Environment and Natural Resources Trust Fund

2027 Request for Proposal

General Information

Proposal ID: 2027-289

Proposal Title: Use Cyanobacteria to Remove PFAS from Minnesota's Water

Project Manager Information

Name: Bo Wang

Organization: U of MN - College of Food, Agricultural and Natural Resource Sciences

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Project Basic Information

Project Summary: Cyanobacteria have been proven capable of removing and degrading PFAS. Model cyanobacterial strains and Minnesota cyanobacterial species will be studied for their capacity and mechanisms in removing PFAS from water.

ENRTF Funds Requested: $337,000

Proposed Project Completion: June 30, 2030

LCCMR Funding Category: Water (B)

Project Location

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

Region(s): Metro

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.

Prevalence of harmful per- and polyfluoroalkyl substances (PFAS) in Minnesota environment calls for immediate attention and development of PFAS remediation technologies. PFAS are a type of synthetic "forever chemicals" that are not readily degraded in the environment. Studies showed that PFAS disrupt ecosystems and can accumulate in human bodies to suppress immune system, delay child development, interfere with hormone signaling pathways, and increase risk of cancer. According to the Minnesota PCA data, PFAS have been found in ground water and surface water across the entire state of Minnesota, with particularly elevated concentrations in the influent and effluent of wastewater treatment plants (WWTPs). As conventional water treatment does not remove PFAS effectively, it remains challenging to remediate PFAS-contaminated ecosystems due to PFAS chemical stability, composition complexity, and usually low environmental concentrations. Traditional PFAS remediation methods often involve PFAS adsorption and subsequent chemical and physical degradation processes. Those processes are constrained by the generation of toxic byproducts, degradation of treatment materials, and high operational costs. More recently, bioremediation has been recognized as a highly promising, environmentally friendly, and energy-efficient alternative to conventional approaches in PFAS remediation.

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.

We propose developing a biological method to remove and degrade PFAS from Minnesota water bodies using cyanobacteria, a type of oxygenic photosynthetic microorganisms. Recently, the freshwater model cyanobacterium, Synechocystis sp. PCC 6803 (hereafter Synechocystis 6803; isolated from a freshwater lake in California; environmentally safe), was found able to enrich and degrade PFAS. The cell growth rate was promoted by PFAS at concentration up to 1 mg/L level (>1000x that in the effluent of WWTPs), while the PFAS removal rate reached 0.36 mg/L/day. Another recent study reported that PFAS at environmentally relevant concentrations improved the photosynthetic activity and cell growth of cyanobacterium Microcystis aeruginosa. Although these findings are quite impressive and exciting, the underlying biological PFAS degradation mechanisms are still elusive and the potential of cyanobacterial remediation of PFAS has not been explored in Minnesota. Here, we will (1) conduct a systematic investigation of PFAS degradation capacity in the model cyanobacterium Synechocystis 6803 and isolated Minnesota native cyanobacterial strains, (2) investing the underlying mechanisms of PFAS removal in the best-performing cyanobacterial strains, and (3) demonstrate the use of eco-friendly cyanobacteria to remove and degrade PFAS from effluent of Minnesota WWTPs.

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?

Developing eco-friendly PFAS remediation technology through selecting nonharmful cyanobacterial strains will render a very promising method for effective removal of PFAS from the Minnesota water bodies. Particularly, this technology might be first deployed at the WWTPs where usually higher concentrations of PFAS are reported. Since cyanobacteria such as Synechocystis 6803 also possess high capacity in removing phosphate and nitrate from water, this could become a consolidated bioprocess for both PFAS remediation and phosphate removal. In addition, nonharmful cyanobacteria use light and CO2 and produce no hazardous byproducts. The generated cyanobacterial biomass could potentially be used as fertilizers or animal feed.

