Environment and Natural Resources Trust Fund

2022 Request for Proposal

General Information

Proposal ID: 2022-099

Proposal Title: Mitigating Cyanobacterial Blooms and Toxins Using Clay-Algae Flocculation

Project Manager Information

Name: Judy Yang

Organization: U of MN - St. Anthony Falls Laboratory

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Project Basic Information

Project Summary: We plan to develop a clay-algae flocculation method to mitigate cyanobacterial blooms, which produce toxins that contaminate drinking water and cause mass mortalities in fishes and other animals in Minnesota.

Funds Requested: $366,000

Proposed Project Completion: June 30 2025

LCCMR Funding 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.

Cyanobacterial blooms, which are widespread in Minnesota's lakes and rivers, produce toxins that contaminate drinking water and cause mass mortalities in fishes and other animals. Mitigation of cyanobacterial blooms is critical to ensure safe drinking water and reduce fishery and tourism losses, which were estimated to cost hundreds of millions of dollars per year in Great Lakes. One of the most promising strategies to mitigate cyanobacterial blooms is rapid sedimentation of cyanobacteria through flocculation with clay, a natural material present in soils. When clay is sprayed to the contaminated water, it causes cyanobacterial cells to flocculate, or aggregate, and sink to the bottom. Once the cells are buried in the sediment, the majority of the toxins are removed from the water and most of the cells die due to lack of oxygen and light. The clay-algae flocculation strategy has successfully controlled cyanobacterial blooms in Eastern Asian Countries for over 30 years, and a modified clay was recently proved to be effective in removing cyanobacteria and toxins in Florida. However, this strategy has not been adapted in the state of Minnesota. Development of a clay-algae flocculation strategy is the most efficient way to mitigate cyanobacterial blooms in Minnesota's waters.

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

The proposed solution is to develop a clay-algae flocculation strategy to mitigate cyanobacterial blooms in Minnesota's waters. While clay-algae flocculation strategies have been successfully implemented in East Asia and helped some Korean regions reduce annual fisheries losses by about 99%, we cannot directly apply their methods in Minnesota's lakes, because the cyanobacterial species and flow conditions are different. In this study, we will first determine the type and amount of clay that can effectively remove the cyanobacteria and toxins typical in Minnesota's lakes, by conducting clay flocculation experiments under controlled conditions in a plankton tower that closely replicate Minnesota lakes' environmental conditions. Furthermore, we will test the laboratory results in two outdoor bioreators at Saint Anthony Falls Laboratory, which draw water directly from Mississippi River and are exposed to natural wind, temperature, and light conditions. Second, we will collaborate with Minnesota Pollution Control Agency (MPCA) to test the findings in one of Minnesota's lakes. A new drone-based technology will be used to evaluate the cyanobacteria and toxin removal in the lake. Third, we will develop a cyanobacteria-mitigation calculator that will provide guidance on the dose of clay-lime mixture and procedure to maximize cyanobacteria and toxin removal.

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 have the following specific expected project outcomes:
1. Development of a clay-algae flocculation method that effectively remove cyanobacterial cells and toxins in Minnesota's waters, including a spreadsheet-type calculator to calculate the optimum mixture of clay and lime.
2. A patent on the design of the structures to mix and spray clay and documentation of the optimized procedure to apply the clay-algae flocculation method in Minnesota's lakes.
3. Communication of the results to MPCA to guide future mitigation projects in Minnesota. Communication of the results to the public to raise public awareness of cyanobacterial blooms.

Activities and Milestones

Activity 1: Determine the optimum mixture of clay and lime that can effectively remove cyanobacteria and toxins

Activity Budget: $118,000

Activity Description:
To determine the optimum dose of clay-lime mixture that effectively remove cyanobacteria and toxins in Minnesota's waters. First, we will conduct a series of controlled clay-algae flocculation experiments in a plankton tower that closely replicate Minnesota lakes' environmental conditions at Saint Anthony Falls Laboratory (SAFL). We will incubate three algae cells that are most abundant in Minnesota's lakes (Microcystis aeruginosa, Anabaena circinalis, and Anabaena flos-aquae) in the plankton tower. Afterwards, we will spray different mixtures of natural clay types (including bentonite and kaolinite) and lime to the water surface and determine the optimum mixture that will maximize the precipitation of algae-clay flocculates. We will periodically sample the water and measure the cell density and floc size using confocal laser microscopy. The cyanotoxin concentration will be quantified using liquid-chromatography/ultraviolet-visible detection methods. Second, we will test the laboratory results in two outdoor bioreactors (10x10x1m), which replicate lakes with water supplied directly from Mississippi River and are exposed to natural conditions of wind, temperature, and light. We will seed the three most abundant lake cyanobacteria in the bioreactors. We will use the pilot-scale field results to verify the optimum dose of clay-lime mixture derived from the plankton tower experiments.

