Environment and Natural Resources Trust Fund

M.L. 2022 Approved Work Plan

General Information

ID Number: 2022-099

Staff Lead: Mike Campana

Date this document submitted to LCCMR: July 6, 2022

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

Project Budget: $326,000

Project Manager Information

Name: Judy Yang

Organization: U of MN - St. Anthony Falls Laboratory

Office Telephone: (617) 415-3478

Email: judyyang@umn.edu

Web Address: https://www.safl.umn.edu/

Project Reporting

Date Work Plan Approved by LCCMR: July 27, 2022

Reporting Schedule: March 1 / September 1 of each year.

Project Completion: June 30, 2025

Final Report Due Date: August 14, 2025

Legal Information

Legal Citation: M.L. 2022, Chp. 94, Sec. 2, Subd. 04c

Appropriation Language: $326,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota for St. Anthony Falls Laboratory to develop and test a clay-algae flocculation method to mitigate cyanobacterial blooms that can contaminate drinking water and cause mass fish mortality. This appropriation is subject to Minnesota Statutes, section 116P.10.

Appropriation End Date: June 30, 2025

Narrative

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.

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

Cyanobacterial blooms, widespread in Minnesota's lakes and rivers, produce toxins that contaminate drinking water and cause mass mortalities in fishes and other animals. Mitigating cyanobacterial blooms is critical to ensuring safe drinking water and reducing fishery and tourism losses, which are estimated to cost hundreds of millions of dollars per year in the 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. A modified clay was recently proved to be effective in removing cyanobacteria and toxins in Florida. However, this strategy has not been adopted in the state of Minnesota. The development of a clay-algae flocculation strategy is a promising way to mitigate cyanobacterial blooms 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.

The overarching goal of the proposed study is to develop a clay-algae flocculation strategy to mitigate cyanobacterial blooms in Minnesota's waters. While clay-cell 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, water chemistry, and flow conditions are different. The objectives of this study are: (1) determine the optimum clay type and clay modifying chemicals that cause clay and cells to aggregate most effectively through microfluidic experiments, (2) determine the optimum dose of the selected clay that remove the cyanobacteria and toxins mostly efficiently, by conducting clay-cell flocculation experiments in a plankton tower that simulates Minnesota lake's environmental conditions, (3) design an effective clay application procedure based on clay-cell flocculation experiments in two representative ponds in Minnesota. The proposed study will guide on the dose of clay to apply and the application procedure to maximize cyanobacteria and toxin removal rate based on each lake's unique water chemistry, size, depth, and wind conditions. The results can also be used to improve designs of constructed ponds, including water depth and sediment texture, to reduce cyanobacterial blooms' occurrence.

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?

The results of this study include (1) selection of a natural or design of a modified clay that can most effectively remove harmful cyanobacterial cells and toxins; the modified clay can potentially result in a patent; (2) determination of the optimum dose of clay that can most effectively remove harmful cyanobacterial cells and toxins in Minnesota's water; (3) design of structures to mix and spray clay and clay application procedures which will enable future successful implementation of the clay-cell flocculation method in the field; the clay mixing and spraying structures will likely result in a second patent.

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

Activities and Milestones

Activity 1: Microfluidic experiments to select optimum clay type, modifying chemicals, and clay dose

Activity Budget: $118,000

Activity Description:

We will determine the optimum clay type, modifying chemicals, and clay dose or concentration by imaging the formation rate of clay-cell aggregates in a microfluidic device using a confocal laser scanning microscope (CLSM). The microfluidic device consists of a micron-size channel and two inlets: one for injecting Microcystis culture solution and one for injecting clay suspension. The formation of the clay-cell aggregates will be visualized over time using a Nikon C2+ CLSM which has sub-micron spatial resolution. We will conduct experiments under the same condition using various types of clays, including kaolinite, bentonite, phosphatic clay, etc., as well as a range of modifying chemicals. By comparing the size of clay-cell aggregates generated using different clays and modifying chemicals, we will identify the optimum clay type and modifying chemical that can mostly effectively cause clay and cells to flocculate. At least four common modifying chemicals will be evaluated. In addition, we will repeat the experiments using six different clay concentrations to evaluate whether the results change with varying clay concentration. Each experiment will be repeated for at least three times to ensure the accuracy of our results.

