Environment and Natural Resources Trust Fund

2025 Request for Proposal

General Information

Proposal ID: 2025-275

Proposal Title: Portable Arsenic and Nitrate Detector for Well 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 tiny, cheap and easy-to-use detector for arsenic and nitrate. It can be used for well water to determine if the water is safe to drink.

ENRTF Funds Requested: $358,000

Proposed Project Completion: June 30, 2027

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.

In Minnesota, arsenic and nitrate contamination in well water poses a significant public health threat. Data from the Minnesota Department of Health reveals that approximately 10% of private wells exceed the U.S. Environmental Protection Agency's standards for arsenic (10 parts per billion) and nitrate (10 parts per million). These contaminants are linked to various health issues, including cancer, cardiovascular problems, and methemoglobinemia, and are particularly hazardous for infants and pregnant women. The reliance on private wells for drinking water exacerbates the issue, as they often lack regulations and routine monitoring. Moreover, Minnesota's geological composition, characterized by arsenic-prone aquifers, complicates the situation. Current detection methods rely on periodic water sampling and testing, which is often time consuming and costly. This intermittent testing increases the risk of contamination going undetected for extended periods, amplifying health risks. Given these challenges, urgent action is necessary to develop portable arsenic and nitrate detectors for well water. These detectors would enable fast, cheap on-site testing, improving the safety of well water statewide. Investing in such technology is crucial to safeguarding public health and ensuring access to clean drinking water for all Minnesotans.

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.

Our proposed solution to the pervasive issue of arsenic and nitrate contamination in well water in Minnesota is the development of an innovative detection system specifically for accurately determining arsenic and nitrate levels in the water. This involves the development of a cutting-edge detection technology: a graphene ion-sensitive field-effect transistor (ISFET) equipped with arsenic and nitrate ion-sensitive membranes. Graphene ISFETs offer unparalleled sensitivity, enabling the detection of minute concentrations of ions or species in water. By incorporating ion-sensitive membranes tailored specifically for arsenic ions and nitrate species, our device can accurately and rapidly detect the presence of these contaminants in well water samples. This innovative approach addresses the shortcomings of current detection methods, providing a portable, cheap, and user-friendly solution. The graphene ISFET technology allows for on-site testing, eliminating the need for laborious and expensive laboratory analysis. Moreover, its sensitivity ensures early detection of contamination, mitigating health risks associated with prolonged exposure. This includes sensor and membrane development, followed by performance optimization to enhance sensitivity and accuracy. In collaboration with the Minnesota Well Owners Organization, field trials will validate the technology's real-world effectiveness. These steps ensure a reliable, portable, and cost-effective solution for safeguarding public health and ensuring safe 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?

The project to develop detectors to identify and evaluate the concentration of arsenic and nitrate in well water using graphene ISFET technology to directly support Minnesota's environmental goals. By safeguarding water quality and preventing further degradation, it contributes to the conservation of groundwater and preservation of ecosystems. Early detection of contaminants promotes sustainable resource management and protects public health, aligning with the state's commitment to environmental stewardship. Ultimately, the project enhances the resilience of Minnesota's natural resources, ensuring they remain viable for future generations while promoting the well-being of communities reliant on clean water sources.

Activities and Milestones

Activity 1: Development of arsenic and nitrate detectors using graphene ion-sensitive field-effect transistors for laboratory testing of water

Activity Budget: $174,133

Activity Description:
The first activity aims to develop, manufacture, and assess individual sensors using graphene ion-sensitive field effect transistors (ISFETs) coupled with arsenic and nitrate ion-sensitive membranes (ISMs). Graphene is a monolayer of carbon atoms which is highly sensitive to pollutants in water. The following steps will ensure successful completion: Firstly, graphene ISFET sensing platform will be designed and fabricated, focusing on optimizing graphene channels, source-drain electrode design, and selecting cost-effective substrates while maintaining high sensing performance. Next, arsenic and nitrate ISMs will be synthesized by immobilizing ionophores within a polymer matrix to enable selective detection of different species in water. ISM compositions will undergo optimization to ensure long-term stability and heightened sensitivity. Subsequently, integration of arsenic and nitrate ISMs with graphene ISFETs will occur, followed by in-laboratory measurement and optimization. Validation of results will involve comparison with standard methods like ion chromatography. The sensors will be fabricated using microfabrication technology at the Minnesota Nano Center, University of Minnesota. Testing and evaluation of arsenic and nitrate detectors in laboratory settings will compare sensing results with standard methods such as Inductively Coupled Plasma Mass Spectrometry.

