Environment and Natural Resources Trust Fund

2027 Request for Proposal

General Information

Proposal ID: 2027-288

Proposal Title: Novel Algae Based Sustainable Bioproducts from Mining Wastewater

Project Manager Information

Name: Veluchamy Chitraichamy

Organization: U of MN - WCROC

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Project Basic Information

Project Summary: This study will explore the potential use of mining wastewater as a growth medium for the robust microalgae with a focus on sustainable bioproduct production as an emerging circular bioeconomy.

ENRTF Funds Requested: $300,000

Proposed Project Completion: June 30, 2030

LCCMR Funding Category: Small Projects (G)

Secondary Category: Water (B)

Project Location

What is the best scale for describing where your work will take place?

Statewide

What is the best scale to describe the area impacted by your work?

Statewide

When will the work impact occur?

During the Project and In the Future

Narrative

Describe the opportunity or problem your proposal seeks to address. Include any relevant background information.

Mining activities generate vast quantities of wastewater containing elevated concentrations of heavy metals, sulfates, acidity, and other contaminants. If not properly treated, this wastewater can lead to severe environmental degradation, including soil contamination, surface and groundwater pollution. Traditional treatments are often costly, energy-intensive, and generate secondary waste streams that require further management. As global mining activities continue to expand, the volume of wastewater is expected to increase significantly.

At the same time, the transition toward a circular bioeconomy requires innovative approaches that convert waste streams into valuable resources. Microalgae represent a promising waste valorization and biological solution. Certain robust microalgal species are known for their resilience in extreme environments, including high metal concentrations, variable pH, and nutrient-limited conditions. Microalgae can assimilate nutrients, sequester heavy metals, and tolerate environmental stressors while producing valuable biomass rich in lipids, proteins, carbohydrates, pigments, and bioactive compounds. Such biomass can be further processed into biofuels, animal feed, fertilizers, bioplastics, and high value bioproducts. However, the potential of mining wastewater as a growth medium for robust microalgae remains underexplored. This project will evaluate and investigate the mining wastewater as a viable and sustainable cultivation medium for selected robust microalgal strains with a sustainable bioproduct production.

What is your proposed solution to the problem or opportunity discussed above? Introduce us to the work you are seeking funding to do. You will be asked to expand on this proposed solution in Activities & Milestones.

Our proposed solution is to develop and validate an integrated bioprocess that utilizes mining wastewater as a cultivation medium for robust, metal-tolerant microalgal strains, simultaneously achieving wastewater remediation and sustainable bioproduct generation. We will identify and evaluate selected microalgae for their tolerance to varying concentrations of metals, acidity, and dissolved solids present in mining wastewater.

The proposed work will involve physicochemical characterization of mining wastewater to determine toxicity thresholds and nutrient availability. We will then conduct laboratory-scale screening of microalgal strains for growth performance and contaminant removal efficiency, and process optimization will focus on pH adjustment, dilution strategies, and nutrient balancing to enhance biomass yield while maximizing contaminant removal. We will assess pollutant reduction such as heavy metals, sulfates, nutrient loads alongside biomass composition, including lipids, proteins, carbohydrates, and high-value metabolites. We will evaluate downstream processing pathways to determine the feasibility of converting the harvested biomass into marketable bioproduct such as biofuels, biofertilizers, bio-stimulants, pigments, or other high value biochemicals.

By integrating bioremediation with resource recovery, this project will demonstrate a scalable circular bioeconomy model that transforms mining wastewater into a sustainable bioproduct production platform, reducing treatment costs while generating economic and environmental value.

What are the specific project outcomes as they relate to the public purpose of protection, conservation, preservation, and enhancement of the state's natural resources?

This project will identify and demonstrate contaminants reduction in mining wastewater prior to environmental discharge, lowering risks to surface water, groundwater, soils, and aquatic ecosystems. By removing heavy metals and excess nutrients biologically, the project supports improved water quality and ecosystem health. It will also reduce reliance on chemical-intensive treatment systems, minimizing secondary waste generation and energy use. Identify the cultivation system that uses mining wastewater as a substitute for freshwater in microalgal production. This project improves sustainable biomass production using non-potable water sources, conserving freshwater resources while promoting circular resource use and climate-resilient bioeconomic development within the state.

