) metal extraction in the state, with a number of operational companies also independently evaluating reuse potential in this context. Further fieldwork to target more sites in Central Queensland is planned in 2024, with the collected datasets to be further evaluated to identify additional valorisation opportunities.

Posters

Theme 2 – Mining and reprocessing pathways

Critical mineral recovery from acid mine drainage using hydrochloric acid processes

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Abstract

With the depletion of natural resources, the development of methods to recover valuable minerals from mine wastes is attracting significant interest as an emerging market opportunity for critical minerals. Acid mine drainage (AMD) dams are a potential source of a range of critical minerals, dependent on the type of tailings disposed and/or the mineralogy of the dam walls. This investigation has developed a flowsheet for neutralising the acidity of the water, while also producing high purity alumina (>99.99 wt% Al_2O_3), a high-grade gypsum (99.9 wt.% $CaSO_4{\cdot}2H_2O$) and a hydrochloric (HCl) acid stream of copper, manganese, zinc and cobalt suitable for ion exchange recovery methods. The process involves lime neutralisation to form gypsum, which becomes the feedstock for HCl leaching to produce a process stream to recover high purity alumina from HCl crystallisation. The HCl waste streams contain appreciable amounts of copper, manganese and zinc (ranging from 2000 - 4000 ppm) and cobalt (100 - 120 ppm) that can be recovered by ion exchange, whilst enabling the recycling of HCl back into the gypsum leaching stage. This study has developed a process that produces multiple critical mineral streams required for the energy transition, while also reducing the environmental risks associated with these large acidic storage dams laden with heavy metals.

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Alternative mineral processing strategies for copper- gold tailings management

Authors

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Abstract

The mining industry continually faces the challenge of sustainably managing its waste. With rising concerns about potential environmental impacts, the drive to develop efficient and ecologically safe reprocessing pathways is vital. This research focuses on the benefits derived from the codisposal of rejects from early gangue rejection technologies such as the High Voltage Pulse (HVP) and Coarse Particle Flotation (CPF) with conventional tailings (CT). In-depth geotechnical, geochemical and column leaching tests are carried out to understand the performance of the co-disposal of different waste streams.

The optimal blend compositions for remining and reprocessing mining wastes, possibly through "heap leaching", is examined. With factors such as water usage and the environmental footprint in focus, the research investigates the hydrological and geochemical behaviour of different tailings and blends. Additionally, the research aims to provide insights into the stability and settling behaviour of the blends of mine waste from these new technologies.

Some key findings include CPF rejects demonstrating lower air entry values than CT, suggesting a faster transition from saturated to unsaturated states. When CPF rejects were integrated into blends, evaporation rates increased, while CT's finer particles slowed this process. Adding HVP notably increased infiltration rates due to coarser particles and large pore spaces being introduced to the blend.

The choice of blend composition depends on site-specific objectives, such as targeting blends that offer high evaporation so that the site is available for earlier rehabilitation or targeting blends that retain moisture to slow down acid mine drainage (AMD) rates. While blends with a higher quantity of CPF could aid surface drying, those with HVP might optimise drainage. CT release both alkalinity and sulfate, leading to neutral-to-alkaline drainage, accompanied by salt and trace element release. The presence of even a minute quantity of CT in blends significantly increased contaminant loads, emphasising the need for a thorough understanding of each component's geochemical behaviour.

Numerical Modeling Challenges in Mining Waste Management

Authors

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Abstract

Mining mineral extraction results in considerable waste, including large volumes of soil, rock, and water residues. These waste, often referred to as tailings, are composed of residues from ore after most of the metals have been extracted, forming a mixture of uneconomic rock and chemical effluent. These tailings pose environmental risks, particularly due to potential groundwater contamination. As reactive solutes move beneath the surface, they are subject to various hydro-physical and chemical interactions. Anticipating these reactions allows for targeted intervention in contaminated zones.

In recent years, reactive transport modelling in porous media has gained traction. This modelling simulates the spatial and temporal distribution of contaminant dispersion and the associated chemical interactions in tailing releases. While numerous software tools have been developed for geochemical modelling and advective flow simulations, their accuracy can be compromised when dealing with sharp front reactions, advective-dominated problems, or strong diffusivity contrasts arising from highly heterogeneous and anisotropic porous media. Such limitations become particularly evident in simulations that require long time or large spatial propagation.

