Environment and Natural Resources Trust Fund

2022 Request for Proposal

General Information

Proposal ID: 2022-192

Proposal Title: Smart 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 a smart system to purify drinking water while monitoring pollutants with tiny sensors. The purification system is very efficient, small, cheap, simple, and easy to use.

Funds Requested: $400,000

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?
>	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 US 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. There are several available methods to monitor drinking water quality on-line or off-line. However, most of the current monitoring systems require samplings for lab tests. 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. It is difficult to operate and needs complicated maintenance. Our group was supported by LCCMR to develop water sensors and purification systems. We propose to integrate a water purification system with built-in sensors for clean drinking water in Minnesota.

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 purification system with built-in sensors for clean drinking water. Our system consists of a filter and sensors. The sensors can detect several materials in water such as arsenic, nitrate, polyfluoroalkyl substances, viruses and bacteria. The tiny sensors are accurate and easy to use at low cost, and they are tiny 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. As a second part of the system, the proposed filter is cheap, small, and easy to operate, compared to the current water purification systems. It can very efficiently remove inorganic and organic pollutants in water. The purification system will purify water using porous activation carbon, columnar UV light source, and a roll of multilayered purification film. Water can be initially treated by the activated carbon to remove odors and particles. Microbes, viruses 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 sensors can monitor and purify water simultaneously. Once the built-in sensors detect a certain level of pollutants at the inlet of water pipelines, the system starts to remove the pollutants. At the outlet of water pipelines, the sensors can double check the level of pollutants after purification. Due to its simplicity, low cost, and high performance, the proposed system can be an excellent solution to solve major problems of the current water sensing system and purification processes. With very clean drinking water, our quality of life can be improved by the new smart purification system.

Activities and Milestones

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

Activity Budget: $265,266

Activity Description:

We propose to improve and optimize tiny sensors and compact systems for purification of drinking water. First, we will design new sensors to detect water pollutants including arsenic, nitrate, PFAS compounds, viruses and bacteria. The sensors will be in an array structure as each sensor aims to detect one type of pollutant. In this design, we will integrate three to five sensors as a sensor array. Next, we will set up a testing system to characterize the sensor array in drinking water. The testing system 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. The fabrication process will be optimized to have good performance. Meanwhile, we will design, fabricate, and test new compact, cheap, and efficient water purification systems for drinking water based on our previous work. The water purification system will be improved by using state-of-the-art modeling for more efficient water purification. We will remove odors and microparticles via activated carbon, eliminate organic compounds and microbes by UV light, and remove toxic ions by conductive electrodes.

Activity Milestones:

Description	Completion Date
Improvement and evaluation of array sensors for on-line monitoring of drinking water quality	June 30 2023
Improvement and evaluation of compact water purification systems in real drinking water	June 30 2024

Activity 2: Development of a water purification system with built-in sensors, and optimization of the water purification system for clean drinking water

Activity Budget: $134,734

Activity Description:

This activity is to develop an integrated and compact water purification system with built-in sensors. The multilayered purification film will be fabricated to remove heavy metal ions. Since a rough surface of the film has increased the total surface area, the film will be modified to have a rough surface for enhancing chemical reactions. The rough surface can also make a stream in the flowing water. As a result, the new film can purify the water more efficiently compared to conventional purification systems. Next, we will modify the film surface with graphene and TiO2 to stimulate the chemical reaction. The prepared film will be assembled with other parts including a carbon filter to remove odors and microparticles, and a UV light to eliminate organic compounds. Once the water purification system is ready, the developed sensors will be installed in the inlet and outlet of the purification system to check the water quality before and after the purification process. Finally, the overall system will be optimized nd evaluated by comparing the results with conventional purification systems. The compact water purification system will be demonstrated with real drinking water pipelines to show the feasibility. We will conduct field tests using our systems.

