Environment and Natural Resources Trust Fund

2021 Request for Proposal

General Information

Proposal ID: 2021-319

Proposal Title: Surface Water Purification System Powered by Renewable Energy

Project Manager Information

Name: Tianhong Cui

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 an efficient water purification system powered by solar energy that can be used to remove the pollutants in lakes and rivers in Minnesota.

Funds Requested: $200,000

Proposed Project Completion: 2024-06-30

LCCMR Funding Category: Small Projects (H)

Secondary Category: Methods to Protect, Restore, and Enhance Land, Water, and Habitat (F)

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.

Water pollution is becoming 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 responsible for 1.8 million deaths on a yearly basis. Access to clean water is a problem not only in developing countries, but also in developed countries like the United States, especially the state of Minnesota. Minnesota has many lakes, rivers and streams, and it is known as the "Land of 10,000 Lakes". However, more than 40 percent of Minnesota's waters are polluted by excess phosphorus, nitrates and chloride. Agriculture and industry are the main sources of these pollutants. Water pollution has significant impacts on the economy and human health. For example, nitrate removal systems in Minnesota caused water supply costs to rise from 5-10 cents per 1,000 gallons to over $4 per 1,000 gallons, and the polluted water can lead to diseases such as acute and chronic gastrointestinal diseases, diarrheal diseases, and lower respiratory tract infections. Surface waters account for 60% of the US water supply, hence surface water purification is particularly important in Minnesota, the United States, and all over the world.

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.

To solve the mentioned problems, the proposed research will design a solar powered water purification system that combines photoelectrocatalyst and solar cells. The system contains a polymer sheet with immobilized photocatalyst, an array of solar cells, a LED UV light, and four motors with propellers. The photocatalyst immobilized on polymer sheet will directly contact water to mineralize toxic organic compounds, water pathogens and disinfectant by-products in water. A small bias potential provided by solar cells will be applied on photocatalyst to achieve photoelectrocatalysis, which has higher degradation efficiency than pure photocatalysis. The combination of solar cells and an LED UV light can transfer the long wavelength portion of the solar spectrum that cannot be used by photocatalysts directly to short wavelength UV light that can activate the photocatalyst. Finally, the motors with propellers will also be powered by solar cells, and they will be used to hold the position of the system close to the water surface, generate turbulence in the water, and therefore enhance mass transfer and enhance the photodegradation efficiency. The entire system is solar powered and requires no additional energy supply, so that it can work in rivers and lakes for a long time without any maintenance.

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 proposed water purification system with one square meter in area can clean about one ton of polluted water per day without external energy consumption based on preliminary experiments. Maintenance cycles of up to several weeks and very low maintenance costs can be expected. By applying the proposed water purification system, the level of water pollution in the surface waters of Minnesota can be significantly reduced, and the threat of water pollution to aquatic animals and human health will be greatly reduced. As the result, the supply cost for drinking water purification will also be reduced to a lower level.

Activities and Milestones

Activity 1: Development of water purification platforms in small scale using new high-efficiency photoelectrocatalysis and an external power supply for lab tests

Activity Budget: $132,461

Activity Description:
We propose to fabricate and evaluate a water purification platform based on photoelectrocatalysis. A shrink thermoplastic film will be used as substrate material because it can shrink more than 80% of its original size after heating without a loss of immobilized photocatalytic performance. The graphene and titanium dioxide composite material synthesized by layer-by-layer self-assembly technique will be used as photocatalyst due to its relatively high photodegradation efficiency. The photoelectrocatalysis will be achieved by applying a bias potential on the photocatalyst, and the power source will be an ordinary battery. The performance of the platform will be tested in laboratory by measuring degradation of dyes under solar light simulator. A separate motor will be used for stirring water. Different synthesis paths of photocatalyst, voltage of bias potential and stirring speed will be tested to achieve optimal degradation and energy efficiency. The energy efficiency determines the energy demand for solar cells, and the rate of degradation determines the degradation efficiency of the final system. As a result, degradation efficiency that is several times higher than the existing methods, and much lower power demand will be expected. The platform will be used as the basis of the integrated water purification system.