In this presentation, we introduce a computational framework designed to address these challenges using a novel numerical stabilization technique [1-3]. Our approach effectively captures accurate physical solutions for unstable scenarios, eliminating the need for artificial terms that can lead to overly diffused solutions. We validate the effectiveness and reliability of our method through numerous numerical experiments, including those related to challenging tailing release scenarios. Furthermore, we will present our latest findings in reactive transport modelling for metal recovery from mine waste, utilizing technologies such as Electrokinetic In-situ leaching.

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Unlocking Critical Metals in Mine Wastes: Potential for bismuth, indium, cobalt and more in Tasmania

Authors

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Abstract

Tasmania features a range of sites which are either already producing or have potential to produce critical metals. The Regional Research Collaboration project for Environmentally Sustainable Production of Critical Metals is examining all aspects of the mining value chain in Tasmania for sources of critical metals, including the characterisation and processing of mine waste. This research focuses on unlocking the considerable critical metal potential of mine tailings and waste rocks, which exist in both controlled (e.g. tailings dams) and uncontrolled (rivers contaminated by mining waste) storage environments especially in Western Tasmania. Remarkably rich metalliferous deposits include Devonian granite-derived tin deposits at Renison Bell and Mt Bischoff, tungsten deposits at Dolphin and Kara, magnetite-magnesite deposits at Savage River and Prospect Ridge along the Arthur Lineament and the copper(-gold) deposits at Mt Lyell. The wastes from few of these deposits have been adequately explored for their critical metal potential (Moyo et al. 2023), and both previous tailings and wastes and currently generated byproducts may contain extractable levels of critical metals such as antimony, bismuth, cobalt, gallium, germanium and indium (Geosciences Australia, 2023). Analytical techniques such as automated mineral liberation analysis, X-ray fluorescence (XRF) and laser ablation inductively coupled plasma mass spectrometry (LA-ICPMS) are currently being used at CODES (Centre for Ore Deposit and Earth Sciences) to characterise the deportment of critical metals in fresh and weathered tailings across a range of sites. Looking beyond Tasmania, the supply of critical metals is one of the most pressing global challenges. With considerable 'resources' existing in waste (van der Ent et al. 2021) that have already been comminuted to small particles during the mining process, the implications of this project extend well beyond the borders of Tasmania, and indeed of Australia.

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Have you got the good stuff? How Synchrotron X-Ray Fluorescence Microscopy can be used to analyse mine waste

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Abstract

Mine waste represents a challenging material to properly analyse and assess. The combination of small grain size, high concentrations and highly mobile materials means that understanding the complexity of tailings can be a significant challenge. The XFM beamline at the Australian Synchrotron is uniquely positioned to address these issues. As bright source, the beamline is capable of mapping low-concentration elements at high resolution over large areas in samples using our raster-scanning technique (Howard et al. 2020).

In addition, the beamline is uniquely positioned in Australia to map the distribution of element oxidation states in these samples. X-ray Absorption Near Edge Spectroscopy probes the oxidation state of elements and their local coordination environment. XFM can utilise this technique with related spatial information to generate XANES maps showing oxidation states in 2D from thin and thick sections. The beamline is capable of mapping XANES for elements from Ti to Nb, and Ba to U.

This presentation will show the capabilities of the XFM beamline in analysing mine waste material to map both element mobility and changing oxidation states within tailings. We shall present data acquired from recent and historic experiments, will give an overview of the beamline capabilities and present recent endeavours to improve the sensitivity and high-energy performance of the beamline.