Activity Milestones:

Description	Approximate Completion Date
Conduct microfluidic experiments and data analysis and select optimum clay type and modifying chemicals	June 30, 2023
Dissemination findings of Activity 1 via 1 open access journal publications	December 31, 2023

Activity 2: Plankton tower experiments to verify the optimum dose of clay and evaluate the efficiency of clay-algae flocculation method

Activity Budget: $108,000

Activity Description:

We will evaluate cell and toxin removal efficiency of the clay-algae flocculation method by conducting clay-cell flocculation experiments in a plankton tower that replicates Minnesota lake's chemical and hydrodynamic conditions. We will fill the plankton tower with water that represents the range of ionic strength, pH, and hardness in Minnesota lakes' water and use an oscillating grid to generate turbulence with a range of turbulent intensity typical in Minnesota's lakes. Afterwards, we will spray clay suspension into the plankton tower under systematically controlled conditions, including varying cell density, water salinity, pH, hardness, and turbulent kinetic energy. Then, we will use imaging and sampling-based methods to quantify the cell and toxin removal rates. We will repeat the experiments in a range of environmental conditions, including 3 turbulent intensities, 3 temperature conditions, 3 pH conditions, and 3 different cell densities. We will use the results to develop a semi-empirical formula for the optimum clay dose that leads to the maximum cell and toxin removal rate as a function of cell density, salinity, pH, hardness, and turbulent kinetic energy. The formula will lay a theoretical foundation for future application of the clay-cell flocculation methods in lakes with different chemistry and hydrodynamic conditions.

Activity Milestones:

Description	Approximate Completion Date
Repair and testing of the plankton tower and design of clay-spraying structures	December 31, 2022
Clay-cell flocculation experiments in a plankton tower and data analysis	September 30, 2023

Develop a formula to calculate optimum clay dose based on cell density, salinity, pH, hardness, and turbulent kinetic energy	June 30, 2024
Dissemination of Activity 2 findings via at least 1 open access journal publications	September 30, 2024

Activity 3: Field test in ponds to determine the optimum clay application procedure

Activity Budget: $100,000

Activity Description:

We will determine the optimum procedure to apply the clay-cell flocculation method in the field by conducting a clay-cell flocculation method in two ponds with different cell densities, water chemistry, and turbulent conditions in Minnesota. We will first calculate the optimum dose of clay using the empirical equation we developed based on the cell density, water salinity, pH, hardness, and turbulent conditions of each pond. Then, we will apply clay to a small region of the Microcystis-contaminated ponds and monitor the cell and toxin removal efficiency. We will test different clay spraying and mixing procedures and determine the optimum procedure that result in maximum cell and toxin removal efficiencies.

Activity Milestones:

Description	Approximate Completion Date
Field test and data analysis	December 31, 2023
Revisit the field sites and assess the results	December 31, 2024
Develop a guideline for future implementation of clay-cell flocculation methods in the field	April 30, 2025
Dissemination of Activity 2 findings via at least 1 open access journal publication	June 30, 2025
Dissemination of our results to local lake agencies and seeking their feedback	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

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 results of this study will be published in reputable journals of the field and will be presented not only in national conferences but also local public seminars in Minnesota to increase awareness about harmful algal blooms in Minnesota. In particular, we will arrange annual public seminars at SAFL to inform the citizens of Minnesota about the danger of harmful algal blooms in Minnesota and update them about the research and actions we are taking at SAFL to understand and mitigate this important environmental problem. 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 also design a calculator to provide guidance on the dose of clay and procedure to maximize cyanobacteria and toxin removal based on each lake's unique water chemistry, size, depth, and wind conditions. Lake associations can use the protocol and the calculator to calculate the optimum dose of selected clay and follow the steps in our document 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. Finally, we will acknowledge the Environment and Natural Resources Trust Fund through use of the trust fund logo or attribution language on project print and electronic media, publications, signage, and other communications and outreach.

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 of this study include a 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.

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%	0.15		$38,875
Miki Hondzo (Co-project manager)		Manage field work			27%	0.09		$31,075
One graduate student researcher		Perform laboratory experiments and analyze data			45%	1.5		$161,651
Ben Erickson (Research scientist)		Fabrication of clay-spray structures			24%	0.3		$25,452
One Undergraduate student researchers		Grow algae and assist with the experiments			0%	2.1		$21,615
							Sub Total	**$278,668**
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.					$11,332
	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					$8,000

	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
	Tools and Supplies	Supplies for HPLC analysis	High Performance Liquid Chromatography Mass Spectrometry (HPLC-MS) analysis will be used to measure the concentration of microcystin. Materials including containers and extracting chemicals will be purchased.					$2,000
							Sub Total	**$30,332**
Capital Expenditures								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Miles/ Meals/ Lodging	Two field trips to conduct experiments in two of Minnesota's ponds. Five people will be involved in the field experiments.	The field trips are needed to conduct in-situ clay-algae flocculation experiments in two ponds and to assess the effect of the project in the following year.					$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	X				$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					$5,000

			Communications which charges “open access” fee; “open access” allows our results to be available to everyone without charges.					
							Sub Total	**$5,000**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$326,000**

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request
Travel In Minnesota	Conference Registration Miles/Meals/Lodging	Minnesota Water Resources Conference for a graduate student, a postdoc, and the project manager.	We will disseminate the results from the proposed study to colleagues and local water related organizations in Minnesota by attending conferences. The budget will cover the cost to make posters ($100), meals(300), Registration ($300), and lodging ($300).