Activity Milestones:

Description	Completion Date
Design and integration of a modular purification system as a testing prototype in water	2022-06-30
Development of graphene and titanium dioxide composite catalyst on a shrink thermoplastic film	2022-06-30
Characterization, evaluation, improvement and optimization of the water purification system design and construction	2023-06-30
Test and improve the performance of the water purification system under different operation conditions	2023-06-30

Activity 2: Development of full-scale photoelectrocatalysis integrated water purification systems powered by renewable energy, and evaluating the performance in field tests

Activity Budget: $67,539

Activity Description:
We propose to design, fabricate, and test a full scale integrated system, which consists of the fabricated photoelectrocatalysis system and a new solar cell power system. The high efficiency solar cell array will be used as the power source for photoelectrocatalysis, an LED UV light, and motors with propellers. The power demand will be estimated based on testing results from the photoelectrocatalysis platform, and a circuit will be designed to ensure each component works under an optimized condition. The photoelectrocatalysis platform, solar cells, an LED light and motors will be integrated on the same system that can be floated on water. The water purification system will be tested in the lab, followed by field tests. The degradation efficiency and long-term stability of the system will be studied during testing. The integrated system is expected to be able to degrade one ton of polluted water in 10 hours with solar light, and show no performance decrease within one week. Then the devices will be deployed in lakes and rivers in Minnesota, and the water quality will be monitored to evaluate the performance of the system. Finally, further improvement and optimization will be performed according to the testing results.

Activity Milestones:

Description	Completion Date
Development, evaluation, and optimization of water purification systems powered by solar cells in lab tests	2024-06-30
Investigation of degradation efficiency and long-term stability of water purification systems by field tests	2024-06-30

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?

As the product of this project, an integrated water purification system will be developed. Patents based on the developed prototypes will be applied for commercialization. The systems will be deployed to rivers and lakes in Minnesota. Products can be recycled after the water quality is improved or deployed in a water system that is easily contaminated. Further work will focus on the integration and intelligence of the system, such as the implantation of energy storage and water quality monitoring units. Other federal funding from NSF and EPA or private funds will be applied to as further potential funding.

Project Manager and Organization Qualifications

Project Manager Name: Tianhong Cui

Job Title: Professor

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

Dr. Tianhong Cui is currently a Distinguished McKnight University Professor at the University of Minnesota. He is a Professor in Mechanical Engineering and an Affiliate Senior Member of the graduate faculty in Department of Electrical Engineering. He joined the faculty of the University of Minnesota in 2003. From 1995 to 2003, he held research or faculty positions at Tsinghua University, University of Minnesota, National Laboratory of Metrology in Japan, and Louisiana Tech University. He is a Distinguished Visiting Fellow at the University of Cambridge, and a Distinguished Visiting Professor at the University of Paris East in France. He is a Fellow of American Society of Mechanical Engineering.

Dr. Cui is an international leading expert on micro devices and advanced manufacturing. He has more than 320 archived publications in scientific journals and prestigious conferences. He has received awards including the STA & NEDO Fellowships in Japan, the Alexander von Humboldt Fellowship in Germany, the Richard & Barbara Endowed Chair and the Distinguished McKnight University Professorship from the University of Minnesota, the Distinguished Visiting Professorship from University of Paris East, the Distinguished Visiting Fellowship from the Royal Academy of Engineering in UK, the Outstanding Editor Award from Nature Publishing Group, and numerous best paper awards. He is the founding Executive Editor-in-Chief for a Nature journal, Microsystems & Nanoengineering. He is also serving as the founding Editor-in-Chief for the first AAAS/Science Partner Journal titled Research.

Dr. Cui will serve as PI and project manager, responsible for overseeing the project, all reports, and deliverables. He will supervise one 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 good progress of this proposed work, in addition to some daily technical discussion with his research assistant.