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3D Geostatistical Modelling for estimating the Resource Potential of Tailings Storage Facilities

Authors

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Abstract

The past centuries of mining have left an enormous legacy of mine-related wastes, the volumes of which are set to rapidly grow in the coming decades as the mining industry expands to meet the requirements of the green-energy transition. Tailings, the fine-grained residues of ore processing, may contain residual contents of valuable and critical metals which may be recoverable with today's technologies. To allow the exploitation of these potential resources, it is vital that a code-compliant resource assessment be performed. However, tailings deposits are heterogeneous in nature, with strong compositional trends resulting from the sedimentary-style sorting of tailings particles by size and density. Geostatistical modelling methods are arguably the most appropriate method to build 3D resource models of tailings by accounting for the strong compositional trends. In this case study, 3D geostatistical modelling of Cu, Zn, Pb and In in the Davidschacht tailings deposit, Freiberg, Germany, was performed using universal kriging-based simulations, allowing for uncertainties in the predicted grades and tonnages to be estimated. Geochemical data was available for 10 deep drill holes (up to ~30 m) and 68 shallow drill holes (1-3 m), with a total of 176 samples of 2 m intervals. Using this data, a 3D grade and density model of the tailings, was constructed with a grid spacing of 2 m. The tonnages of Cu, Zn, Pb and In were subsequently calculated. Zinc is the most abundant valuable metal (~5,170±517 t), followed by Pb (~2,060±206 t), Cu (~550±66 t) and In (~11±1 t), with errors given for 95 % confidence levels. Robust and reliable grade and tonnage estimates were produced, even with relatively few samples. The modelling method applied should prove reliable for resource and reserve estimation of tailings deposits in industry to reduce the technical and financial uncertainties associated with re-mining.

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Geometallurgical opportunities for cobalt recovery from tailings

Authors

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Abstract

Cobalt is a critical metal in the green energy transition, compelling major global economies including the EU, USA, UK, Australia and Japan to seek alternative cobalt resources from secure and ethical supply chains (Australian Government, 2023). Reprocessing mine waste to recover cobalt and other critical metals is a circular economy approach to securing supplementary cobalt resources, while also reducing environmental risk associated with legacy sites and current mine waste production. Geometallurgical characterisation of waste material is critical to assessing the recovery potential and inferring economic and environmental outcomes.

A case study exploring historical copper tailings for secondary cobalt resources was undertaken on a site in the copper-rich North West Queensland Minerals Province. Due to the fine grained and heterogenous nature of tailings, several techniques were employed to investigate cobalt deportment, including SEM-EDS, MLA, microprobe, XANES and XFM mapping (Australian Synchrotron) and laser ablation. Primary cobalt hosts were identified as pyrite and cobaltiferous sulphides (cobaltite, carrollite, cobalt-pentlandite, alloclasite). However, significant remobilization occurred during weathering to generate secondary Co-sulphates and oxides. Primary sulphide liberation ranged from 25 to 58 %, with the remainder locked in quartz and clay gangue mineralogy. Tailings particle size average *p*80 was 97 µm, while pyrite was much finer with an average *p*80 of 46 µm. The average cobalt grade in pyrite was 485 ppm, with individual grains ranging from 1.8 ppm to 8% (w/w). XANES and XFM mapping identified that cobalt hosted in secondary sulphates were commonly intermingled with copper and iron (Figure 1), as well as nickel and arsenic. These geometallurgical observations are key to developing appropriate mineral processing flowsheets and an economic case for reprocessing and recovery. Opportunities to recover cobalt may leverage conventional or innovative technologies, including flotation and, or hydrometallurgy acid- or bio- leaching, to generate a saleable product and reduce environmental risk.

