Environment and Natural Resources Trust Fund

2021 Request for Proposal

General Information

Proposal ID: 2021-317

Proposal Title: Sensor-Embedded Purification System for Clean Drinking Water

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 an integrated system for the purification of drinking water while monitoring pollutants with embedded sensors, which are small, simple, cheap, efficient, and easy to use.

Funds Requested: $536,000

Proposed Project Completion: 2024-06-30

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.

Water pollution accounts for 1.8 million premature deaths worldwide annually. It is very important to ensure drinking water is clean for daily life. Although tap water meeting U.S. federal standards is usually safe to drink, people are still confronted with an increasing threat. It was reported that over 200,000 violations to federal drinking water standards occur each year, the majority are due to poor water monitoring and inadequate purification. The Minnesota Pollution Control Agency (MPCA) monitors water quality to enforce environmental regulations. Monitoring water quality in lakes and rivers is essential work for environmental protection and human activities in Minnesota. There are several available methods to monitor drinking water quality on-line or off-line. However, most of the current monitoring systems require several types of samplings for lab test. The collected water samples need to be treated through a complex process. However, these time-consuming processes cannot guarantee accurate results. Meanwhile, the current water purification system consists of large and expensive equipment for filtration. The purification system is also difficult to operate, and needs significant maintenance and service. As a result, an integration of a water purification system with embedded sensors needs to be developed.

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.

We propose a sensor embedded purification system for clean drinking water. The proposed tiny sensor of this project is accurate and easy to use at very low cost. The sensors can detect several ions in water such as lead, arsenic, cadmium, mercury, chloride, microbes and organic compounds. The sensor is very small and easily installed into the water purification system. The sensors will be installed on both ends of the water purification system to check the water quality before and after the purification process. Our proposed water purification system is cheap, small, and easy to operate, compared to the current water purification systems. It can very efficiently remove organic and inorganic pollutants in water. The purification system will purify water using porous activation carbon, columnar UV light source, and a roll of multilayered purification film, which is made of a conductive film. Water can be initially treated by the activated carbon to remove odors and particles. Microbes and organic materials can be deactivated by UV light and a conductive film where a voltage is applied. Several diseases related to the pollutants can be prevented by simultaneously detecting and removing the toxic pollutants for clean drinking water in Minnesota.

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 purification system with embedded sensors can purify and monitor water simultaneously. At the inlet of water pipelines, when the embedded sensors detect the pollutants at a certain level, the system starts to remove the pollutants. At the outlet of water pipelines, the sensors check the pollutants again to ensure an efficient removal of pollutants. Due to its simplicity, low cost, and high performance, the proposed system can be an excellent solution to solve major problems of current water purification systems. With very clean drinking water, our quality of life can be improved by the new purification system.

Activities and Milestones

Activity 1: Development of tiny, cheap, accurate sensors for detection of pollutants, and construction of compact, cheap, efficient systems for water purification

Activity Budget: $356,000

Activity Description:
We propose to design and fabricate tiny sensors and compact systems for the purification of drinking water. We will design new sensors to detect water pollutants including lead, arsenic, cadmium, mercury, chloride, microbes, and organic compounds. The sensors will consist of an array structure because each sensor aims to detect one type of ion. In this fashion, we will integrate seven sensors as a sensor array. Next, we will set up a testing facility to characterize the fabricated sensor array in drinking water. The testing facility consists of a semiconductor analyzer and computer, which will measure the performance of the sensor array and display the results. Based on the experimental data, we will analyze the detection limit, sensitivity, response time, accuracy, and stability of the sensor array. We will optimize the sensor array to achieve the best performance. Meanwhile we will design, fabricate, and test new compact, cheap, and efficient water purification systems with improved performance. We will improve the water purification system using state-of-the-art modeling followed by improved construction for more efficient purification systems. We will remove odors and micro particles via activated carbon, eliminate organic compounds and microbes by UV light, and remove toxic ions by conductive electrodes.

