Environment and Natural Resources Trust Fund

2022 Request for Proposal

General Information

Proposal ID: 2022-213

Proposal Title: Toxic Algae Removal System Powered by Solar Energy

Project Manager Information

Name: Terrence Simon

Organization: U of MN - College of Science and Engineering

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Project Basic Information

Project Summary: We propose to develop a cheap and efficient water purification system powered by solar energy that can simultaneously remove algae and organic pollutants from lakes and rivers in Minnesota.

Funds Requested: $200,000

Proposed Project Completion: June 30 2025

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?

In the Future

Narrative

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

Water pollution is a global challenge. A survey conducted by the United Nations indicates that over 80% of wastewater is discharged into the environment without proper treatment. This contaminated water is the cause of 1.8 million deaths yearly. Access to clean water is a problem not only in developing countries, but also in developed countries like the United States. In Minnesota, the surface area is nearly one-quarter wetlands, lakes, rivers, and streams. More than 40 percent of Minnesota's waters are polluted by excess phosphorus, nitrates, and chlorides. Excessive nutrients in the water result in the growth of harmful algal blooms, which appear every summer. Harmful algal blooms, together with organic pollutants, lead to diseases such as acute and chronic gastrointestinal diseases, diarrheal diseases, and lower respiratory tract infections. Current treatment of harmful algal blooms is in reducing nutrients in water bodies, which is a difficult and expensive method to implement. For example, nitrate removal systems in Minnesota causes water supply costs to rise from 5-10 cents per 1,000 gallons to over $4 per 1,000 gallons. Therefore, it is particularly important to effectively remove harmful algal blooms.

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.

Toward solution to this problem, the proposed research will develop a solar-powered water purification system that combines a photocatalyst, UV light, and solar cells. The system mainly contains polymer sheets with an immobilized photocatalyst, a solar panel, four LED UV light sources, and two propellers. The photocatalyst immobilized on polymer sheets will directly contact water to mineralize nutrients, harmful algal blooms, and other toxic organic compounds in water. The combination of a solar panel and the UV lights will transfer the long-wavelength portion of the solar spectrum to short wavelength UV light for direct elimination of harmful algal blooms by destroying their DNA and photosynthetic pigments. The UV light can also provide an extra light supply for the photocatalyst to enhance its efficiency. Finally, the propellers and their motors, also powered by the solar cells, will be used to position the solar panel to face the sun and, by hovering about its set point, create relative motion between the reacting surface and the water to enhance mass transfer and photodegradation. The entire system, being solar-powered, requires no additional energy supply so it can operate over long periods in the bed of water.

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?

Preliminary experiments have shown that the proposed water purification system, having one square meter in active area, can clean about one ton of polluted water per day. Maintenance cycles of up to several weeks with low maintenance costs can be expected. By broadly applying the proposed water purification system, harmful algal blooms can be effectively suppressed and removed, and the level of organic pollution in the surface waters of Minnesota can be significantly reduced. As the result, the threat of water pollution to aquatic animals and human health can be greatly reduced.

Activities and Milestones

Activity 1: Development of small-scale water purification platform for lab tests using high-efficiency photocatalysis and UV light powered by an external power

Activity Budget: $136,517

Activity Description:
A water purification platform based on photocatalysis and UV treatment will be fabricated and tested. A shrink thermoplastic film will be used as substrate material since it can be shrunk by heating more than 80% of its original size without loss of immobilized photocatalytic performance. Graphene and titanium dioxide composite material synthesized by the layer-by-layer self-assembly technique is used as photocatalyst due to its relatively high photodegradation efficiency. The LED UV light with an external power supply will be directly used for verification of the scheme. The performance of the platform will be tested in the laboratory by measuring the removal of algae and the degradation of nutrients. Algae grown in the laboratory will first be exposed to LED UV light to test its removal rate. Then the photocatalyst will be added to the system to evaluate the efficiency of direct photocatalytic removal of algae. Finally, the real living environment of green algae will be simulated to study the inhibitory effect of photocatalyst on the growth of green algae in a nutrient environment. As the result, efficient algae removal and organic pollutant degradation will be documented.

Activity Milestones:

Description	Completion Date
Develop photocatalyst, Design and fabrication of components	June 30 2023
Integrate modular system	June 30 2024
Evaluate for lake water	June 30 2025

Activity 2: Develop a full-scale, integrated water purification system powered by renewable solar energy, and evaluation of its performance in field tests.

Activity Budget: $63,483

Activity Description:
A full-scale integrated system, which consists of the fabricated photocatalysis system and a solar-powered LED UV light system will be fabricated and tested. The high-efficiency solar panel will be used as the power source for the LED UV lights and propeller motors. The power demand will be estimated based on testing results from the small-scale platform, and a circuit will be designed to ensure each component operates optimally. The photocatalysis platform, solar panel, LED lights, and motors will be integrated into a system that floats on the water. The water purification system, first tested in the lab, will move to field tests. The degradation efficiency and long-term stability of the system will be evaluated by testing. The integrated system is expected to degrade one ton of polluted water in 10 hours of daily solar light over one week without performance decrease. Next, the device will be deployed in a Minnesota lake and the water quality will be monitored to evaluate the system performance. Finally, further improvements and optimization based on the tests will be implemented.

Activity Milestones:

Description	Completion Date
Design and fabrication of components	June 30 2024
Field tests for long-term stability and optimize for lakes	June 30 2025

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Professor Tianhong Cui	University of Minnesota	Co-PI	Yes

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?

An integrated water purification system will be developed because of this project. Patent applications based on the prototypes will be written, for commercialization. The systems will be deployed in wetlands, rivers, and lakes in Minnesota. Further work will focus on integration of the system into the larger cleanup environment and further development of its capability, such as implantation of energy storage sources for non-daytime operation and more advanced water quality monitoring units. Applications will be applied for federal funding from NSF and EPA or private funds for the continued development.