Organization: U of MN - College of Science and Engineering

Organization Description:

This work will be performed at the University of Minnesota in the Technology Integration & Advanced Nano/Microsystems Laboratory (TIAN Lab), located in the Mechanical Engineering Building. Professor Cui is the director of TIAN Lab equipped with the state-of-the-art instrument and facility to conduct the proposed research, with a variety of fabrication and characterization equipment and tools, sufficient for Professor Cui, his postdoc, and Ph.D. student to design, fabricate, characterize and analyze the proposed surface water purification systems .

Some fabrication work will be done in 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. The Lab contains all of the major pieces of processing equipment. Minnesota Nano Center well 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. In addition to clean room tools available, the center will also operate two new non-cleanroom labs in nanomaterials and nanotechnology.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
1 Graduate Research Assistant		To design, fabricate, and test of water purification systems			19.9%	1.5		$156,019
Principle Investigator		To manage the overall project, and to conduct overall research			36.5%	0.06		$24,955
							Sub Total	**$180,974**
Contracts and Services								
							Sub Total	**-**
Equipment, Tools, and Supplies								
	Tools and Supplies	To use the facility and equipment at the Minnesota Nano Center	To fabricate and assemble the water purification systems					$9,000
	Tools and Supplies	Lab supplies, instrument and equipment consumables, minor equipments for settting up lab and field experimental and testing systems and equipment repairs and calibration costs	To build and test the sensors and sensor networks					$10,026
							Sub Total	**$19,026**
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	In kind: Indirect Cost at the University of Minnesota (55% MTDC)	In-kind support at the University of Minnesota	Secured	$82,896
			State Sub Total	**$82,896**
Non-State				
			Non State Sub Total	**-**
			Funds Total	**$82,896**

Attachments

Required Attachments

Visual Component

File: 389e2b5f-268.pdf

Alternate Text for Visual Component

Current technology, proposed technology, sensor scheme, and sensing mechanism.

Optional Attachments

Support Letter or Other

Title	File
University SPA Supporting Letter	4dd4dd82-746.docx

Administrative Use

Does your project include restoration or acquisition of land rights?

No

Does your project have patent, royalties, or revenue potential?

Yes,

- Patent, Copyright, or Royalty Potential

Does your project include research?

Yes

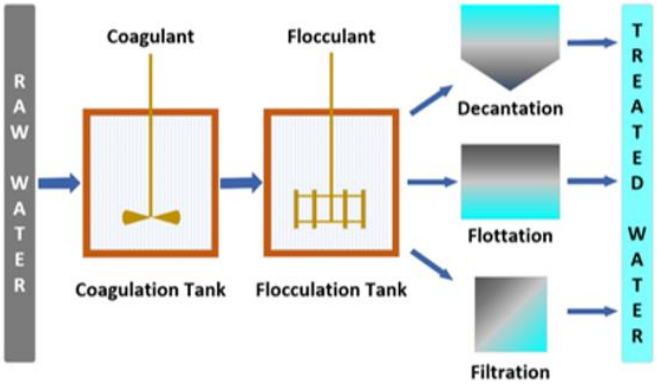
Does the organization have a fiscal agent for this project?

Yes, Sponsored Projects Administration

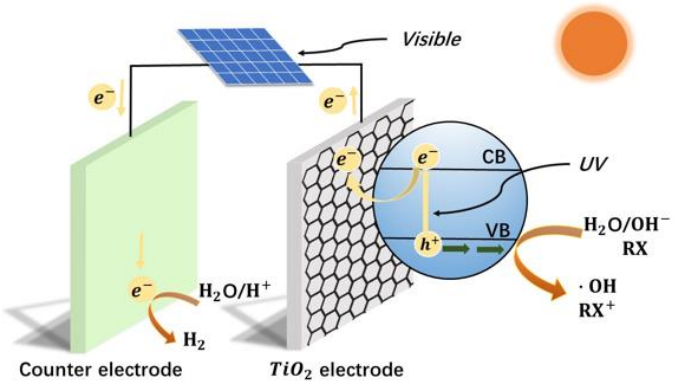
PI/PD: Tianhong Cui, University of Minnesota