Activity Milestones:

Description	Approximate Completion Date
Design, fabrication, and testing of arsenic detectors as testing prototypes in laboratory	December 31, 2025
Design, fabrication, and testing of nitrate detectors as testing prototypes in laboratory	June 30, 2026
Improvement and optimization of arsenic and nitrate detectors in laboratory	June 30, 2026

Activity 2: Portable detection system development by integration of arsenic and nitrate sensors, detector system parameter optimization, and field tests

Activity Budget: $183,867

Activity Description:
The second activity of the proposed project aims to develop a portable detector system suitable for field testing by non-trained individuals. This involves four key milestones: (1) Designing and fabricating an integrated graphene ISFET platform comprising arsenic and nitrate sensors, which will undergo testing and optimization with synthesized ISMs. (2) Developing the detector's readout circuit, portable chassis, and user-friendly interface, with a modular design allowing for easy sensor replacement. (3) Conducting laboratory testing to validate the detector's performance against standard techniques like Inductively Coupled Plasma Mass Spectrometry. (4) Field-testing the detector for onsite arsenic and nitrate detection in well water, where environmental scientists will utilize it, providing valuable feedback for further optimization. Field tests will be performed at the free well-testing clinics for private well-owners throughout Minnesota, led by the Minnesota Well Owners Organization, where traditional analytical techniques will be used to confirm the ISFET sensor accuracy and inform technology optimization. By integrating advanced technology with accessible design, this portable detector system ensures efficient and reliable onsite detection of arsenic and nitrate contamination. Such advancements are crucial for safeguarding public health and preserving natural water resources, ultimately contributing to the broader goal of environmental sustainability and clean water access.

Activity Milestones:

Description	Approximate Completion Date
Design, fabricating, and optimizing the integrated graphene ISFET platform for arsenic and nitrate detection	December 31, 2026
Design and fabrication of the detector's readout circuit, chassis, and user-interface	December 31, 2026
In-lab validation and field test of the portable arsenic/nitrate detector for well water	June 30, 2027
Field testing at MNWOO free testing clinics for accuracy assessments and technology optimization	June 30, 2027

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Cara Santelli	University of Minnesota	Co-PI; Be responsible for field tests and assessments of the developed sensors.	Yes
Jeffrey Broberg	Minnesota Well Owners Association	Organize and collaborate on nitrate and arsenic well-testing clinics for private well-owners.	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 work be funded?

A portable arsenic and nitrate detector will be developed. Patents based on the developed prototypes will be applied for commercialization. The systems will be used for well waters in Minnesota. Further work will focus on the highly integrated pre-processing and post-processing units and field tests for a broader area. Other federal funding from NSF (i.e., programs including the funded Convergence Accelerator, the funded Regional Innovation Engine, etc.), USDA (i.e., the AFRI Foundational and Applied Science Program), EPA, USGS, or private funds will be applied as potential funding sources for further development of arsenic and nitrate sensors.

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 Electrical and Computer Engineering. 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 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. 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, a recent JSPS faculty fellowship at the University of Tokyo, and numerous best paper awards. Recently Drs. Cui and Cara Santelli 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 PhD student to work on the design, fabrication, and characterization of the arsenic and nitrate sensors for water pollutant detection. He will hold weekly meetings and daily technical discussions with his advisee to ensure good progress of this proposed work. Dr. Cui will work with Dr. Santelli and her student who will be responsible for field tests and assessment of the proposed arsenic and nitrate sensors.

Organization: U of MN - College of Science and Engineering

Organization Description:

All programs in the College of Science and Engineering at the University of Minnesota were ranked in the top 25 in the

nation by U.S. News. The Department of Mechanical Engineering at the University of Minnesota is one of the foremost programs in the United States, serving the state and nation as a leading center of education, research, and innovation.

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 and his student to design, fabricate, characterize, and analyze the proposed sensors to detect pollutants in water. Some fabrication work will be done in Minnesota Nano Center, a state-of-the-art facility for research in nanoscience and applied nanotechnology. 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 the Center to offer academic rates, normally less than half of the actual cost of operation.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Tianhong Cui		Principal Investigator			27.06%	0.24		$56,399
Cara Santelli		Co-PI			27.06%	0.24		$37,240
Research Assistants		Research Assistants			42.97%	3		$185,757
							Sub Total	**$279,396**
Contracts and Services								
MNWOO	Professional or Technical Service Contract	Running well-testing clinics for local community members to bring well water samples. Arsenic and nitrate levels will be quantified by traditional analytical techniques and sensors will be tested to determine accuracy and optimization needs.				0		$27,000
							Sub Total	**$27,000**
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 arsenic and nitrate detector					$18,104
							Sub Total	**$18,104**
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					$12,500
							Sub Total	**$12,500**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
							Sub Total	**-**
Other Expenses								
		Scientific Servicescientific services at the University of Minnesota's Minnesota Nano Center and the Characterization facility	Fabrication and characterization costs of the arsenic and nitrate detectors in central facilities					$21,000
							Sub Total	**$21,000**
							Grand Total	**$358,000**

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 55% MTDC	Support of ME facilities where research will be conducted.	Secured	$167,626
			Non State Sub Total	**$167,626**
			Funds Total	**$167,626**

Total Project Cost: $525,626

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: 469e0d75-692.pdf

Alternate Text for Visual Component

Comparison of the current and proposed technologies for detection of arsenic and nitrate...

Supplemental Attachments

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

Title	File
USGS Support Letter	cab3ae5b-8ec.pdf
MNWOO Letter	bfda9035-3ae.pdf
University Support Letter	ce2fcc8e-6d2.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

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:

Alexandra Sullivan <sull1129@umn.edu>