Activities and Milestones

Activity 1: Systematic investigation of PFAS degradation capacity in the model cyanobacterium Synechocystis and isolated Minnesota native cyanobacterial strains

Activity Budget: $107,607

Activity Description:
First, the capability of the model cyanobacterium Synechocystis 6803 in removing and degrading PFAS under various environmental conditions will be investigated. According to a previous report, Synechocystis 6803 was able to degrade PFAS at 30oC under moderate light intensity (150 µmol photons m-2 s-1; <10% of full sun radiation). Here, its PFAS degradation capacity will be investigated with varied temperature and light intensity. The temperature will span from 25 to 30 to 35 oC, while the light intensity to be tested will be 25, 50, 100, 200 and 500 µmol photons m-2 s-1.
Next, we will isolate Minnesota native cyanobacterial strains and characterize their capacity in remove PFAS. Particularly, cyanobacterial species from the high-level-PFAS water bodies, such as the discharging sites of WWTPs, will be isolated and grown in our laboratory. We will then characterize these cyanobacterial isolates for their PFAS degradation capability using an approach like that described above. Ultimately, 16S rDNA sequencing will be applied to identify the cyanobacterial species. Eco-friendly cyanobacterial species will be moved forward for further characterization in Activity 2 and 3.

Activity Milestones:

Description	Approximate Completion Date
Establish a standard protocol for precise quantification of PFAS	December 31, 2027
Investigate the effects of PFAS on Synechocystis 6803 under various temperature and light conditions	June 30, 2028
Examine the capacity of Synechocystis 6803 in PFAS degradation	June 30, 2028
Isolate Minnesota native cyanobacterial strains and examine their capacity in PFAS degradation	December 31, 2028

Activity 2: Investing the underlying mechanisms of PFAS removal in the best-performing cyanobacterial strains

Activity Budget: $120,380

Activity Description:
We will investigate the molecular mechanisms underlying PFAS degradation in the model cyanobacterium strain Synechocystis 6803 and the best-performing Minnesota native cyanobacterial strains. Although cyanobacteria have been reported capable of degrading PFAS, there has been lack of systematic investigation of the degradation pathways as well as the intermediate and final products from PFAS biodegradation. Among all cyanobacterial strains, Synechocystis 6803 was the first strain to have its whole genome sequenced and annotated. On the other hand, Minnesota cyanobacterial species may exhibit advantage in surviving in their native habitat while possessing different mechanisms in mitigating PFAS. Here, cells from cyanobacterial cultures with and without PFAS supplemented will be collected and subjected to comparative proteomics and metabolomics analysis to identify key genes responsible for PFAS degradation. Additionally, isotope labeling and 13C-metabolic flux analysis will be performed for these cyanobacterial strains to study how PFAS degradation impact the cell metabolism. This activity will enable us to elucidate possible PFAS degradation mechanisms in the best-performing cyanobacterial strains, which will not only address an important scientific question but also guide us to further improve the PFAS remediation process.

Activity Milestones:

Description	Approximate Completion Date

Comparative proteomic and metabolomic analysis for Synechocystis 6803 in the absence and presence of PFAS	December 31, 2029
Isotope labeling and 13C-metabolic flux analysis to study how PFAS degradation impact the cell metabolism	June 30, 2030

Activity 3: Using cyanobacteria to remove and degrade PFAS from effluent of Minnesota WWTPs

Activity Budget: $109,013

Activity Description:

This task aims to conduct a preliminary demonstration of using the best-performing cyanobacterial strains characterized in Activity 1 to remove PFAS. To accomplish this goal, effluents from nearby Minnesota WWTPs will be collected and then used to cultivate the best-performing PFAS-degrading cyanobacterial strains in our laboratory. The cyanobacterial strains will be inoculated directly into the WWTPs effluent and cultivated under the optimal PFAS degradation conditions as investigated in Activity 1. WWTPs effluent without addition of cyanobacterial cells will be incubated under the same culture conditions to serve as an experimental control. Cultures will be sampled every day for a period of 7 days. The cell density, the chlorophyll content (which indicates the photosynthetic activity) and the PFAS concentrations will be monitored. PFAS will be analyzed following the standard PFAS analysis protocol – U.S. Environmental Protection Agency Draft Method 1633.

