IITB-Monash Research Academy

Indian Institute of Technology Bombay | MONASH University

An Indian-Australian research partnership

Project Title:	**Selective recovery of metals from zinc mine tailings using biodegradable solvents and novel integrated approach**	
Project Number	**IMURA1292**	
Monash Main Supervisor (Name, Email Id, Phone)	Prof. Parama Chakraborty Banerjee	*Full name, Email*
Monash Co-supervisor(s) (Name, Email Id, Phone)	Prof. Mohan Yellishetty	
Monash Head of Dept/Centre (Name,Email)	Prof. Sankar Bhattacharya	*Full name, email*
Monash Department:	Chemical & Biological Engineering	
Monash ADGR (Name,Email)	Prof. Timothy Scott	*Full name, email*
IITB Main Supervisor (Name, Email Id, Phone)	Prof. Indrajit Chakraborty Indra.esed@iitb.ac.in	*Full name, Email*
IITB Co-supervisor(s) (Name, Email Id, Phone)		*Full name, Email*
IITB Head of Dept (Name, Email, Phone)	Prof. Munish Chandel head.esed@iitb.ac.in	*Full name, email*
IITB Department:	Environmental Science and Engineering Department	

Research Clusters:

Research Themes:

Highlight which of the Academy's CLUSTERS this project will address? *(Please nominate JUST **one.** For more information, see www.iitbmonash.org)*		**Highlight which of the Academy's Theme(s) this project will address?** *(Feel free to nominate more than one. For more information, see www.iitbmonash.org)*	
1	***Material Science/Engineering (including Nano, Metallurgy)***	***1***	*Artificial Intelligence and Advanced Computational Modelling*
2	*Energy, Green Chem, Chemistry, Catalysis, Reaction Eng*	2	*Circular Economy*
3	*Math, CFD, Modelling, Manufacturing*	3	*Clean Energy*
4	*CSE, IT, Optimisation, Data, Sensors, Systems, Signal Processing, Control*	4	*Health Sciences*
5	*Earth Sciences and Civil Engineering (Geo, Water, Climate)*	5	*Smart Materials*
6	*Bio, Stem Cells, Bio Chem, Pharma, Food*	6	*Sustainable Societies*
7	*Semi-Conductors, Optics, Photonics, Networks, Telecomm, Power Eng*	7	*Infrastructure*
8	*HSS, Design, Management*		

The research problem

Define the problem

Critical minerals are one of the most sought after valuable resources in the current global, national and stakeholder economies which are falling short owing to the depleting virgin resources globally. In this context, the different governmental and international organizations are currently promoting the recovery of such critical minerals from alternative sources or to be more precise, the waste streams from different mineral processing industries. Recovery of minerals is not a new concept and there have been successful pilot and full scale demonstrations of such mineral recovery from waste streams using different techniques such as hydrometallurgy, pyrometallurgy, biorecovery etc. As with any process, there are limitations associated with individual processes which need yet to be addressed. For instance, the pyrometallurgical processes are high on the energy cost which tantamounts to a long return-on-investment of such processes. For the hydrometallurgical processes, involvement of hazardous and high purity extractants or lixiviants pose challenges to the sustainability of the process.

Application of deep eutectic solvents is a sustainable proposition for extraction of metals from mine tailings. The DES are usually a mixture of a hydrogen bond donor (HBD) hydrogen bond acceptor (HBA) and have a melting point which is drastically lower than the individual components. Deep eutectic solvents though are sustainable for such metal extraction, suffer from disadvantages such as high viscosity, higher cost of compounds, regeneration issues, solvent loss owing to water extraction etc. Moreover direct application of DES to mine tailing increases the operating cost owing to several interfering species present in the mine tailings. One solution is to provide a pre-treatment to such mine tailing which can produce a mixture of metals that can be further extracted sequentially/preferentially using DES. In this regard, bioleaching of mine tailings followed by DES recovery of mixed metal streams produced during such bioleaching can add sustainability to the proposed process. Furthermore, as a downstream post-treatment, protein mediated stabilization of the metal recovered using DES can further ensure enhanced recovery of such extracted metals.