Activity Milestones:

Description	Completion Date
Clay-algae flocculation experiments in the plankton tower	June 30 2023
Clay-algae flocculation experiments in the outdoor bioreactors	December 31 2023
Data analysis and report preparation	June 30 2024

Activity 2: Establish mitigation steps to maximize the removal of cyanobacteria and toxins at site-specific applications

Activity Budget: $140,000

Activity Description:
We will establish a protocol for applying the clay-algae flocculation method to mitigate cyanobacterial blooms in the field, including steps to mix and spray clay from a boat. First, we will collaborate with SAFL's engineering team to design and optimize structures to mix and spray clay and lime to the water surface. We will test these designs in the outdoor bioreactors at SAFL. Second, we will bring about 50 Gallons of clay in a SAFL boat to test the findings from Activity 1 in one of Minnesota's lakes. We will collaborate with Minnesota Pollution Control Agency (MPCA) to obtain permissions to conduct the field test under their oversight. We will evaluate the cell and toxin removal in the lake by (1) collecting water samples and (2) using the drone-spectroradiometer technology. We will use the field experiments to verify the formula for the optimum dose of clay and lime mixture to maximize the cyanobacteria and toxin removal.

Activity Milestones:

Description	Completion Date
Field test preparation	June 30 2023
In-situ clay-algae flocculation experiments	December 31 2024
Data analysis and report preparation	June 30 2025

Activity 3: Develop a spreadsheet-type calculator to calculate the optimum dose of clay and lime for cyanobacteria and toxin removal, and outreach

Activity Budget: $108,000

Activity Description:

We will develop a spreadsheet-type calculator for lake associations and the public to calculate the optimum dose of clay and lime for given average water temperature profile, lake depth, sediment type, pH, wind speed, and area of spread of cyanobacteria. The calculator will be based on the formula developed from the laboratory and filed experiments and will be implemented in both Excel and open-source language Python. We will invite UMN students as beta tests to improve the program and make it user-friendly. Afterwards, we will share this cyanobacteria-mitigation calculator with MPCA (Dr. Matt Lindon) and Minneapolis Public Works (Dr. Shahram Missaghi). Furthermore, we will design a mini enclosed clay-algae flocculation device and bring it to the Minnesota State Fair to demonstrate the effectiveness of clay in removing cyanobacterial blooms and toxins. We will publish our results in academic journals and present at academic and local conferences.

Activity Milestones:

Description	Completion Date
Develop the cyanobacterial bloom mitigation calculator	December 31 2024
Report preparation and outreach	June 30 2025

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Miki Hondzo	University of Minnesota	Co-Project Manager. Dr. Hondzo, a professor in the Department of Civil, Environmental, and Geo-Engineering, will guide the field experiments and be responsible for the development and guidance of the drone-based cyanobacteria and toxin detection technology.	Yes
Shahram Missaghi	Minneapolis Public Works - Surface Water & Sewers Division	Dr. Missaghi, Water Resources Regulatory Coordinator, will facilitate the field investigation and the outreach project.	No
Matt Lindon	Minnesota Pollution Control Agency (MPCA)	Dr. Lindon, research scientist, will facilitate the field investigation and the promotion of the clay-algae flocculation method in removing cyanobacterial blooms in Minnesota's waters.	No

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 be funded?

The results of this study include a patentable protocol to apply the clay flocculation method to remove cyanobacteria and toxins in Minnesota's lakes. Lake associations can use the cyanobacteria-mitigation calculator to calculate the optimum dose of clay-lime mixture and follow the steps in our report to successfully remove cyanobacteria and toxins in their specific sites. We are hopeful that our results will help mitigate cyanobacterial blooms in Minnesota's waters, which will likely help reduce fishery loss by millions of dollars per year and help improve the water quality and water-related tourism industry in the state.

Project Manager and Organization Qualifications

Project Manager Name: Judy Yang

Job Title: Assistant professor

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

Dr. Yang is an assistant professor in the Department of Civil, Environmental, and Geo- Engineering at the University of Minnesota. Dr. Yang is an interdisciplinary researcher, specialize in fluid mechanics, sediment transport, and clay-bacteria interactions. She has over seven years' research experience on transport of sediment in water and her sediment transport work has been highlighted by American Geophysics Union's News as a study that "shifts paradigm of coastal sediment modeling" (https://eos.org/research-spotlights/new-study-shifts-paradigm-of-coastal-sediment-modeling). She is also a technology inventor and invented the first 4D imaging method that demonstrates how carbon is sequestrated in clay and how bacteria aggregate to clay. This work has been highlighted in over 10 news outlets (https://scienmag.com/carbon-chomping-soil-bacteria-may-pose-hidden-climate-risk/) and got interviewed by the Counter (https://thecounter.org/soil-sequestration-carbon-farming-biden-climate-strategy/).