Activity Milestones:

Description	Completion Date
Development of single sensor and array sensors for on-line monitoring of drinking water quality	2022-06-30
Development of compact purification systems to efficiently remove various pollutants from drinking water	2022-06-30
Evaluation and improvement of compact water purification systems in real drinking water	2023-06-30
Evaluation and improvement of tiny sensors and sensor arrays in real drinking water	2023-06-30

Activity 2: Development of sensor embedded water purification systems and optimization of the water purification systems for high-quality drinking water

Activity Budget: $180,000

Activity Description:
The objective of this activity is to develop an integrated and compact water purification system by assembling the sensor arrays and the purification system together. The multilayered purification film will be fabricated to remove heavy metal ions. The film will have a rough surface, which can be modified to enhance chemical reactions due to an increase of the total surface area. The rough surface can also make a stream in the flowing water. As a result, the new film can purify the water in a short time when compared to the conventional purification systems. Next, we will modify the surface with graphene and TiO2 to promote the chemical reaction. The fabricated film will be assembled with other parts including a carbon filter to remove odors and micro particles and a UV light to eliminate organic compounds. Once the water purification system is ready, the developed sensor arrays will be installed on both sides of the purification system to check the water quality before and after the purification process. Finally, the system will be evaluated and optimized by comparing the results against conventional purification systems. The compact water purification system will be characterized in real drinking water pipelines for field tests.

Activity Milestones:

Description	Completion Date
Development of compact water purification systems integrated with tiny sensor array for lab tests	2024-06-30
Optimization of compact water purification systems embedded with tiny sensor arrays for 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?

The funds will be used to develop a water monitoring system for detection of several toxic pollutants in water pipelines. The funds will be spent to develop the water purification system optimized from Phase I ending in 2021. The funds will also be used for the integration of water purification systems with embedded sensors. We plan to file patents on the proposed water purification system for commercialization in Minnesota. We can also apply our integrated water purification systems to clean environmental water or waste water. We will also apply for funding from NSF, EPA, and private foundations for additional work.

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 (ASME).

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 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 post-doc and one Ph.D. student to work on design, fabrication, and characterization of sensor-embedded purification systems. He will hold weekly meetings with his advisees to ensure good progress of this proposed work, in addition to some daily technical discussion with his post-doc and graduate 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 sensor-embedded purification system .

Some fabrication work will be partially done in 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. 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, 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 Postdoc		To design, fabrication, and test the compact water purification systems embedded with sensor arrays			25.4%	1.5		$124,727
1 Graduate Research Assistant		To design, fabricate, and test tiny sensors and sensor arrays			19.9%	1.5		$156,019
Principle Investigator		To manage the overall poject amd to conduct overall research			36.5%	0.24		$99,818
							Sub Total	**$380,564**
Contracts and Services								
							Sub Total	**-**
Equipment, Tools, and Supplies								
	Tools and Supplies	To use the facility of Minnesota Nano Center	To fabricate the sensors and the sensor networks					$71,000
	Tools and Supplies	Lab supplies, instrument and equipment consumables, minor equipment for setting up lab/ field testing systems, and equipment repairs and calibration costs	To build and test the sensors and sensor networks					$75,436
							Sub Total	**$146,436**
Capital Expenditures								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								

	Miles/ Meals/ Lodging	Travel for collecting samples and field test	Per University of Minnesota travel policy, this is for researchers to travel to collect samples in fields, and between campus and demonstration sites over the 3 years project period. In addition, Professor Cui, his postdoc and graduate assistant will attend one conference per year.					$9,000
							Sub Total	**$9,000**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
							Sub Total	**-**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$536,000**

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	$267,696
			State Sub Total	**$267,696**
Non-State				
			Non State Sub Total	**-**
			Funds Total	**$267,696**

Attachments

Required Attachments

Visual Component

File: f997bbe7-ec3.pdf

Alternate Text for Visual Component

This visual component shows current technology, proposed technology, and a compact water purification system design.