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: efff3383-089.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. We plan to develop a clay-algae flocculation method to remove cyanobacterial blooms and toxins in Minnesota's water....

Optional Attachments

Support Letter or Other

Title	File
Support Letter	54d6894e-182.pdf
Background check form	73e293fe-f47.pdf
UMN official cover letter	3d0b0b06-8fe.pdf
ResearchAddendum_Yang2022-099	b4386609-832.pdf

Difference between Proposal and Work Plan

Describe changes from Proposal to Work Plan Stage

The major change is the budget: (1) the request for two summer undergraduate students has been reduced to one, (2) the budget for co-investigator Miki Hondzo has been reduced by 30% and the budget for a research staff has been reduced by 30%

Additional Acknowledgements and Conditions:

The following are acknowledgements and conditions beyond those already included in the above workplan:

Do you understand and acknowledge the ENRTF repayment requirements if the use of capital equipment changes?

N/A

Do you agree travel expenses must 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 agree to the UMN Policy.

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?

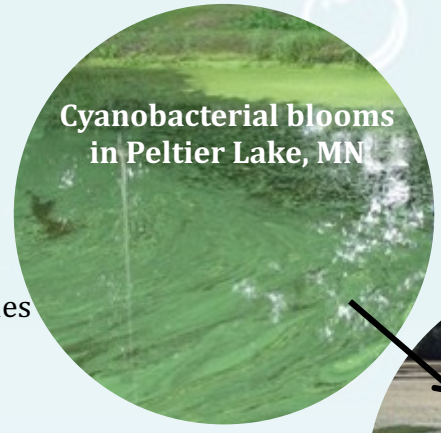
Yes, Sponsored Projects Administration

Mitigating Cyanobacterial Blooms and Toxins Using Clay-Algae Flocculation

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

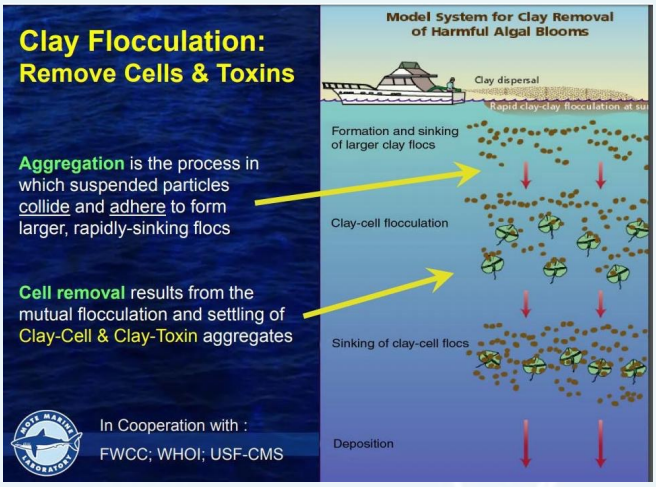
Problem

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

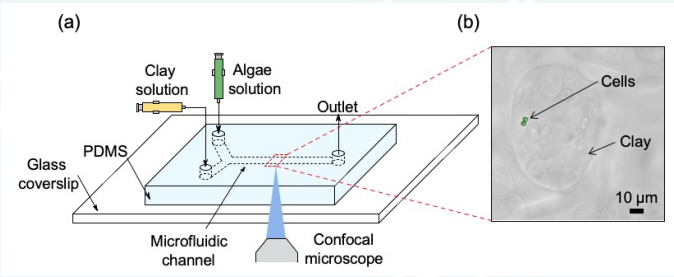
Develop a clay-algae flocculation method to mitigate cyanobacterial blooms and toxins in Minnesota's waters.



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 using microfluidic chambers and high resolution confocal microscopy, as shown in the right figure.
- Test the clay-algae flocculation method in a plankton tower 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

- Selection of a natural or design of a modified clay that can effectively remove cyanobacterial cells and toxins typical in Minnesota's waters.
- Determination of the optimum dose of clay.
- Design of structures to mix and spray clay and clay application procedures.