Activity Milestones:

Description	Completion Date
Development of a compact water purification system integrated with tiny sensor array for lab tests	June 30 2025
Optimization of the water purification system with tiny sensors for field tests in water pipelines	June 30 2025

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 an array of water sensor to detect several toxic pollutants in water pipelines. The funds will be spent to further develop the water purification system for real water pipelines. The funds will be used for the integration and development of a water purification system with built-in 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 wastewater. We will also apply for funding from NSF, EPA, and private foundations for future work.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Development of Innovative Sensor Technologies for Water Monitoring	M.L. 2016, Chp. 186, Sec. 2, Subd. 04j	$509,000
Develop Small and Inexpensive Purification System for Community Drinking Water	M.L. 2018, Chp. 214, Art. 4, Sec. 2, Subd. 04e	$425,000
Develop Inexpensive Energy from Simple Roll-to-Roll Manufacturing	M.L. 2018, Chp. 214, Art. 4, Sec. 2, Subd. 07c	$300,000

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 the 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 350 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 Ph.D. graduate assistant to work on the design, fabrication, and characterization of purification systems

with built-in sensors. He will hold weekly meetings with his graduate assistant to ensure good progress of this proposed work, in addition to some daily technical discussion with his 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 and 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 and Ph.D. student to design, fabricate, characterize and analyze the proposed purification systems with built-in sensors.

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 on nanomaterials and nanotechnology.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Tianhong Cui		PI, Management of the overall project			36.5%	0.24		$99,818
Graduate Research Assistant		Design, fabrication, testing, and evaluation of purification systems with sensors			47.8%	1.5		$159,225
							Sub Total	**$259,043**
Contracts and Services								
Minnesota Nano Center and Characterization Facility	Internal services or fees (uncommon)	Fabrication and testing cost at Minnesota Nano Center and Characterization Facility				-		$60,000
							Sub Total	**$60,000**
Equipment, Tools, and Supplies								
	Tools and Supplies	Materials 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					$71,957
							Sub Total	**$71,957**
Capital Expenditures								
							Sub Total	-
Acquisitions and Stewardship								
							Sub Total	-

Travel In Minnesota								
	Conference Registration Miles/ Meals/ Lodging	Travels from university campus to testing fields	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 3yrs project period.					$9,000
							Sub Total	**$9,000**
Travel Outside Minnesota								
-							**Sub Total**	-
Printing and Publication								
							Sub Total	-
Other Expenses								
-							**Sub Total**	-
							Grand Total	**$400,000**

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 match of the University of Minnesota	Office supplies, computers, etc.	Potential	$192,896
			State Sub Total	**$192,896**
Non-State				
-			**Non State Sub Total**	-
			Funds Total	**$192,896**

Attachments

Required Attachments

Visual Component

File: [8db89067-0fe.pdf](8db89067-0fe.pdf)

Alternate Text for Visual Component

Comparison of old technologies of drinking water purification and our proposed new technologies using a smart purification system with built-in sensors for clean drinking water...

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: Tianhong Cui, University of Minnesota

Project Title: Smart Purification System for Clean Drinking Water

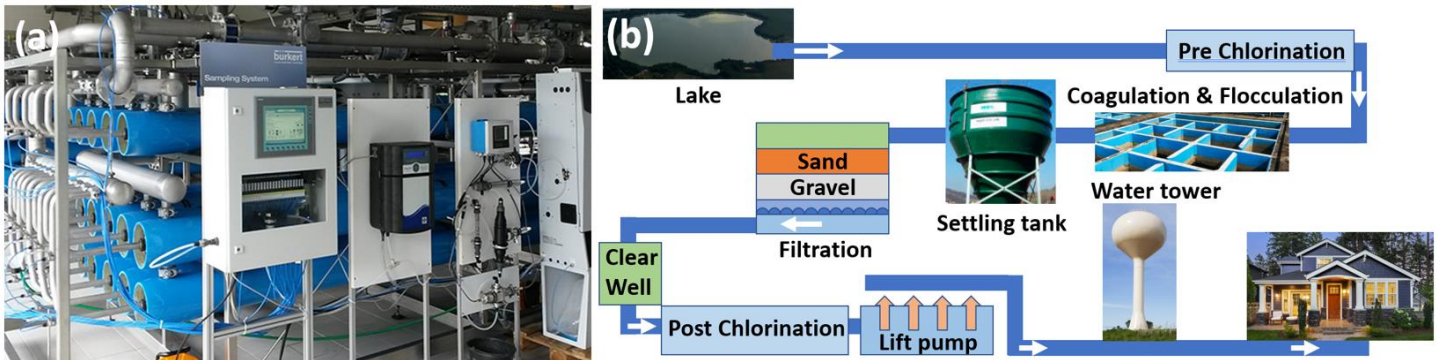# Current Technology (Large, Complex, and Expensive)

Figure 1. *(a) Monitoring System for Reverse Osmosis and Filtration, (b) Traditional purification process for lake and river water.*