Activities and Milestones

Activity 1: Mining wastewater characterization and robust microalgae strain selection and batch cultivation

Activity Budget: $103,836

Activity Description:
We will collect and establish the scientific foundation on mining wastewater characteristics. Representative samples of mining wastewater will be collected and comprehensively characterized for physicochemical properties, including pH, conductivity, nitrogen and phosphorus concentrations, heavy metals, sulfate content, chemical oxygen demand, and total suspended solids.
We will screen a variety of robust microalgal strains known for tolerance to elevated metals, salinity, and nutrient-rich environments and select microalgal strains capable of tolerating conditions commonly found in Minnesota's water systems. We will develop culture strategies to optimize microalgal growth and biomass productivity, ensuring maximum nutrient and heavy metals uptake for efficient mining wastewater treatment. Batch experiments will be conducted to evaluate growth kinetics, biomass productivity, nutrient uptake efficiency, and metal tolerance thresholds. The most promising strain will be identified and selected based on performance, resilience, along with high starch and lipid accumulation. This activity will provide and ensure biological compatibility and minimizes downstream process risks.

Activity Milestones:

Description	Approximate Completion Date
Collect and chemically characterize representative mining wastewater samples.	September 30, 2027
Screen and select robust, metal-tolerant microalgal strains and growth performance under controlled conditions	October 31, 2027
Identify optimal strain and mining wastewater combinations for further development.	February 28, 2028

Activity 2: Development and experimental evaluation of an integrated microalgae based bioremediation and sustainable biomass production

Activity Budget: $100,891

Activity Description:
We will develop, design, and construct an integrated facility for microalgae process parameter testing and improvement. The selected stain from previous activity will be utilized for our bench-scale batch photobioreactor. We will determine the optimal operating conditions, including dilution ratios, hydraulic retention time, light intensity, aeration, carbon supplementation, and pH management. We will focus on cultivating high-starch and high-lipid microalgae, which serve as an ideal feedstock for sustainable biofuel production. We will select microalgal strains capable of tolerating the heavy metals and pollutants found in Minnesota's mining wastewater systems. Strains demonstrating efficiently and high starch and lipid accumulation, will be used. Since lipid and starch biosynthesis share a common metabolic pathway in most microalgae species, we will induce targeted mutations through UV and chemical treatments to inactivate key enzymes involved in lipid and starch biosynthesis, thereby enhancing lipid and starch accumulation in the selected microalgal stains.
We will also develop culture strategies to optimize algal growth and biomass productivity, ensuring maximum heavy metals and nutrient uptake and efficient mining wastewater treatment. This work will contribute to a sustainable approach for managing mining wastewater while producing valuable bioproducts for industrial applications.

Activity Milestones:

Description	Approximate Completion Date
Design and optimize microalgae cultivation systems for mining wastewater	March 31, 2028
Develop and optimize culturing parameter conditions for enhanced microalgal growth, production and harvesting system	July 31, 2028
Evaluate the pollutant, heavy metals, nutrient removal rate along with high starch or lipid content	December 31, 2028

Activity 3: Develop a fermentation technology to convert microalgae into biofuel production

Activity Budget: $75,271

Activity Description:
We will investigate the fermentation process to convert cultured and harvested algal biomass into value-added bioproducts and chemicals, to evaluate its suitability for biofuel production. We will investigate different biomass pretreatment methods (e.g., cell disruption, hydrolysis) to improve substrate accessibility for the subsequent fermentation process. Algae with high starch or lipid content will be subjected to saccharification process by either using amylase, acid hydrolysis or engineered E. coli to break down complex carbohydrate into ferment sugars. These sugars will then be converted into biofuels through fermentation, with key process conditions such as feeding rate, growth media composition, temperature, pH, and dissolved oxygen levels will be determined and optimized experimentally. Fermentation process parameters will be optimized to enhance the rate and yield of target products such as isobutanol, isobutyrate, etc. Biofuel yield, productivity, and quality will be quantified, along with characterization of residual solids and potential co-products. Process integration will be assessed to determine how fermentation can be coupled with upstream cultivation and nutrient recovery operations. This step ensures that the system not only treats waste streams but also generates renewable energy carriers, strengthening economic feasibility.

