Environment and Natural Resources Trust Fund

2025 Request for Proposal

General Information

Proposal ID: 2025-084

Proposal Title: Cyanotoxins in Minnesota Lakes: The Role of Sunlight

Project Manager Information

Name: William Arnold

Organization: U of MN - College of Science and Engineering

Office Telephone: (612) 625-8582

Email: arnol032@umn.edu

Project Basic Information

Project Summary: The degradation of cyanobacterial toxins by sunlight will be quantified to understand how increasing frequency of cyanobacterial (harmful algal) blooms and changing environmental conditions influence toxin persistence in natural waters.

ENRTF Funds Requested: $220,000

Proposed Project Completion: June 30, 2027

LCCMR Funding Category: Small Projects (H)

Secondary Category: Water Resources (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.

The combination of increased temperatures and nutrient loads to Minnesota's lakes and rivers are increasing the duration and frequency of blooms of harmful cyanobacteria (also known as harmful algal blooms). These blooms produce cyanotoxins that are a threat to humans who drink or recreate in Minnesota's waters as well as wildlife. Additionally, these blooms will affect the composition of dissolved organic matter (DOM), the material that gives water its brown color in lakes and rivers. When the DOM absorbs sunlight, it creates reactive species that are critical to the degradation of a cyanotoxins. Yet the presence of cyanobacteria and cyanobacterial organic matter will influence the production and quenching of these same reactive intermediates in natural waters. Additionally, we do not fully understand how different wavelengths of light influence this process. Due to stratospheric ozone recovery and the emission of more greenhouse gases and other particles into the atmosphere, many bodies of water will experience a future shift in the intensity and spectrum of sunlight they receive. We do not know how this combination of conditions will affect the longevity of cyanotoxins in Minnesota's waters.

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.

This proposal seeks to address how the cascading effects of temperature, nutrients, organic matter composition and changes in sunlight will affect the persistence of cyanotoxins in Minnesota waters, so we can develop better warnings about water use and recommendations for additional treatment of drinking water. Using a combination of laboratory grown cyanobacteria and waters collected from lakes before, during, and after cyanobacteria blooms, the production of reactive intermediates by cyanobacterial organic matter will be measured and compared to materials present in unimpacted waters. The effect of different wavelengths of light will be tested. From this information, the production rate of reactive intermediates will be calculated and used to predict how the concentrations of cyanotoxins in Minnesota lakes will change under different scenarios. The levels of cyanotoxins in the lakes and the rate at which these toxins degrade in the presence of different organic matter will then be measured directly. Finally, the specific reactive species responsible for the degradation of the cyanotoxins will be identified, and this data will provide the information needed to assess how different environmental conditions affect the persistence of cyanotoxins in Minnesota lakes.

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?

Understanding cyanotoxin persistence in our water is important for the protection of all water users. Furthermore, the presence of cyanotoxins poses a threat to the fish and other aquatic life that live in these waters. Understanding how the cascading effects of temperature, light, and water quality will affect the surface-water photochemistry and longevity of cyanotoxins in Minnesota's waters will be critically important for management decisions, public notification of potential dangers, and adaptive drinking water treatment.

Activities and Milestones

Activity 1: Quantify the ability of cyanobacterial organic matter to produce reactive intermidiates that can degrade cyanobacterial toxins

Activity Budget: $130,000

Activity Description:
A cyanobacterial strain (M. aeruginosa strain UTEX B 2662) known to produce cyanotoxins will be grown in the laboratory. Once the culture is established, the water will be filtered/extracted to collect the organic matter. Water samples from lakes, including sentinel lakes monitored by the Minnesota Pollution Control Agency, will be collected before, during, and after cyanobacterial blooms. These waters and the material collected from the lab grown strain will be used in photochemistry experiments. The spectral and chemical properties of the organic matter will be characterized. A series of chemical probes will be used to quantify hydroxyl radicals, carbonate radials, singlet oxygen, and reactive triplet species from the organic matter. These are the reactive intermediates likely to degrade cyanotoxins. Comparisons will be made to the production of the reactive intermediates from reference organic material, collected from lakes without cyanobacterial blooms. The light wavelength dependence of these reactions will be explored by comparing the reactive intermediate production at a range of wavelengths using a solar simulator and narrow bandwidth light emitting diodes (LEDs).

Activity Milestones:

Description	Approximate Completion Date
Grow cyanobacterial cultures and harvest organic matter	December 31, 2025
Collect cyanobacterial bloom impacted waters	October 31, 2026
Experiments to quantify reactive intermediates - solar light	October 31, 2026
Manuscript publication	December 31, 2026
Experiments to quantify reactive intermediates - light emitting diodes	March 31, 2027

Activity 2: Establish the rate and pathway of cyanobacterial toxin degradation under different light and solution conditions

Activity Budget: $90,000

Activity Description:
The degradation of cyanotoxins when exposed to light in the presence of organic matter will be explored. Probe and quencher experiments will be used to isolate the specific reactive species responsible for the degradation. Known reactive intermediate sensitizers will be used to verify the reactivity and determine the second order rate constants. The effect of light wavelength will again be explored by comparing cyanotoxin degradation at a range of wavelengths using a solar simulator and narrow bandwidth light emitting diodes. The information about reactive intermediate production from Activity 1 and the degradation rate constants in Activity 2 will be combined into a model that will be able to predict cyanotoxin persistence for various organic matter compositions and light intensities/spectra.

