Environment and Natural Resources Trust Fund

2026 Request for Proposal

General Information

Proposal ID: 2026-444

Proposal Title: Easy-To-Use Tiny Sensor to Detect Mercury in Fish

Project Manager Information

Name: Tianhong Cui

Organization: U of MN - College of Science and Engineering

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Project Basic Information

Project Summary: This project develops a low-cost, portable sensor to detect mercury in fish, helping anglers and communities make safe consumption choices while supporting public health and fisheries management with quick testing.

ENRTF Funds Requested: $517,000

Proposed Project Completion: June 30, 2029

LCCMR Funding Category: Fish and Wildlife (D)

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.

Minnesota, the "Land of 10,000 Lakes," provides abundant fish that are a key source of protein, omega-3s, and essential nutrients. However, mercury contamination is a major concern, with 26% of Minnesota's polluted waters listed due to high mercury levels in fish. Methylmercury (MeHg), the most toxic form, builds up in fish and poses serious health risks, especially for pregnant women, children, and frequent fish consumers. Unlike inorganic mercury (Hg^{2+}), MeHg is easily absorbed and can harm brain and nervous system development. Government agencies, including the Minnesota Pollution Control Agency and Minnesota Department of Health, primarily measure total mercury (THg) in fish, assuming 80-100% of it is MeHg. Federal agencies including EPA, FDA, and USGS follow the same approach, with MeHg testing reserved for special studies. However, THg measurements do not separate highly toxic MeHg from the less harmful inorganic form, limiting their usefulness for health risk assessments. This project will develop a low-cost, portable sensor to measure MeHg and inorganic mercury separately, right at the testing site. By providing more precise mercury data, this tool will improve fish consumption safety, support better environmental monitoring, and help protect public health.

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.

This project aims to develop a simple, low-cost, and portable sensor to detect two types of mercury including both methylmercury (MeHg) and inorganic mercury (Hg^{2+}) in fish. The sensor is a small paper test strip with two separate detection areas that work as the sample flows through. At the first detection spot, a special chemical (PDCA) captures inorganic mercury (Hg^{2+}) so it can be measured. Meanwhile, methylmercury (MeHg) continues moving downstream to the second detection area, where it is measured separately. Adding the two results gives an accurate total mercury (THg) value. The sensor uses a highly sensitive electrochemical technique called anodic stripping voltammetry, which allows it to detect extremely small amounts of mercury, down to the parts-per-trillion (ppt) level. The natural flow of liquid through the test strip helps move the sample efficiently, improving accuracy. This easy-to-use system costs less than $1 per test and eliminates the need for complex lab equipment or sample preparation. It works like a blood glucose test, which just inserts the test strip into a small portable reader to test samples and get results. This technology will make mercury testing more accessible, helping people make safer choices about eating fish and improving environmental monitoring.

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?

This project will help Minnesotans safely eat fish while protecting lakes. We will develop an affordable, portable mercury sensor that lets regulators, researchers, and consumers easily test fish for mercury. This will help reduce health risks, especially for pregnant women and children. Unlike traditional methods, this tool can measure both organic and inorganic mercury separately, providing more accurate safety information to improve fish consumption guidelines. It will also help agencies monitor mercury pollution in Minnesota lakes, supporting efforts to keep water clean. This project will promote healthy fisheries, improve public health, and raise awareness of water pollution risks.

Activities and Milestones

Activity 1: Development and Optimization of the Paper-Based Mercury Sensor

Activity Budget: $238,000

Activity Description:
We plan to design and build a paper-based sensor that can detect mercury in fish. The sensor will be made by Prof. Cui's group using advanced manufacturing technology at the Minnesota Nano Center to ensure precision and scalability. It will have two sensors on a small microfluidic strip to detect two types of mercury: inorganic mercury (Hg^{2+}) and methylmercury (MeHg). The key features of this sensor include (1) Advanced electrodes: The electrodes will be made from a special material called pyrolyzed glassy carbon. This material is stable, conducts electricity well, and reduces the energy needed to detect mercury, making the sensor more sensitive; (2) Capillary-driven microfluidics: The sensor will use a simple design to move liquids through the strip without pumps, making it easier and faster to detect mercury; (3) Miniaturized sample processing: The sensor will have a small system to break down fish tissue to extract mercury, making it portable and easy to use; (4) Wireless data transmission: The sensor will send results directly to a smartphone, allowing for quick analysis and data logging. We will test the sensor in the lab to make sure it's sensitive, accurate, and reliable, comparing it to more traditional methods like ICP-MS.

Activity Milestones:

Description	Approximate Completion Date
Design, fabrication, and testing of initial sensor prototypes	June 30, 2027
Optimization of chemical modification and detection parameters	June 30, 2028
Lab validation of sensor accuracy against standard methods (ICP-MS)	June 30, 2029

Activity 2: Field Validation and Fish Sample Analysis in Minnesota Lakes

Activity Budget: $279,000

Activity Description:
Prof. Cui's lab will work with the Minnesota Pollution Control Agency (supporting letter attached) to test the sensor in the field and analyze fish samples from Minnesota lakes. Initial tests will focus on lakes around the Twin Cities, with plans to expand to other lakes. Fish samples will be collected from lakes with mercury contamination, covering different species and levels of the food chain to study mercury distribution. The main goals include (1) Sensor performance: Test the sensor's accuracy, stability, and ease of use in different environmental conditions. (2) Comparing with standard methods: Check the sensor's results against mercury measurements from ICP-MS to ensure reliability. (3) Mercury distribution in fish: Measure methylmercury and inorganic mercury levels in different fish tissues (like muscle and liver) to understand how mercury accumulates in different species and organs. Compare fish mercury levels with water contamination to create models showing how mercury builds up in fish, aiding fish consumption safety and environmental monitoring. (4) Identifying pollution sources: Analyze fish mercury levels alongside industrial and farming activities to identify contamination sources and suggest ways to protect water resources. The results will improve the sensor and demonstrate its potential for regular mercury testing, supporting better environmental monitoring.