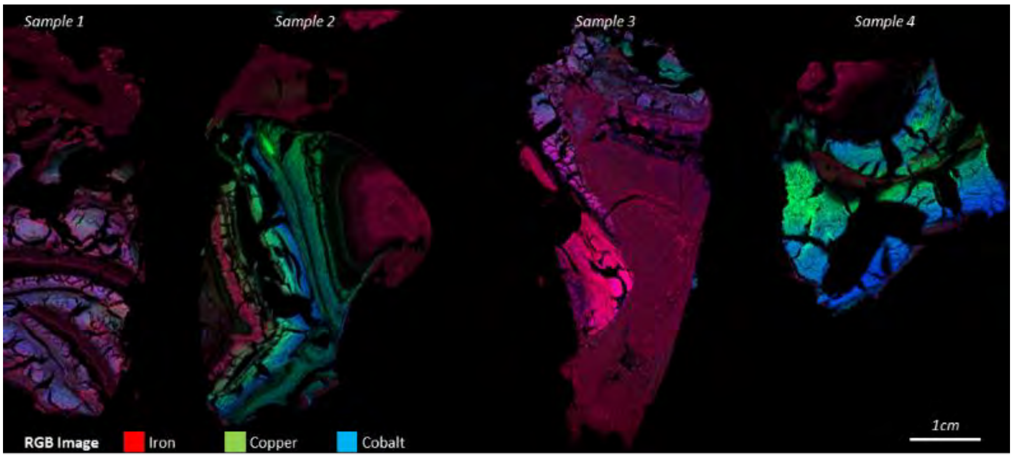

Figure 1 RGB image of Iron-Copper-Cobalt relative intensity in 4x tailings samples from the XFM Beamline (Australian Synchrotron).

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Analysis of tailings from facilities in Victoria and New South Wales

Authors

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Abstract

As the scale of mining has increased substantially in the last century (1), so too has the production of mine tailings. The management of tailings remains almost exclusively through the use of large scale engineered dams. The challenge with dams, however, is that catastrophic failure can be caused by seismic events, flooding, or poor design, construction and/or management (2). Across the world, there is increasing interest and need in the supply of critical minerals – such as those required for renewable energy, electric vehicles and energy storage batteries (amongst others) – many of which were not the focus of previous processing and extraction. This means that there could be critical minerals remaining in historic and currently managed tailings and leading to opportunities for reprocessing the tailings for critical minerals. This research looks to analyse tailings samples from tailings storage facilities in Victoria and New South Wales with the goal to determine chemical makeup to determine viability for tailings reprocessing. These tailings storage facilities have shown interesting, if not unexpected, levels of gold, antimony, coal ash, and arsenic. After reprocessing, there are opportunities to implement improved tailings management and achieve better long-term environmental outcomes which eliminate risks such as tailings dam failures (e.g., backfilling a closed open pit mine). The goal of this research is to use the tailings data collected from these tailings storage facilities to build a new environmental assessment framework for the use of government and industry to facilitate the reprocessing of tailings from legacy and active mines. This framework will be focused on improving environmental, social, and economic outcomes for mines, local communities, and governments.

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Experimental study of leachability of amorphous Pbo-Cuo-Feo-Sio_2 slag: Development of methodology and initial results

Authors

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Abstract

Understanding of the leaching behaviour of toxic elements is critical to the use of the copper metallurgical slags as value-added materials (slag valorisation). A comprehensive approach based on experimental investigation and thermodynamic modelling is being established to study the leaching behaviour of waste generated from non-ferrous metal smelting process. A novel experimental methodology has been developed with an aim to understand the leaching mechanism utilizing advanced analytical techniques. Experimental results showed preferential dissolution of copper due to metallic nanoparticles being washed off in acidic environment, while leachability values of all other elements were at least one order of magnitude less. Formation of intermediate altered layer during acidic leaching is demonstrated using EDS-equipped TEM. The method developed in the present study allows the detailed investigation of the effect of mineralogy of the waste material on the leaching behaviour of the elements of interest. The information generated from the current study coupled with internally developed thermodynamic database [1] is expected to guide the design of metallurgical by-products through process control in the smelting, converting and refining stage of the metal production, to enhance recycling of future metallurgical waste.

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Protein identification for binding of critical elements in bauxite residue