Project Title: Surface Water Purification System Powered by Renewable Energy

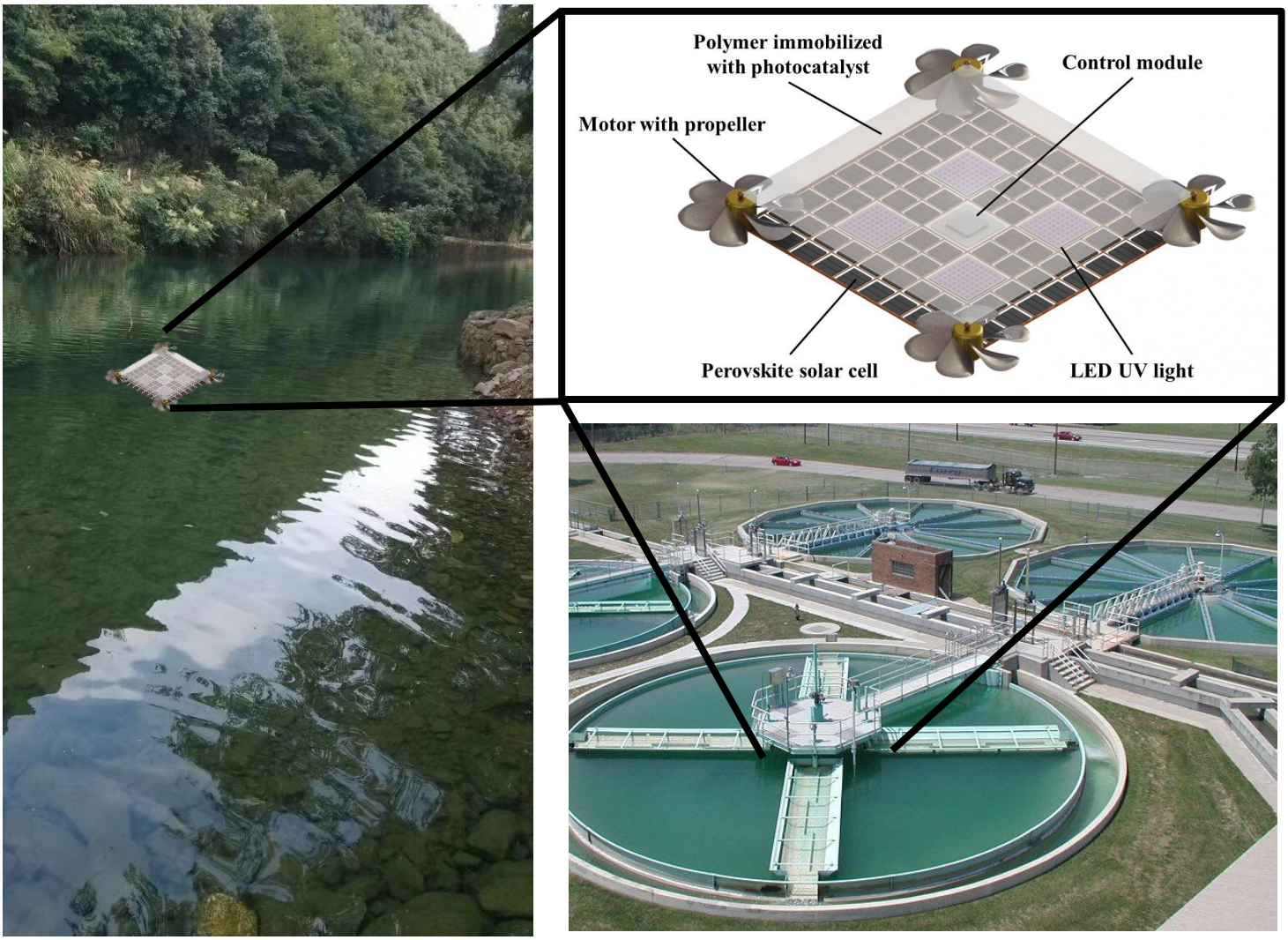
Current Technology



New Technology Proposed



High Efficiency No Energy Consumption Easy Maintenance



Proposed Water Purification System Applications to Decompose Toxic Organic Compounds in Surface Water and Water Treatment Plants