Proposed New Technology (Small, Simple, and Cheap)

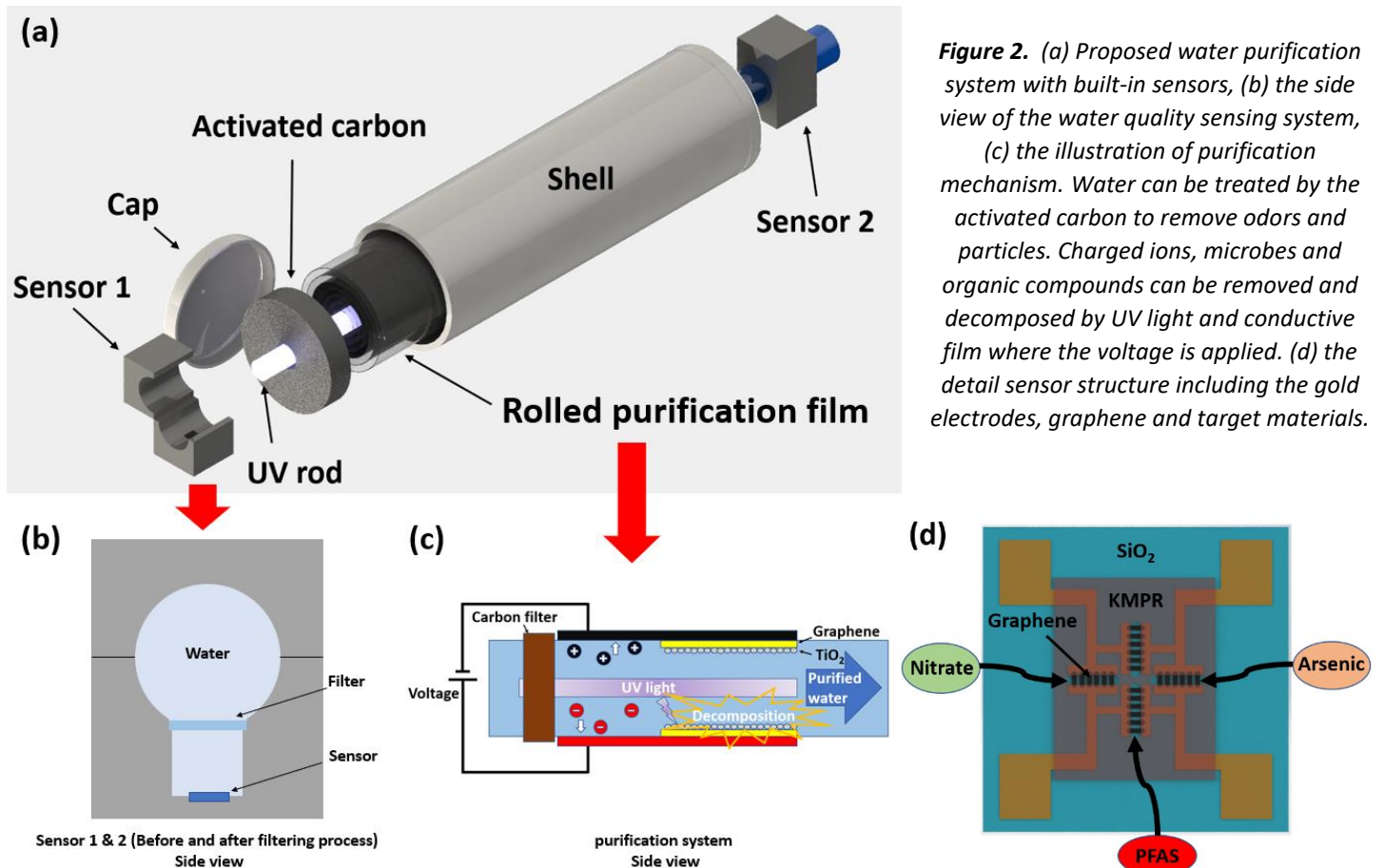**Proposed water purification system with built-in sensors**

Figure 2. *(a) Proposed water purification system with built-in sensors, (b) the side view of the water quality sensing system, (c) the illustration of purification mechanism. Water can be treated by the activated carbon to remove odors and particles. Charged ions, microbes and organic compounds can be removed and decomposed by UV light and conductive film where the voltage is applied. (d) the detail sensor structure including the gold electrodes, graphene and target materials.*