Authors

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Abstract

Critical elements are becoming increasingly important to the global economy due to advancement of alternative energy and electronic technologies. These include rare-earth elements, and metals such as gallium (Ga), germanium (Ge), and vanadium (V). Australia produces an estimated 30 million tonnes per-year (Scullett-Dean et al., 2022) of alumina refinery waste (bauxite residue), which contains an array of critical elements. Sustainable methods need to be developed to target these elements from the waste matrix in an economical and sustainable way. Biomining could be the key to harnessing this untapped critical element supply, as current chemical separation methods are costly and environmentally damaging (Vo et al., 2024). This approach relies upon using identified microorganisms with prior demonstration of critical element utilisation, and the presence of these species across various mine waste sites. Candidate microorganisms include *Pseudomonas putida*, *Shewanella oneidensis*, *Geobacter metallireducens* and *Aspergillus niger*. This study aims at identifying the Ga, La, Dy, and Ge binding capacity of *P. Putida* and the proteins related to critical metal metabolism using bioinformatics and "omics" research. Initial proteomics analyses have identified 80 statistically relevant proteins associated with Ga interactions, including transcriptional regulation proteins associated with arsenic metal tolerance (ArsR1 and ArsH) and proteins previously identified as having metal-binding capacity. These include pyrroloquinoline quinone (PQQ) dependent alcohol dehydrogenases which have previously demonstrated lanthanide dependence and binding capability (Wehrmann et al., 2017). These proteins will be produced and tested for their potential use as biomaterial to recover Ga, which will pave the way for developing a sustainable method to recover this highly demanded element. Adaptive laboratory evolution (ALE) will also be conducted, to drive artificial evolution in heavy metal tolerance associated proteins. This research could be used as a platform to create novel sustainable biomining solutions for the valorisation of alumina refinery waste.

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Stabilisation of mine tailings with Biocement and Geopolymers: Towards low carbon goals

Author

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Abstract

Mine tailings have become a major environmental and safety concern in the mining industry following a series of storage facility failures resulting in loss of life, economic damage, and environmental catastrophe (1). These tailings are complex ecosystems containing a range of organic and inorganic contaminants (2). Creating a circular economy for mine waste is critical as the world intends to transition toward a *sustainable and low-carbon footprint future.* One such opportunity is via exploration of sustainable alternative cements for management and stabilisation of tailings.

For this, we have investigated the potential application of two eco-friendly technologies: Biocementation and Geopolymerisation of tailings from two mine sites in Australia. Biocementation, also called as microbial induced mineralisation (MIM) has recently emerged as a promising technology that utilises native soil microbes for creation of minerals and polymers at ambient temperature conditions (3,4). Geopolymers are a class of aluminosilicate binders synthesized by the reaction of an aluminosilicate mineral and an alkali activator that can utilise Al-Si (from mine waste) as a precursor for polymerisation (5). In this study, mine tailing samples were characterised and then cast in cylindrical moulds followed by treatment with a novel phosphate carbonate based biocement and geopolymer. The impact of the treatment was analysed by assessing mechanical properties, acid tolerance, permeability, chloride ingress and microstructural behaviour performance. The outcome demonstrated significant improvement in the mechanical properties of tailing cylinders treated with geopolymers as well as biocement. Reduction in the permeability, effective immobilisation of contaminants, significant improvement in acid resistance were recorded. These results indicate promising applications of these alternate cements for stabilisation of tailings in different areas of mining and construction sector. Future studies need to be carried out using a range of tailing materials and long-term studies should be conducted to evaluate the impact of these novel cements over time.

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Posters

Theme 3 – Barriers to success

A Remining-Restoration Solution for Abandoned Mine Sites

Author

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Abstract

There are well over 100,000 significant inactive mine sites across the globe, many belonging to current or prior operators and an equally large number of legacy or "orphan" sites, in the hands of governments. Many represent major liabilities for owners, significant risks to communities, and enormous public relations challenges for the sector. Regeneration Enterprises is a public benefit company whose goal is to address these challenges. Regeneration plans to remine waste, create biodiversity and carbon credits through restoration while repurposing or restoring sites to meet the needs of communities and other stakeholders.

Each abandoned mine site, and the jurisdiction where it is located, present unique opportunities and challenges demanding innovative solutions. In most cases, policy or regulatory changes are required to encourage and regulate clean-up, separating historical legacy from current remining-restoration activities, and differentiating it from traditional mining. For each site, a range of established and potential novel technologies will be required to assess and evaluate the waste, remine tailings or waste rock, treat wastewater and recover valuable metals, many critical, and repurpose or safely manage remaining waste. The value created will fund and facilitate restoration. Extensive consultation with traditional owners, communities, other stakeholders, and governments is required to seek the optimal outcome for the future, whether that is agricultural, recreational, conservation, energy source, or employment opportunity, etc.