Dr. Miki Hondzo (co-PI), James L. Record Professor
Department of Civil, Environmental, and Geo- Engineering, University of Minnesota
Dr. Hondzo will guide the laboratory and field experiments and be responsible for the development and guidance of the

drone-based cyanobacteria and toxin detection technology. Dr. Hondzo has 20 years of experience in physical limnology and water quality monitoring and modeling in lakes. Dr. Hondzo is an expert in detecting and monitoring harmful algae blooms and designed the facilities to grow and study cyanobacteria at St. Anthony's Falls Laboratory. Dr. Hondzo is also an Associate Editor of the Environmental Fluid Mechanics journal.

Organization: U of MN - St. Anthony Falls Laboratory

Organization Description:
St. Anthony Falls Laboratory (SAFL) is an interdisciplinary fluid mechanics research center, renowned for its fluid mechanics facilities, scientists, and engineers. The EcoFluids Laboratory, developed by Dr. Hondzo (Project Partners), allows researchers to study the interactions among fundamental fluid mechanics, microalgal metabolism, and chemical processes in aquatic environments. SAFL have most of the instruments we need to conduct the study, including the plankton tower that simulate lakes, the outdoor bioreactors which are artificial lakes, the boat to conduct field test, as well as the drone technology to detect the algae bloom and estimate algae cell density in natural lakes. In addition, SAFL has five water quality data sondes with SDI12 communication protocols for continuous, adaptive, and in situ field sensing of temperature, dissolved oxygen, nitrate, pH, turbidity, PAR, and chlorophyll-a concentrations. The SAFL staff is particularly experienced in conducting and analyzing filed measurements of water quality in lakes, rivers, and reservoirs, and they will help us manufacture and optimize tools to mix and spray clay to the surface of water suffering from cyanobacterial blooms.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Judy Yang (Project Manager)		Manage the whole project			27%	0.24		$39,162
Miki Hondzo (Co-project manager)		Manage field work			27%	0.18		$46,956
One graduate student researcher		Perform laboratory experiments and analyze data			45%	1.5		$151,140
Ben Erickson (Research scientist)		Fabrication of clay-spray structures			24%	0.45		$38,512
Two Undergraduate student researchers		Grow algae and assist with the experiments			0%	0.39		$43,230
							Sub Total	**$319,000**
Contracts and Services								
University of Minnesota, Nano center	Internal services or fees (uncommon)	The Nano center at University of Minnesota provide tools to fabricate microfluidic chips, which will be used to study clay-cyanobacteria aggregation.				-		$6,000
							Sub Total	**$6,000**
Equipment, Tools, and Supplies								
	Tools and Supplies	Cyanobacterial strains, Solutions (BG-11), culture flasks, pipettes, petri dishes, cell counting chip (deep haemocytometer)	Tools to grow cyanobacteria and measure cell density. A large volume of growth solution will be needed.					$12,000
	Tools and Supplies	Clay (bentonite and kaolinite), coagulants (to modify clay) and lime	Clay is used to flocculate algae cells					$6,000

	Tools and Supplies	Mechanical components for clay-spray structures	Different clay spray technology will be tested					$9,000
	Tools and Supplies	PDMS kits, SU8, silicon wafers	Fabricate microfluidic chambers to examine algae-clay aggregation					$1,000
	Equipment	Hydrolab water quality probe	Calibration solutions and spare parts					$2,000
							Sub Total	**$30,000**
Capital Expenditures								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Miles/ Meals/ Lodging	Two field trip to conduct experiments in one of Minnesota's lakes. Five people will be involved in the field experiments.	The field trips are needed to conduct in-situ clay-algae flocculation experiments in several of Minnesota's major lakes and rivers					$5,000
	Conference Registration Miles/ Meals/ Lodging	Minnesota Water Resources Conference for a graduate student, a postdoc, and the project manager.	Present our results to academic community and local Minnesota Organizations					$1,000
							Sub Total	**$6,000**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
	Publication	Page charges for publication	Our goal is to publish our results in leading-edge journals, such as Nature Communications which charges "open access" fee; "open access" allows our results to be available to everyone without charges.					$5,000

							Sub Total	**$5,000**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$366,000**

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	Unrecovered F&A	Support of SAFL facilities where research will be conducted.	Secured	$173,375
			Non State Sub Total	**$173,375**
			Funds Total	**$173,375**

Attachments

Required Attachments

Visual Component

File: 2a4b98e2-057.pdf

Alternate Text for Visual Component

Cyanobacterial blooms, which are widespread in Minnesota's waters, produce toxins that contaminate drinking water and cause mass mortalities in fishes and other animals. Tens to hundreds of millions of dollars are lost per year due to losses in fisheries and tourism in the Great Lakes. We plan to develop a clay-algae flocculation strategy to mitigate cyanobacterial blooms in Minnesota's waters. Clay-algae flocculation methods have been used to remove cyanobacterial blooms and toxins in East A...