This research activity will deliver a preliminary demonstration of cyanobacterial remediation of PFAS, which could be scaled up and integrated into the water treatment pipeline at Minnesota WWTPs in the future. The development of this technology directly addresses the imminent issue of lacking effective remediation method to treat PFAS in Minnesota water bodies and it well aligns the mission of LCCMR.

Activity Milestones:

Description	Approximate Completion Date
Investigate the capacity of best-performing cyanobacterial strains in removing PFAS from effluent of Minnesota WWTPs	June 30, 2030
Characterize the physiology of cyanobacterial strains grown with effluent of Minnesota WWTPs	June 30, 2030

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.
Results from this project will be actively disseminated to stakeholders and the public to support protection of Minnesota's environment and natural resources from Per- and Polyfluoroalkyl Substances (PFAS). We will actively engage Minnesota Pollution Control Agency (MPCA), municipalities, and wastewater treatment plants (WWTPs). Our findings on cyanobacterial degradation of PFAS will be shared with the Minnesota PCA and the Minnesota Department of Natural Resources through periodic meetings, webinars, and technical briefings. We will share our technical reports and fact sheets with WWTPs and Minnesota agencies like MPCA, and Minnesota Department of Natural Resources (DNR), and Minnesota Environmental Quality Board (EQB). We hope this will translate scientific results into practical recommendations that support improved monitoring, treatment, and management strategies for PFAS contamination.

We will also communicate results to Minnesotans through plain-language summaries, infographics, and outreach presentations. For example, the results will be shown to the public during our department's annual Open House and Recruitment events. We plan to showcase our progress and findings at our college's booth at Minnesota State Fair.

Research outcomes will also be communicated with the scientific community through presentations at regional, national and international conferences and publication at peer-reviewed journals. We will take advantage of the UMN's University Digital Conservancy (UDC) to make our articles open and free to the public. To ensure long-term accessibility, project datasets, analytical methods, and reports will be archived in publicly accessible UMN data platforms - Data Repository for the University of Minnesota (DRUM). We will always acknowledge support from the Environment and Natural Resources Trust Fund.

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?
The proposed research will be carried out by Dr. Bo Wang and his students at University of Minnesota. After successful demonstration of the technology at lab scale by the end of this project, Dr. Bo Wang will seek collaboration with Minnesota WWTPs and bioprocess engineers to acquire a larger grant for designing a prototype PFAS remediation bioprocess that will be implemented at Minnesota WWTPs. The potential additional funding for scaling up and demonstration will be sought through the Minnesota Pollution Control Agency, Minnesota Department of Health, and federal funding agencies such as NSF and EPA.

Project Manager and Organization Qualifications

Project Manager Name: Bo Wang

Job Title: Assistant Professor

Provide description of the project manager's qualifications to manage the proposed project.
Bo Wang is a tenure-track assistant professor at the Department of Bioproducts and Biosystems Engineering at the University of Minnesota (UMN). Bo is also a member of the BioTechnology Institute which aims to advance multidisciplinary research and innovation at the forefront of biotechnology. Bo earned his Bachelor's and Master's degrees in Chemical Engineering from Tsinghua University and his Ph.D. degree in Biological Design from Arizona State University. He was a postdoctoral fellow and research scientist at the National Renewable Energy Laboratory, and worked as a research assistant professor at Vanderbilt University before he joined UMN in August 2024.

Bo has extensive research experience in working with cyanobacteria, renewable energy, and bioproducts. His professional background includes chemical engineering, molecular biology, metabolic engineering, and bioprocess engineering, which qualifies him to take the lead in coordinating this project. His research interests include understanding the fundamental metabolism of microorganisms and engineering microbial metabolism for biomanufacturing and bioremediation purposes. Bo has authored >20 articles in peer-reviewed journals or as book chapters and has been awarded 4 US patents on biomanufacturing and biodegradation technologies.

Bo has participated as key personnel in multiple federal grants before he joined UMN. At the University of Minnesota, Bo is a Principal Investigator who is running a lab centered on microbial metabolism and metabolic engineering. He has been a mentor for 3 graduate students, and 3 undergraduate students at UMN.