Regeneration is examining many sites searching for the best cases to demonstrate this new approach. As a public benefit company, we hope others will follow and collectively we will address the worst examples of this visible mining legacy. Collaboration, partnerships, and a range of business models that are not typical of current industry practices will be key drivers. Policy, regulatory, and financial innovation are needed, along with innovation in technology, planning, and engineering. We will identify these challenges and responses.

Understanding the True Costs of Tailings Management for meaningful comparisons with alternative solutions.

Authors

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Abstract

Vast amounts of energy are spent on transporting, crushing and grinding mined materials in order to liberate and extract target commodities. A large quantity of the mined material becomes a mine waste by-product known as tailings that are stored indefinitely in facilities. Not only is this material lost to potential users, but it can also pose ongoing threats to local communities and the environment, even after mine closure. Any breach in the storage facility's structural integrity and capacity can lead to significant costs for the mine, including cleanup, production disruption, and compensation to affected parties – communities, and the environment.

The true cost of these tailings facilities goes beyond regular CAPEX and OPEX calculations, which often exclude unexpected events, bonds, and post-closure expenses that are likely to occur in reality. Understanding the true cost is crucial for meaningful comparisons with alternative solutions. Unfortunately, guidelines for such assessments and standardised reporting are lacking. By developing such a guideline, it will assist mining companies in making informed decisions from the project's outset or at any stage of development.

In this evolving landscape of tailings management, we introduce a new option of repurposing tailings as a resource for other industries alongside the existing main categories: tailings dams and filtered tailings stacks. Our solution centres on decontaminating tailings and converting them into fertile soils, construction materials for local use, or high-value products for distant markets, with the added potential for carbon capture. This will enable mining companies to compare these categories effectively. Crucially, repurposing leads to the removal of a substantial amount of tailings from the site, mitigating the risk of uncontrolled events such as tailings spillage, embankment failures, production disruptions, and adverse impacts on communities and the environment. Moreover, it opens doors for other industries, potentially creating additional income streams for mining operation.

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Posters

Theme 4 – The future landscape

Reimagining Beauty: Repurposing Mine Wate for Sustainable Design and Artistry

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Woodlawn Tailings Damn, 2023. Photo by Marlo Lyda

Abstract

Designers and artists perceive much of the world's beauty through the metals and minerals we extract, shaping our visual and functional landscape. However, the future of design, like most industries, hinges on the ability to craft similar beauty, efficiency, and diversity from materials sourced through reclamation rather than new extraction. Initiatives worldwide are addressing the challenge of mine waste transformation, and designers have taken up the challenge. Exemplified by Agne Kucerenkaite's 'Ignorance in Bliss' project, showcasing ceramics, glass, and textiles crafted from metal waste sourced from water supply and soil remediation industries. The movement toward embracing waste as a future resource gains momentum as resource depletion, rising costs, and factors from the Anthropocene era escalate, transforming creative expression within this domain into a powerful form of activism advocating for sustainability, circularity, and localization. Dutch duo Studio Thus That extends this vision, utilizing Red Mud and copper slag to create materials that redefine mine waste as a resource, urging recognition of its role within the circular economy. Expanding on my project, 'Scraptopia,' which involved recovering copper from electronic waste and transforming it into domestic artifacts for a utopian future, my current research focuses on integrating tailings into ceramics and glazes. This exploration involves embracing the latent beauty within the acidic and potentially hazardous samples collected from a legacy tailing damn at Woodlawn copper, zinc, and lead mine in New South Wales.

This symposium will explore the evolving landscape of repurposing mine waste, delving into innovative approaches, challenges, and the potential for creating beauty and functionality from materials once deemed unusable.

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Circular Economy opportunities across the Lifecycle of the Resources Sector

Author

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Abstract

Economies are transitioning from a linear to a circular economy (CE) as a viable solution to address global challenges, such as climate change. Not only that, CE also opens up economic and societal opportunities. CE decouples economic growth from natural resource consumption, which appears to see a conflict with the purpose of the resources sector. But, as an industry that utilises scarce natural resources and technical resources made of natural resources, CE practices can still be applied to the industry to pave the way for a more sustainable future.