Project aims

The research thus would involve the following broad aims:

1. Design a bio-electrochemical leaching and/or bioleaching process for fast and efficient recovery of mixed metal stream from mine tailings
2. Selective extraction of metals from the mixed metal stream using biodegradable DES
3. Enhanced recovery of metals extracted using DES by protein-mediated stabilization
4. Life cycle costing and analysis of the developed process

How skills/experience of the IITB and the Monash supervisor(s) support the proposed project

Highlight the purpose of the collaboration and/or the complementary skills/experience that you bring to the project. Do you have any joint or independent publications in the area of the proposed project?

The Faculty at IIT Bombay, Prof. Indrajit Chakraborty, has research experience of working with microbial systems for both resource recovery and biological treatment of wastewater. In particular, his research focuses on materials-microbes interaction for different systems. One instance of such research currently being pursued in the lab is to understand the effect of potential imposition on fermentation products. Another research project is currently focussing on the effect of biochar addition to the change in the microbial diversity in the rhizosphere of plants. For the current

project, Indrajit's lab is equipped with a basic setup for conducting microbiology experiments and bioelectrochemical experiments relevant to the project.

External Supervisor/advisor for the project: Dr. Bhuvana Shanbhag (Asso.Prof, Amity Institute of Biotechnology, Amity University Bengaluru)
Dr. Shanbhag is a downstream processing expert and specializes in protein biomaterial development for resource recovery. In this project, her role will focus on providing inputs on integrating metal-binding proteins with biodegradable solvents for selective recovery of metal from bioleachate of zinc tailings. Dr. Shanbhag's lab will provide purified proteins for testing with biodegradable solvents. She will also provide her inputs based on her expertise in process development, technology scale-up to the student and contribute towards conceiving, planning and preparation of manuscripts/conference papers where applicable.

Monash Supervisor profile
Dr. Parama Chakraborty Banerjee has extensive expertise in recovery of critical metals from e-wastes using chemical and electrochemical leaching. Parama's team specialises in designing and synthesizing novel, sustainable, green solvents for the selective recovery of critical metals from e-wastes. Parama has supervised a number of PhD and final year research project students on this topic. One of her PhD students working on critical metal recovery had won the prestigious ClimateLauchpad competition Victoria segment. Parama's team has published in high impact journals on this topic including a few recent ones in Renewable and Sustainable Energy Reviews and Resources, Conservation and Recycling.

Monash Co-supervisor profile

Prof. Mohan Yellishetty has been working on different projects on critical mineral recovery and beneficiation and is associated in a pivotal role in different consortium and Institutes associated with critical minerals both in India and Australia as well as in India-Australia joint forums such as **Australia-India Critical Minerals Research Hub** and **Australia India Institute**. His role in this project will be to guide the student in the overall process design, ascertaining the sustainability of the process through life-cycle costing and life-cycle analysis and effective knowledge dissemination through strategic networking.

What is expected of the student when at IITB and when at Monash?

Highlight how the project will gain from the students stay at IITB and at Monash
The work envisaged in this proposal is an integrated approach of bioleaching followed by DES coupled with protein-based stabilization of the DES-recovered metals. The bioleaching experiments will be conducted in the IITB PI's lab which is well equipped for working with different bioremediation and biorecovery projects. The second part of this integrated system will be done at the Monash Lead Supervisor, Dr. Parama Chakraborty Banerjee's lab given that her lab expertises in metal recovery from waste stream using different novel strategies. In addition, Dr. Bhuvana Shanbaag, the external expert from Amity University Bangalore will work closely with both groups at Monash and IIT Bombay for the specific protein-mediated enhanced recovery of the metals extracted through DES.

Expected outcomes

Highlight the expected outcomes of the project
Based on the above discussed objectives and project aim, the following deliverables are expected from the project:

1) Identification, defining and establishing enhanced bioleaching process design parameters
2) Design of a novel solvo-metallurgical process using (biodegradable) deep eutectic solvents
3) Enhanced recovery strategy of extracted metals using protein-mediated stabilization of the process

How will the project address the Goals of the above Themes?