Activity Milestones:

Description	Approximate Completion Date
Collection of fish samples from Minnesota waters for validation using sensors and ICP-MS	June 30, 2027
On-site sensor validation with results compared to ICP-MS mercury testing in fish	June 30, 2028
Further testing, data analysis, and reporting to assess the distribution of mercury in fish	June 30, 2029

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?

As a result of this project, a sensor for detecting mercury in fish will be developed. Patents will be filed for prototypes to enable commercialization. The sensor systems will be deployed in water across Minnesota and eventually nationwide. Future work will focus on improving the pre-processing and post-processing units and expanding field testing to a larger area. Additional funding will be sought from federal sources such as NSF and EPA, as well as private funds, to support further development.

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 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 Departments of Electrical & Computer Engineering and Bioengineering. He joined the faculty of the University of Minnesota in 2003. He is a Fellow of the American Society of Mechanical Engineering. He is also a member of the European Academy of Sciences and Arts. Dr. Cui is an international leading expert on micro sensors and advanced manufacturing. He has 380 archived publications in scientific journals and prestigious conferences and 10 US patents. He is the founding Executive Editor-in-Chief for a Nature journal, Microsystems & Nanoengineering. 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 Blaise Pascal Chair Visiting Professorship in France (named after famous French scientist Blaise Pascal), the Distinguished Visiting Fellowship from the Royal Academy of Engineering and the Global Chair at the University of Bath in UK, JSPS faculty fellowship at the University of Tokyo, and numerous best paper awards. Most recently Dr. Cui has received two NSF grants on micro-chemical sensors for detection of water pollutants.

Dr. Cui will serve as the PI and project manager, responsible for overseeing the project, all reports, and deliverables. He will supervise one senior research scientist to work on design, fabrication, and characterization of the proposed sensors for detection of mercury in fish. He will hold weekly meetings and daily technical discussions with his advisee to ensure good progress in this proposed work. Dr. Cui and his staff will also be responsible for field tests and assessment of the proposed mercury sensor.

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 staff to design, fabricate, characterize and analyze the proposed mercury sensors.

Some fabrication work will be done in Minnesota Nano Center (cse.umn.edu/mnc), 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								
Tianhong Cui		Principal Investigator			26.79%	0.24		$89,299
Staff Scientist		Staff Scientist			24.41%	3		$306,695
							Sub Total	**$395,994**
Contracts and Services								
Minnesota Pollution Control Agency (MPCA)	Service Contract	MPCA will consult with Dr. Cui group for guidance on fish sample collection and data comparison with traditional analyses, ensuring the sensor supports management decisions.				3		$41,400
							Sub Total	**$41,400**
Equipment, Tools, and Supplies								
	Tools and Supplies	Silicon wafers, polymer substrates, graphene, chemicals, and components for testing set-up	Materials and supplies for various items required to fabricate and characterize the Mercury sensor					$27,106
							Sub Total	**$27,106**
Capital Expenditures								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Miles/ Meals/ Lodging	Travels in Minnesota	Sampling and field tests in Minnesota waters					$13,500

							Sub Total	**$13,500**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
							Sub Total	**-**
Other Expenses								
		Scientific Services - University Of Minnesota Nano Center	Scientific Service at the University of Minnesota's Minnesota Nano Center and the Characterization facility. Fabrication and characterization costs of the Mercury detectors in central facilities					$39,000
							Sub Total	**$39,000**
							Grand Total	**$517,000**

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				
			State Sub Total	**-**
Non-State				
In-Kind	Unrecovered F&A calculated at 54% MTDC	Support of ME facilities where research will be conducted.	Secured	$279,180
			Non State Sub Total	**$279,180**
			Funds Total	**$279,180**

Total Project Cost: $796,180

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: db99bdda-be3.pdf

Alternate Text for Visual Component

Comparison of the current and proposed technologies, as well as the description of sensor design and workflow diagram....

Supplemental Attachments

Capital Project Questionnaire, Budget Supplements, Support Letter, Photos, Media, Other

Title	File
Authorization Letter	0eb7a496-e44.pdf
MPCA Supporting Letter	4996b8b9-d7e.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

Do you understand that travel expenses are only approved if they 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 understand the UMN Policy on travel applies.

Does your project have potential for royalties, copyrights, patents, sale of products and assets, or revenue generation?

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?

No

Does your project include the pre-design, design, construction, or renovation of a building, trail, campground, or other fixed capital asset costing $10,000 or more or large-scale stream or wetland restoration?

No

Do you propose using an appropriation from the Environment and Natural Resources Trust Fund to conduct a project that provides children's services (as defined in Minnesota Statutes section 299C.61 Subd.7 as "the provision of care, treatment, education, training, instruction, or recreation to children")?

No

Provide the name(s) and organization(s) of additional individuals assisting in the completion of this proposal:

Josh Gates <gates191@umn.edu>

Do you understand that a named service contract does not constitute a funder-designated subrecipient or approval of a sole-source contract? In other words, a service contract entity is only approved if it has been selected according to the contracting rules identified in state law and policy for organizations that receive ENRTF funds through direct appropriations, or in the DNR's reimbursement manual for non-state organizations. These rules may include competitive bidding and prevailing wage requirements

Yes, I understand