A circular economy prioritises actions such as rethinking, redesigning, reusing and repairing over lower-order actions such as resource recovery and recycling[I]. Many examples of recovering and reusing mine tailings and mine site waste have demonstrated abundant economic gains for mining companies[II,III], yet a number of circular economy actions are possible right from the design stages of a mine site.

Figure 1 outlines the different stages of a mine's life – starting from pre-exploration, exploration, feasibility, planning and development, mining, processing and finally, mine closure and rehabilitation. To enable a systems change as posited by a circular economy, decisions must consider circular economy actions in the planning and design stages of a mine site's operations, in addition to identifying opportunities for resource efficiency and optimisation during the core operations.

This research illustrates the different circular economy actions that provide important considerations throughout the life of the mine site. The findings will provide useful insights for the resources sector to flip the focus from waste management towards designing out waste, identifying opportunities for resource circularity across the lifecycle, thereby reducing the environmental and human health impacts of mining. Technology is identified as a key enabler to support the circular economy transition for the resources sector.

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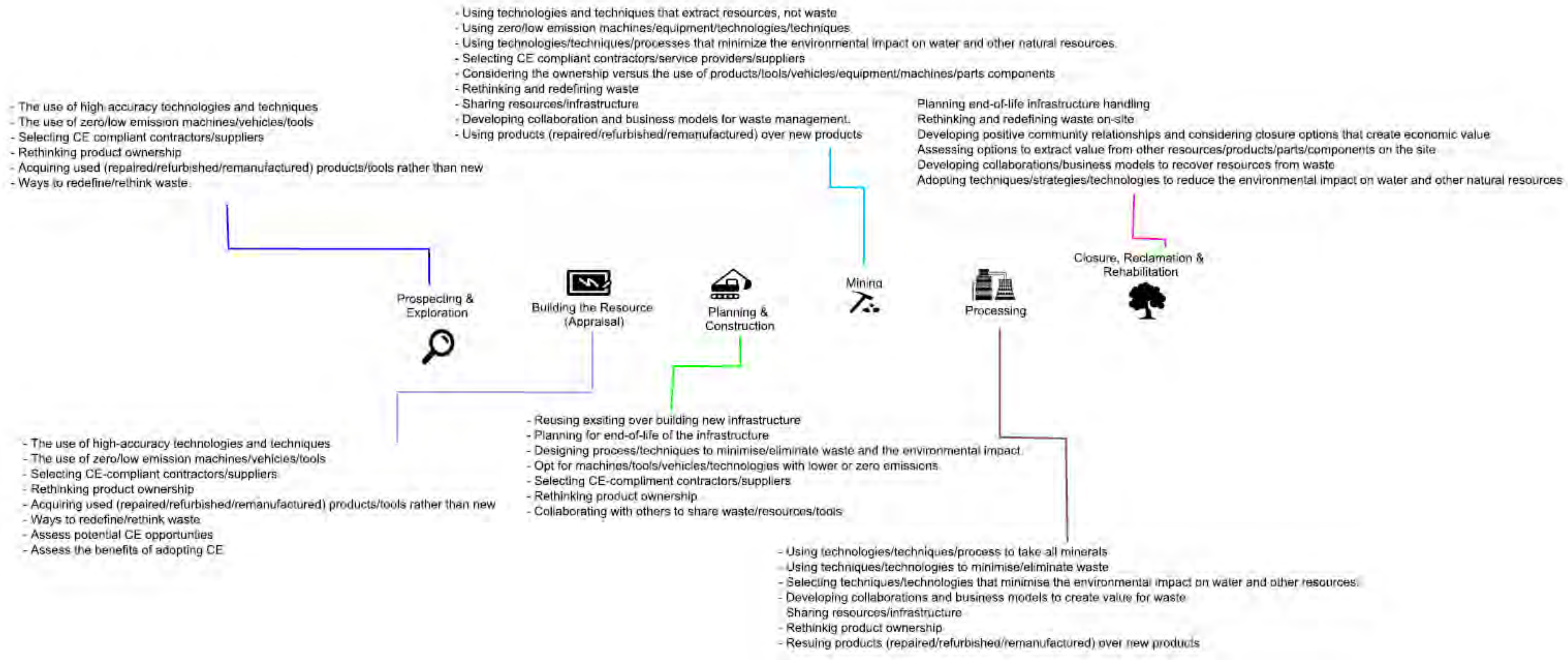