Describe how the project will address the goals of one or more of the 6 Themes listed above.
The project builds its foundation on the recovery of valuable metals from waste streams which connects it to the circular economy theme of the academy. In addition, by scoping the research on bio-based methods for the integrated approach, it is also contributing to the energy reduction of the extraction

process as well as the environmental footprint thereby contributing to the sustainable society theme of the academy. Finally, the incorporation of protein-mediated stabilization of recovered metal, it also connects to the design of smart materials theme. The following points of the project aligns with these two state themes:

1) recovery of metals from mine tailing: This itself reduces the stress on the virgin resources and focuses on maximizing recovery from alternative sources
2) Application of bioleaching process for non-selective extraction of metals: This step would use mixed microbial consortia unlike other bioleaching studies wherein the cost of maintaining an axenic culture can sky rocket the cost of bioleaching. Such pre-treatment would also reduce the cost of chemicals in the subsequent DES metal extraction step
3) Application of DES for metal extraction: The research will focus on the finding novel DES constituents possibly biodegradable which can be generated, rejuvenated and discarded with lower environmental footprint, designing such process will adhere well to the circular economy and sustainable infrastructure models which are key themes of the Monash Academy's research.
4) Protein-mediated stabilization of recovered metals: The metals extracted through integrated bioleaching-DES technology has to be further stabilized to avoid further loss through precipitation and complexation. For facilitating this, specific proteins which will be capable of binding to specific target metals will be designed by taking help of Dr. Shanbhag's expertise on the topic which will contribute to the smart materials theme of the academy

How well the IITB and the Monash supervisor(s) know each other

Provide details of previous collaborations (if any). For new collaborators, have you had a chance to meet each other in person or through VC or Skype?

This is a new collaboration, however, this resulted from the interaction Dr. Indrajit Chakraborty had with Prof. Mohan Yellishetty during his visit to Monash University in May 2025 as a part of the IITB-Monash Delegation.

Potential RPCs from IITB and Monash

Provide names of the potential research progress committee members (RPCs) and describe why they are most suited for the proposed project

IITB RPC members:

1. Prof. Swatantra Pratap Singh
2. Prof. Pradip Kalbar

Monash RPC member

1. Dr. Rishabh More
2. Dr. Priya Samudrala

Capabilities and Degrees Required

List the ideal set of capabilities that a student should have for this project. Feel free to be as specific or as general as you like. These capabilities will be input into the online application form and students who opt for this project will be required to show that they can demonstrate these capabilities.

Candidates meeting either criteria 1 or 2 as well as **the criteria listed in 3 & 4** eligible to apply:

1. M.Sc. in Chemistry/Physics/Environmental Science/Nanotechnology

OR

2. Masters in Environmental Engineering/Civil Engineering with Environmental Engineering specialization/Chemical Engineering/Nanotechnology
3. Should have secured 60% or equivalent CPI in Class 10, 10+2, graduation and post-graduation examinations.
4. The medium of instruction of the candidate's education should have been English for undergraduate and post-graduation degrees.

The student should be motivated and proactive with excellent problem-solving skills. A general proficiency in English is also desirable since the student would have to spend a considerable time at Monash University. Should be able to work in diverse cultural settings.

Necessary Courses

Name three tentative courses relevant to the project that the student should complete during his/her coursework at IITB (the student will require to secure 8 point in these courses)

Environmental Chemistry, Environmental Microbiology, electrochemistry courses if required

Potential Collaborators

Please visit the IITB website www.iitb.ac.in OR Monash Website www.monash.edu to highlight some potential collaborators that would be best suited for the area of research you are intending to float.

Dr. Parama Chakraborty Banerjee (PI), Dr. Mohan Yellishetty (Co-PI)

K**eywords** relating to this project to make it easier for the students to apply.

Biorecovery, Critical Minerals, Mine tailings, Solvometallurgy, Waste-to-wealth