Organization: U of MN - College of Food, Agricultural and Natural Resource Sciences

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. Almost 93 percent of students who earn CFANS undergraduate degrees find jobs in their career field or enter graduate school within six months of graduation.

The Department of Bioproducts and Biosystems Engineering, 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.

We have a public impact through community engagement and extension efforts. We develop and deliver high quality, regionally and nationally-recognized research-based programs to meet current and emerging needs of industry and communities. We also have a long-standing tradition of close partnerships with alumni, industry professionals, organizations, government agencies, donors, and community members.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Principal Investigator, 9 month appointment, seeking summer salary		Oversee all research and personnel, reporting			26.8%	0.24		$43,632
graduate student - full appointment (50% work, 50% education)		conduct experiments and analysis			46%	3		$188,326
Undergraduate students		experiment set up and take down, assist graduate student			0%	0.6		$22,779
							Sub Total	**$254,737**
Contracts and Services								
UMN Center for Metabolomics and Proteomics	Internal services or fees (uncommon)	Analysis of PFAS using LC-MS/MS, which is critical to accurately quantifying the PFAS degradation rates by cyanobacteria investigated in this project. The service cost will be approximately $50 per sample. This center will also be responsible for proteomic analysis, the cost of which will be $9,775.				0		$50,763
							Sub Total	**$50,763**
Equipment, Tools, and Supplies								
	Tools and Supplies	Laboratory chemicals and reagents (PFAS standards, isotope tracer compounds, derivative reagents for GC-MS analysis, cell culture medium), LED lights, digital dimmer, gas flow controllers	These chemicals, reagents and tools are necessary for the PI and students to set up and execute the proposed experiments.					$15,000
	Tools and Supplies	Laboratory consumables - pipettes, pipettes tips, centrifuge tubes, cuvettes, petri dishes, medium	To conduct experiments and maintain safety of all personnel in lab. Pipettes,					$15,000

		bottles, special HDPE and polypropylene culture flasks, gloves, lab coats, safety goggles	pipettes tips, centrifuge tubes are needed for processing cell culture samples and PFAS samples. Cuvettes are for reading the optical density of cell culture. Special High-density polyethylene (HDPE) or polypropylene (PP) flasks are for handling PFAS-containing cell cultures. Gloves, lab coats and safety goggles are for personal protection in the lab and in the field.					
							Sub Total	**$30,000**
Capital Equipment								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Conference Registration Miles/ Meals/ Lodging	For Year 2 and Year 3. One conference trip for the PI and two students each year. Registration: $100 per person on average; about 200 miles each year; transport & meals: $200 each year. $500 each year.	PI and students will present the progress and findings on cyanobacterial degradation of PFAS at conferences held within Minnesota; we will communicate with peers, government agencies and stakeholders to seek collaborations and support.					$1,000
	Miles/ Meals/ Lodging	During Year 1, PI and two students will have two trips within Minnesota. Will travel 200 miles in total. Transport and Meals: $500.	PI and two students will have two trips for collecting biological samples from PFAS-rich Minnesota water bodies for isolating potential PFAS-degrading cyanobacterial species.					$500
							Sub Total	**$1,500**
Travel Outside Minnesota								

							Sub Total	**-**
Printing and Publication								
	Publication	Publishing peer-reviewed journal articles.	To disseminate the research findings. The University Digital Conservancy (UDC) provides free and world-wide open access to scholarly works authored by UMN faculty. Therefore, no additional budget for publication.					-
							Sub Total	**-**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$337,000**

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: $337,000

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: 9185743a-c14.pdf

Alternate Text for Visual Component

A bioprocess using freshwater nonharmful cyanobacteria will be developed to biotransform water pollutant such as PFAS, phosphate and nitrate, to environmentally friendly chemicals and fertilizers....

Supplemental Attachments

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

Title	File
Letter of Approval to Submit	82a73b02-7ba.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?

Yes

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

Yes

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

No

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

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