Optional Attachments

Support Letter or Other

Title	File
University SPA Supporting Letter	05f9e90d-921.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: Sensor-Embedded Purification System for Clean Drinking Water

Current Technology (Large, Complex, and Expensive)

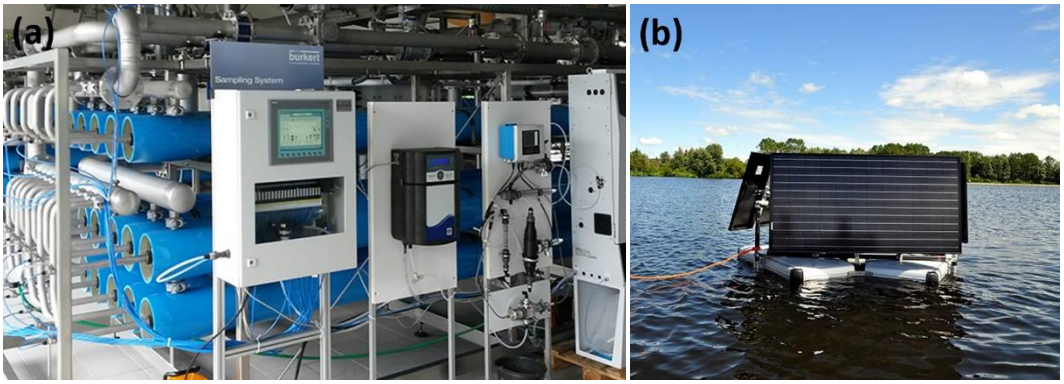

Figure 1. *(a) Monitoring System for Reverse Osmosis and Filtration, (b) The Buoy is a solar-powered system that combines continuous online water quality monitoring, web-based software, and ultrasonic technology to control harmful algae blooms in large water surfaces, such as lakes and drinking water reservoirs.*

Lake Water Purification System **Surface Water Purification System**

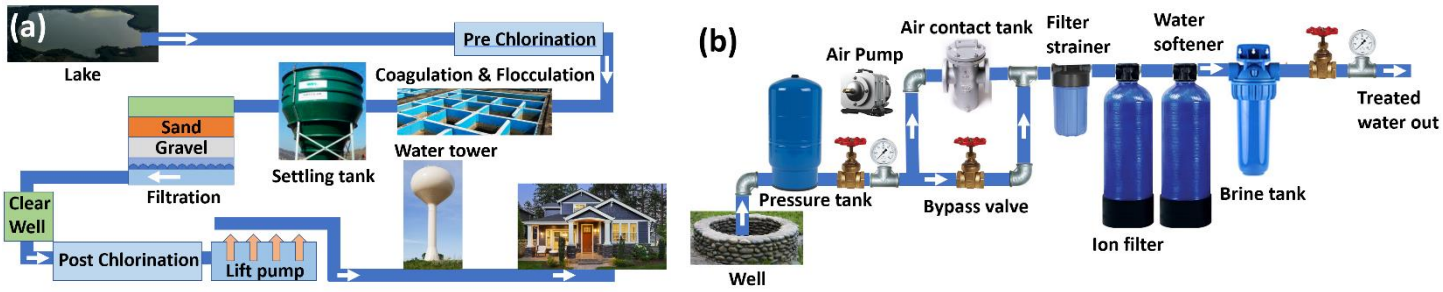

Figure 2. *Traditional purification process for (a) lake and river water and (b) surface water.*

Proposed New Technology (Small, Simple, and Cheap)