Activity Milestones:

Description	Approximate Completion Date
Evaluate microalgae pretreatment requirements and conversion efficiency.	January 31, 2029
Develop and optimize fermentation technology to convert harvested microalgal biomass into biofuel (isobutanol, isobutyrate, etc)	June 30, 2029
Analyze biofuel yield, quality parameters, and byproduct streams.	October 31, 2029

Activity 4: Conduct techno-economic analysis (TEA) and and life-cycle assessment (LCA) for the integrated microalgae based mining wastewater treatment

Activity Budget: $20,002

Activity Description:
We will conduct a comprehensive techno-economic analysis (TEA) and life-cycle assessment (LCA) of integrated microalgae-based mining wastewater treatment system. We will evaluate the system's economic feasibility, environmental performance, and overall sustainability of the integrated project. Based on the results obtained from previous activity, a TEA will be conducted to assess the initial investment and estimated operational costs, energy consumption, chemical inputs, maintenance requirements, and potential revenue streams from recovered bioproducts. Sensitivity analyses will be performed to identify key cost drivers and evaluate the economic viability under varying operational, market conditions and to provide the economic validation of the mining wastewater to microalgae process for value-added biofuels and chemicals.
We will also conduct the LCA which includes assessment of environmental impacts of materials sourcing, reactor construction, operation, chemical usage, energy consumption, nutrient recovery, and end-product utilization. The results of the process will be compared with the conventional processes for isobutanol, isobutyrate or 1,4-butanediol

production. The combined TEA and LCA results will provide an integrated sustainability assessment, identify trade-offs between economic and environmental performance, and support decision-making for process optimization, scale-up, and commercial implementation.

Activity Milestones:

Description	Approximate Completion Date
Develop a techno-economic model to assess the production cost scalability, and revenue potential	December 31, 2029
Perform life-cycle assessment to quantify environmental impacts, including GHG emissions, energy use, and resource efficiency	March 31, 2030
Finalize both models using optimized parameters obtained from activity 1, 2, and 3	June 30, 2030

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Prasanth K S Pillai	University of Minnesota, department of Food Science and Nutrition	Collaborator- Research scientist- Mentoring the graduate student to conduct fermentation, support analyses	Yes

Dissemination

Describe your plans for dissemination, presentation, documentation, or sharing of data, results, samples, physical collections, and other products and how they will follow ENRTF Acknowledgement Requirements and Guidelines.
The project team will implement a comprehensive dissemination and data-sharing strategy to ensure that project findings, data, products, and outcomes are accessible to stakeholders, researchers, policymakers, and the public while fully complying with ENRTF Guidelines. Findings on algal strain, heavy metals and nutrient recovery performance, and water quality parameters will be shared through peer-reviewed journal publications, conference presentations. Annual and final reports will be submitted to ENRTF as required, and plain-language summaries, fact sheets, and webinars will be developed to reach non-technical audiences. All datasets including water quality monitoring data, heavy metals and nutrient analyses, and recovery efficiency results will be quality controlled, documented with metadata, and made publicly available through a UMN supported repository. Identified algal strain and related documentation will be shared for research and demonstration purposes where appropriate. All publications, presentations, outreach materials, and digital content will prominently acknowledge support from the Environment and Natural Resources Trust Fund using the required funding statement and official logo, ensuring full adherence to ENRTF acknowledgement policies.