Activity Milestones:

Description	Approximate Completion Date
Confirm cyanobacterial toxin analytical method	October 31, 2025
Measurement of cyanobacterial compound degradation - solar light and light emitting diodes	January 31, 2027
Measure rates of cyanobacterial compound degradation - solution conditions	March 31, 2027
Model development	June 30, 2027
Manuscript publication	June 30, 2027

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 results will be communicated to stakeholders, including state agencies, watershed districts, and science/engineering consulting firms, through direct communication, presentation and local/regional conferences, and peer-reviewed publications.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Determining Influence of Insecticides on Algal Blooms	M.L. 2019, First Special Session, Chp. 4, Art. 2, Sec. 2, Subd. 04a	$350,000
Benign Design: Environmental Studies Leading to Sustainable Pharmaceuticals	M.L. 2019, First Special Session, Chp. 4, Art. 2, Sec. 2, Subd. 04b	$415,000
Improving Drinking Water for Minnesotans through Pollution Prevention	M.L. 2019, First Special Session, Chp. 4, Art. 2, Sec. 2, Subd. 04f	$345,000
Technology For Energy-Generating Onsite Industrial Wastewater Treatment	M.L. 2021, First Special Session, Chp. 6, Art. 5, Sec. 2, Subd. 04b	$450,000
Microgeographic Impact of Antibiotics Released from Identified Hotspots	M.L. 2021, First Special Session, Chp. 6, Art. 6, Sec. 2, Subd. 04d	$508,000
Finding, Capturing, and Destroying PFAS in Minnesota Waters	M.L. 2023, , Chp. 60, Art. 2, Sec. 2, Subd. 04d	$478,000
Removing CECs from Stormwater with Biofiltration	M.L. 2023, , Chp. 60, Art. 2, Sec. 2, Subd. 04j	$641,000

Project Manager and Organization Qualifications

Project Manager Name: William Arnold

Job Title: Distinguished McKnight University Professor

Provide description of the project manager's qualifications to manage the proposed project.

Dr. William Arnold is a Distinguished McKnight and the Joseph T. and Rose S. Ling Professor in the Department of Civil, Environmental, and Geo- Engineering at the University of Minnesota. He received his B.S. in Chemical Engineering from MIT in 1994 his M.S. in Chemical Engineering from Yale in 1995, and a Ph.D. in Environmental Engineering from The Johns Hopkins University in 1999. He has supervised 25 Ph.D. students and 24 M.S. students. He has been studying the fate of micropollutants, including pharmaceuticals, pesticides, and PFAS compounds in aquatic environments for twenty years. As part of these studies, he has evaluated the presence and removal of various CECs in Minnesota's waters, including past work supported by the ENRTF. His work has specifically focused on how sunlight in natural and engineered systems leads to transformation of pollutants. He has also evaluated how organic matter from wastewater or stormwater produces reactive species that can degrade contaminants when exposed to sunlight. Past ENTRF funded work has been impactful to Minnesota, particularly work on triclosan and quaternary ammonium compounds.

Organization: U of MN - College of Science and Engineering

Organization Description:

The University of Minnesota (UMN) is one of the largest, most comprehensive, and most prestigious public universities in the United States (http://www1.umn.edu/twincities/01_about.php). The College of Science and Engineering at the University of Minnesota is ranked among the top engineering and science academic programs in the country. The college includes 12 academic departments offering a wide range of degree programs at the baccalaureate, master's, and

doctoral levels. Researchers within the College of Science and Engineering are on the leading edge of finding ways to solve some of the world's greatest problems by developing new forms of environment-friendly energy, designing new medical devices, improving digital and electronic technologies, and developing a strong national infrastructure. The College of Science and Engineering also offers students a rigorous, world-class education tailored to their interests and goals. The Department of Civil, Environmental, and Geo- Engineering (CEGE) at UMN is known for its pioneering work in analytical, computational, and experimental methods. We practice research excellence grounded in rigorous fundamentals for wide-ranging applications. The laboratories in CEGE and centralized research facilities have all of the necessary space and equipment to perform the proposed work.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
William Arnold		Project Manager			27%	0.16		$57,800
Graduate Student Research Assistant		Laboratory work			44%	0.94		$106,785
							Sub Total	**$164,585**
Contracts and Services								
TBD	Internal services or fees (uncommon)	analytical fees in UMN central laboratory facilities				-		$8,000
							Sub Total	**$8,000**
Equipment, Tools, and Supplies								
	Tools and Supplies	Laboratory supplies	Chemicals, solvents, and material to conduct the work					$23,415
	Tools and Supplies	Instrument maintenance	Support for upkeep of mass spectrometry system					$12,000
							Sub Total	**$35,415**
Capital Expenditures								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								

	Miles/ Meals/ Lodging	Anticipate up to 6 trips per year, up to 200 miles, 2 people per trip.	Travel to lakes to collect samples before, during, and after blooms.					$2,500
	Conference Registration Miles/ Meals/ Lodging	Two conference events in Minnesota (e.g., MN AWWA, MN Water Conference)	Present results to community/stakeholders					$1,500
							Sub Total	**$4,000**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
	Publication	Open access fees	Provide maximum exposure for publications					$8,000
							Sub Total	**$8,000**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$220,000**

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				
In-Kind	U of MN Indirect Costs	UMN facilities and administration	Secured	$101,000
			Non State Sub Total	**$101,000**
			Funds Total	**$101,000**

Total Project Cost: $321,000

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: bc67b027-5da.pdf

Alternate Text for Visual Component

A picture of a sunlit lake with green growth (cyanobacteria) due to the presence of nutrients, light, and heat. The cyanobacteria generate toxins, and these are degraded by reactive species generated by sunlight. Understanding the details of this cycle is key to protecting humans and wildlife from these toxins....

Supplemental Attachments

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

Title	File
Approval to Submit - UMN	c4fdf656-49a.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

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:

Katie Sauer (budget)