Project Manager and Organization Qualifications

Project Manager Name: Terrence Simon

Job Title: Professor

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

Dr. Terrence Simon is the Ernst Eckert Chair of Mechanical Engineering at the University of Minnesota. He joined the faculty of the University of Minnesota in 1980. Previously, he was in industry at the General Electric Co. He is a past Chairman of the Department's Heat Transfer Division, a past Senior Technical Editor of the American Society of Mechanical Engineers' (ASME) Journal of Heat Transfer and is a Fellow of ASME. He has taken leaves in industry at United Technology Research Center, U.S. Air Force Academy, U.S.A.F Wright Labs, and Solar Turbines, Inc. Over his 40 years at the University of Minnesota, he has managed many projects as sole-PI sponsored by NASA., Air Force Office of Scientific Research, Solar Turbines Inc., National Science Foundation, Department of Energy, and several small companies. He has taken major roles as Co-PI on several more.

Dr. Simon will serve as PI and project manager, responsible for overseeing the project, all reports, and deliverables. He will co-supervise the Ph.D. student to work on the design, fabrication, and characterization of the surface water purification system powered by solar energy. He will hold weekly meetings with his advisee to ensure continued progress on this proposed work, in addition to regular daily technical discussions with the research team.

Organization: U of MN - College of Science and Engineering

Organization Description:

This work will be performed at the UofM Heat Transfer (Simon) and Microsystems (Cui) Laboratories, in the Mechanical Engineering Building. They are equipped with state-of-the-art instrumentation and facilities to conduct the proposed research, with a variety of fabrication and characterization tools, sufficient for the design, fabrication, characterization, and analyze the proposed surface water purification system. The Heat Transfer Lab provides 1690 sq. ft. of laboratory space for research toward design and characterization of transport in engineering system. The lab is outfitted with a wide range of sensors, data acquisition equipment, velocity measuring devices and flow visualization equipment.

Some fabrication work will be at the Minnesota Nano Center (www.nfc.umn.edu), a state-of-the-art facility for research in nanoscience and applied nanotechnology. It is located at the University of Minnesota in a 7000 square foot facility, including 3000 square feet of class 10 clean room. Minnesota Nano Center maintains these systems, keeps safe

operating procedures, and trains students. State support, support from NSF through NNCI, and industry usage allows Minnesota Nano Center to offer academic rates that are normally less than half of the actual cost of operation. Modeling aspects of the project will utilize the computational resources of UofMN.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Terrence Simon		PI Manage the overall project			36.5%	0.09		$43,599
Tianhong Cui		Co-PI Management of microfabrication			36.5%	0.09		$39,928
Research Assistant		Lab and development work			47.8%	1.5		$87,826
							Sub Total	**$171,353**
Contracts and Services								
Characterization Facility and MN Nano Center	Internal services or fees (uncommon)	Professional Services for Acquisition (Scientific Services (i.e. Characterization Facility and MN Nano Center to fabricate sensors cells, and UV source)				-		$17,000
							Sub Total	**$17,000**
Equipment, Tools, and Supplies								
	Tools and Supplies	Supplied and maintenance	For fabrication, testing and maintenance					$11,647
							Sub Total	**$11,647**
Capital Expenditures								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
							Sub Total	**-**

Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
							Sub Total	**-**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$200,000**

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				
In-Kind	Overhead at the U of Minnesota	Office supplies, computer account	Potential	$91,683
			State Sub Total	**$91,683**
Non-State				
			Non State Sub Total	**-**
			Funds Total	**$91,683**

Attachments

Required Attachments

Visual Component

File: 75d4d6b5-b29.pdf

Alternate Text for Visual Component

Comparison of old technology and new technology of the proposed system for algae cleanup...

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

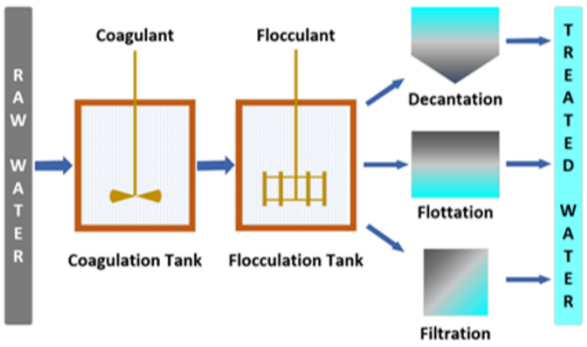
Does the organization have a fiscal agent for this project?

Yes, Sponsored Projects Administration

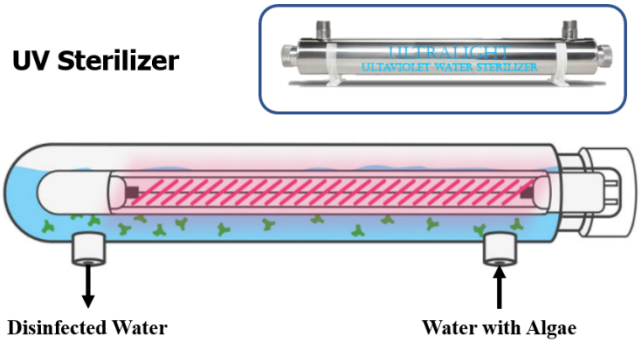
PI/PD: Terrence Simon, University of Minnesota

Project Title: Toxic Algae Removal System Powered by Solar Energy

Current Technologies



Organic Pollutants Removal



Algae Removal

Proposed New Technology: High Efficiency, No Energy Consumption, Easy Maintenance