Long-Term Implementation and Funding

Describe how the results will be implemented and how any ongoing effort will be funded. If not already addressed as part of the project, how will findings, results, and products developed be implemented after project completion? If additional work is needed, how will this work be funded?
Project results will be implemented through partnerships with mining operators and state environmental agencies to pilot the optimized microalgae-based treatment system at demonstration scale workshops at West central research and Outreach center, Morris. Standard cultivation and remediation protocols will be developed during the project, will support technology transfer.
Ongoing efforts will seek funding through federal and state grants, industry partnerships, and private investments. Future research will focus on system optimization and commercialization. Additional work will be pursued through competitive grants (e.g., USDA, NSF), corporate sponsorships, and collaborations with agricultural innovation centers to ensure long-term sustainability and impact.

Project Manager and Organization Qualifications

Project Manager Name: Veluchamy Chitraichamy

Job Title: Research Assistant Professor

Provide description of the project manager's qualifications to manage the proposed project.
Dr. Veluchamy Chitraichamy is a Research Assistant Professor in the College of Food, Agricultural and Natural Resources Science at the University of Minnesota, Twin Cities. Dr. Chitraichamy finished his post-doctoral training at the University of Guelph Canada on various research project that focus on biomass valorization, waste management and resource recovery, and environmental sustainability. He earned PhD in Civil Engineering specialized in Environmental Engineering

at the Indian Institute of Technology Guwahati, India and B.Tech degree in Agricultural Engineering from Tamil Nadu Agricultural University, India. Dr. Chitraichamy has 9 years of research experience in sustainable waste management and resource recovery from various bioresource waste materials. His interdisciplinary research program focuses on integration of renewable bioenergy with agriculture and the environment. He has successfully conducted interdisciplinary research projects by collaborating with various academic institutions, industry stakeholders, and government agencies. Dr. Chitraichamy has guided students in laboratory research, experimental design, data analysis, fostering a collaborative and productive research environment that ensures rigorous project oversight and effective knowledge transfer to team members and stakeholders. His current and past research projects include the conversion of organic wastes into biofuel and value-added byproduct development, bioreactor designs, development of kinetic model and evaluating techno-economic analysis (TEA), evaluating novel farm-scale technologies, determining the fate of various contaminant and pathogens, monitoring greenhouse gas emissions and developing decision support guidance. He has a proven track record of publishing peer-reviewed journals, presenting research findings at national and international conferences. He advocates dissemination of science to the public through research outreach and extension activities, public talk and social media.

Organization: U of MN - WCROC

Organization Description:
In the College of Food, Agricultural and Natural Resources Sciences (CFANS) at the University of Minnesota, we look at the bigger picture. When we envision a better tomorrow, it includes disease- resistant crops, products that protect our health, lakes free from invasive species, and so much more. We use science to find answers to Minnesota and the world's grand challenges and solve tomorrow's problems.

The Department of Bioproducts and Biosystems Engineering (BBE), in CFANS, discovers and teaches solutions for the sustainable use of renewable resources and the enhancement of the environment. We discover innovative solutions to address challenges in the sustainable production and consumption of food, feed, fiber, materials, and chemicals by integrating engineering, science, technology, and management into all degree programs.

The UMN West central Research and Outreach Center (WCROC), located at Morris, will serve as the primary project location. The WCROC is a 1,100-acre, one of the University's living laboratories where agricultural research can be demonstrated at scale, and it serves as a regional center for agricultural stakeholders to discuss current issues in agriculture. The faculty and staff have considerable experience in developing and effectively implementing applied research, outreach, and extension programs at the applied farm-level.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
1 Research Assistant professor, 9 month appointment, seeking summer salary		Principal Investigator, coordinate the research efforts, design experiments, mentor the graduate research assistant, write project reports			36.6%	0.3		$45,401
Assistant Professor, 9 month appointment, seeking summer salary		Collaborator - assist the research efforts, mentor the graduate research assistant			36.6%	0.05		$7,309
1 Graduate Research Assistant (stipend and tuition fee)		Conducting the experiments, data collection, validation of results as proposed, manuscript preparation, presenting results at conference			24.2%	3		$166,438
One undergraduate students ($17.46 per hour, 10 hour per week, and 20 weeks each year; 3% increase in each year afterwards)		Receive research training and collect experimental data			0%	0.9		$10,847
							Sub Total	**$229,995**
Contracts and Services								
							Sub Total	**-**