Figure 1: CE actions across the mining life cycle

Using rainfall simulators to design and assess the post-mining erosional stability

Author

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Abstract

Changes to the mining environmental approvals process in Queensland have been rolled out under the MERFP Act (2018). This includes requirements for a Progressive Rehabilitation and Closure Plan (PRC Plan). Key considerations of the landform design report within the PRC Plan must include:

- identification of materials available for landform rehabilitation including their ability to achieve the required landform design outcomes.
- erosion assessments to determine landform heights, gradients, profiles, and material placement.
- slope profile design considering the interactions between soil erodibility, rainfall erosivity, landform height, gradient and vegetation cover to identify acceptable erosion rates over a long-term average.
- an analysis of future stability based on the factors described above e.g., erosion and/or landform evolution modelling.

ACARP funded an extensive and thorough erosion assessment program using rainfall simulators from 1998 to 2010. The ACARP program included laboratory assessment of 35 soil and spoil samples from 16 coal mines and samples from a gold mine in Queensland using a 3 x 0.8 m laboratory rainfall simulator. The reliability of the laboratory rainfall simulator was verified through field measurements using larger flumes 20 x 5 meter and catchment scale measurements at three sites (3 different catchments, average area of 2.5 ha each).

Soil cover systems are a primary component of a constructed mine landform. The primary functions of a soil cover system are to sustain vegetation and limit the infiltration of water and oxygen into underlying reactive mine waste. If the external surface of the landform erodes the functions of the cover system cannot be maintained and the cover system will most likely fail. Assessing a constructed landform's potential 'long-term' erosion stability requires defensible erosion rate thresholds below which rehabilitation landform designs are considered acceptably erosion resistant or 'stable'.

The process used to quantify erosion rates using rainfall simulators (flumes) to measure rill and inter-rill erosion on bulk samples under laboratory conditions or on in-situ material under field conditions will be explained.

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Why repurposing tailings is the future of mining

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Abstract

Amidst escalating tailings dam risks, a unique opportunity emerges for the mining industry to collaborate with other sectors. Repurposing mine waste into valuable products can drive a sustainable global economy, meeting industries' needs for eco-friendly raw materials. This collaborative potential extends to agriculture, construction, forestry, and pharmaceuticals, reducing carbon footprints and creating circular hubs to cut waste production, generate local jobs, and protect ecosystems.

The urgency matches up climate change, making alternative waste storage imperative. To solve this, global collaboration is vital to resetting mining waste practices. In the current state of play, mining supports society but faces challenges from escalating mine waste's environmental impact. In agriculture, climate-induced storm events cause soil loss, worsened by intensive farming and fertilisers. Here, mining can supply fertile soils.

Embracing a Circular Economy, efforts aim to eliminate tailings storage, reducing waste, risks, and creating opportunities. The Circular Mine Consortium explores mining, construction, and agriculture collaboration, aligning with principles from Denmark's Kalundborg city. Global collaboration among tailings repurposing engineers is essential, with Europe's advanced sustainable policies setting the stage.

Industrial symbiosis with mining

Making these ideas reality, the Consortium converts waste into resources for construction and agriculture, benefiting through decontamination, carbon sequestration, and eliminating tailings dams. Local conditions improve with recycling plants and tailored agriculture. Even remote areas benefit, adapting farming to local conditions and creating high-value products like geopolymer-based construction materials from repurposed tailings. Transport costs pose challenges, but changing market conditions could favour economical remote resource access, including urban mining growth and reduced need for greenfield mine sites.

In conclusion, the Consortium actively explores global solutions that reduce waste and consider the full life cycle costs of tailings dams, including closure, malfunctions, and potential catastrophic losses. Repurposing waste is a viable solution, and the mining industry can become a valuable resource hub, promoting sustainability and a circular economy.

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