Proposed sensor embedded water purification system

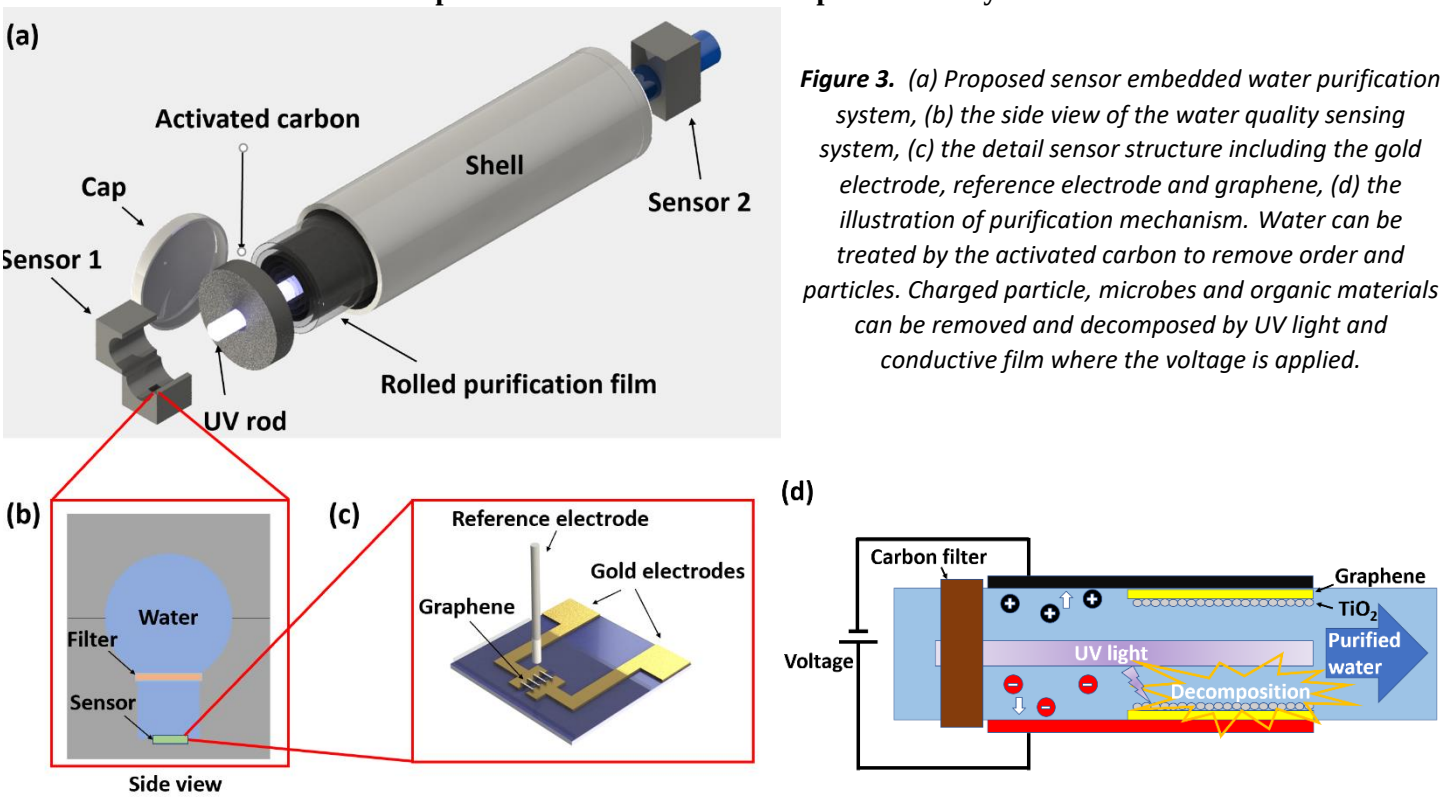

Figure 3. *(a) Proposed sensor embedded water purification system, (b) the side view of the water quality sensing system, (c) the detail sensor structure including the gold electrode, reference electrode and graphene, (d) the illustration of purification mechanism. Water can be treated by the activated carbon to remove order and particles. Charged particle, microbes and organic materials can be removed and decomposed by UV light and conductive film where the voltage is applied.*