Equipment, Tools, and Supplies								
	Equipment	A algal photobioreactor ($6,000) will be built in the second year. A 10L lab scale fermenter ($17,000) will be designed and fabricated for fermenting the produced algal biomass from mining wastewater. The components includes, fermenter reactor, gas measuring devises,, oxygen and CO2 probe, pumps, air compressor, insulation etc	This lab-scale photoreactor and fermenter will enable us to test our proposed process in the mining wastewater					$23,000
	Tools and Supplies	Funds ($10,000 in Year 1, $13,000 in Year 2, and $ 13,825 in Year 3) are requested for experimental chemicals supplies, pumps, analysis kit, and PPE supplies. Analytical supplies for conducting algal cultivation, fermentation and heavy metals and nutrient analysis of replicated wastewater samples. Chemicals, analysis kits and personal protection supplies such as gloves masks, etc. Supplies for the system include bags, pvc piping, compressor, heat sealer, filters, centrifuge, chemicals, metal racks, pumps, lights, electrical wiring, pH monitoring and control, and CO2 sparging etc. Purchase of small, non-capital lab equipment supplies to enable research.	These chemicals and analytical supplies are need to carryout the proposed experimental work.					$36,825
							Sub Total	**$59,825**
Capital Equipment								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Conference Registration Miles/ Meals/ Lodging	One conference trip on second and third year for PI and 2 student per year, $250 registration per person ($750 total per year), 500 miles per year ($300), lodging for 3 persons and 2 nights ($900), and meals ($620 for 3 persons, two days per year)	PI and graduate student each year will present and share research results in in-state conferences, and network with peers.					$4,180

							Sub Total	**$4,180**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
	Publication	Open-access journal publication cost	Publish research results in open-access journal, about $2,000 per year for one paper					$6,000
							Sub Total	**$6,000**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$300,000**

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request

Non ENRTF Funds

Category	Specific Source	Use	Status	Amount
State				
			State Sub Total	**-**
Non-State				
			Non State Sub Total	**-**
			Funds Total	**-**

Total Project Cost: $300,000

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: fa540ecd-9ee.pdf

Alternate Text for Visual Component

The graphical abstract outlines the integrated bioprocess that utilizes mining wastewater as a cultivation medium for robust, metal tolerant microalgal strains cultivation for mining wastewater remediation and sustainable bioproduct production....

Supplemental Attachments

Capital Project Questionnaire, Budget Supplements, Support Letter, Photos, Media, Other

Title	File
Letter of Authorization to Submit	218f110b-edc.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

Do you understand that travel expenses are only approved if they follow the "Commissioner's Plan" promulgated by the Commissioner of Management of Budget or, for University of Minnesota projects, the University of Minnesota plan?

Yes, I understand the UMN Policy on travel applies.

Does your project have potential for royalties, copyrights, patents, sale of products and assets, or revenue generation?

No

Do you understand and acknowledge IP and revenue-return and sharing requirements in 116P.10?

N/A

Do you wish to request reinvestment of any revenues into your project instead of returning revenue to the ENRTF?

N/A

Does your project include original, hypothesis-driven research?

Yes

Does the organization have a fiscal agent for this project?

No

Does your project include the pre-design, design, construction, or renovation of a building, trail, campground, or other fixed capital asset costing $10,000 or more or large-scale stream or wetland restoration?

No

Do you propose using an appropriation from the Environment and Natural Resources Trust Fund to conduct a project that provides children's services (as defined in Minnesota Statutes section 299C.61 Subd.7 as "the provision of care, treatment, education, training, instruction, or recreation to children")?

No

Provide the name(s) and organization(s) of additional individuals assisting in the completion of this proposal:

Wendy Moylan, University of Minnesota

Do you understand that a named service contract does not constitute a funder-designated subrecipient or approval of a sole-source contract? In other words, a service contract entity is only approved if it has been selected according to the contracting rules identified in state law and policy for organizations that receive ENRTF funds through direct appropriations, or in the DNR's reimbursement manual for non-state organizations. These rules may include competitive bidding and prevailing wage requirements

N/A