Optional Attachments

Support Letter or Other

Title	File
Support Letter	54d6894e-182.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

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

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?

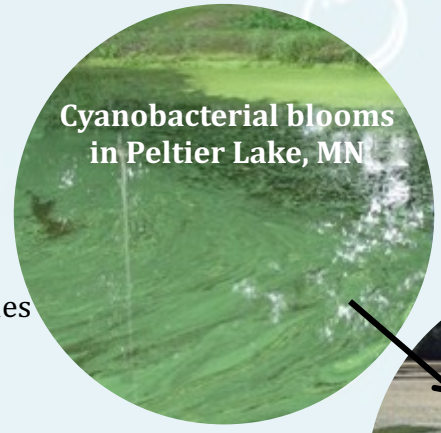
Yes, Sponsored Projects Administration

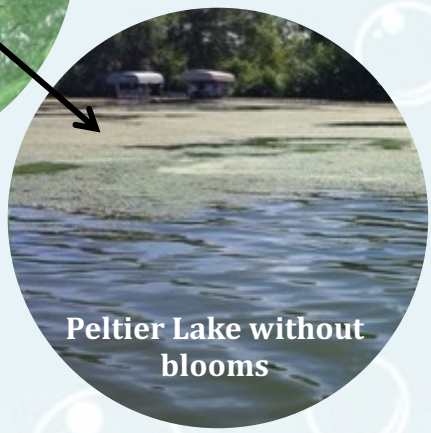
Mitigating Cyanobacterial Blooms and Toxins Using Clay-Algae Flocculation

Judy Yang, University of Minnesota, https://yang.cege.umn.edu/

Problem

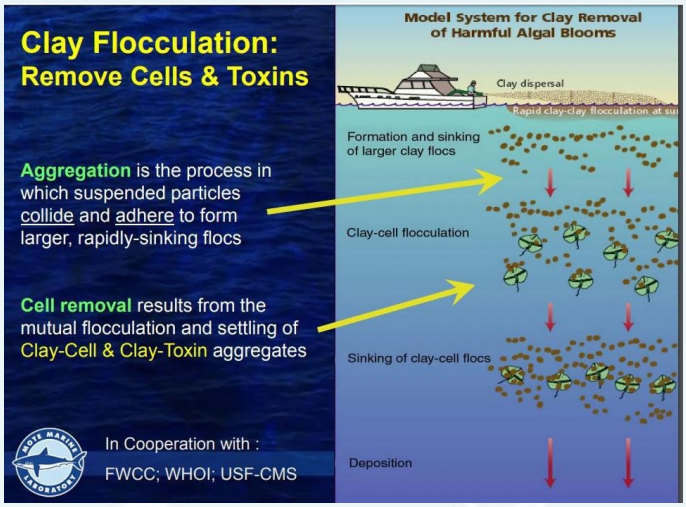
Cyanobacterial blooms, which are widespread in Minnesota's waters, produce toxins that contaminate drinking water and cause mass mortalities in fishes and other animals. Tens to hundreds of millions of dollars are lost per year due to losses in fisheries and tourism in the Great Lakes.





Solution

Develop a clay-algae flocculation method to mitigate cyanobacterial blooms and toxins in Minnesota's waters.



Clay-algae flocculation methods have been used to remove cyanobacterial blooms and toxins in East Asia for over 30 years, reducing fishery losses by about 99% in some Korean regions. It has also been recently adapted in Florida (as shown in the left figure from Mote Marine Laboratory in Florida).

Plans

- Conduct clay-algae flocculation experiments in two bioreactors (10 m wide) that replicate Minnesota's lakes at St. Anthony Falls laboratory (SAFL).
- Conduct clay-algae flocculation experiments in one of Minnesota's lakes to verify our laboratory results.

Projected Outcomes

- Development of a clay-algae flocculation method that can effectively remove cyanobacterial cells and toxins typical in Minnesota's waters.
- A patent on the design of the structures to mix and spray clay and documentation of the optimized procedure to apply the clay-algae flocculation method in Minnesota's lakes.
- Communication of the results to MPCA to guide future mitigation projects in Minnesota.