Environment and Natural Resources Trust Fund

2023 Request for Proposal

General Information

Proposal ID: 2023-123

Proposal Title: Small Cheap Portable COVID-19 Monitoring Device in Wastewater

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 is to develop a low-cost device for continuous monitoring of COVID-19 in wastewater, providing a comprehensive snapshot of community transmission to form an outbreak early warning system.

Funds Requested: $200,000

Proposed Project Completion: June 30, 2025

LCCMR Funding Category: Small Projects (H)

Secondary 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.

The ongoing outbreak of COVID-19 has caused a global pandemic with considerable morbidity and mortality. Better understanding the spread of COVID-19 is of great importance to give early warning for pandemic management. Traditional methods by testing people experiencing symptoms or checking those who have been in close contact with COVID-19 patients do not capture the full extent to the COVID-19 spread within a community. In contrast, monitoring wastewater for traces of COVID-19 enables effective surveillance of an entire community in a cost-effective way, providing a broader understanding of COVID-19 activity, which allows to form an outbreak early warning system. Due to the low virus concentration in wastewater, current methods for detection of SARS-CoV-2 viral RNA require steps including viral concentration and RNA extraction, which can take more than 8 hours to complete one test, and may not generate consistent results. Moreover, their reliance on sophisticated infrastructures and trained operators are other obstacles. As a result, an integrated, easy operation while low-cost device for continuous sampling and monitoring of COVID-19 virus in wastewater is of great importance in identification of potential outbreaks before they occur actively.

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.

For continuous monitoring COVID-19 in wastewater, we propose a low-cost, easy operation while highly sensitive device. The device consists of two parts: 1) a low-cost sampling device based on FTA papers that can be used for continuous collection of SARS-CoV-2 viral RNA; 2) a highly sensitive detection device adapted to the sampling device for detection of COVID-19 on-site. The size of the sampling device is very small, which is easily to be installed into wastewater pipes or pools for continuous sampling and testing. The virus in the wastewater will be lysed and the corresponding nucleic acids will be adsorbed onto the FTA paper of the sampling device. After a period of continuous sampling, the device will be taken out and inserted into the back-end detection device. The new on-site detection device is portable: less than 100 g in weight and smaller than 10 cm in length and 3 cm in height and width. Based on the nucleic acid amplification method, the sensitivity of the device is ultra-high, suitable for detection of low-concentration virus. The entire detection process can be achieved within 25 minutes. Moreover, the detection results can be read directly by our naked eye.

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 device proposed is for continuous monitoring COVID-19 in wastewater. In normal conditions, SARS-CoV-2 RNA can be detected in human feces a few days to a week before the onset of symptoms, which means wastewater surveillance can predict COVID-19 outbreaks even before individual patient testing and hospital admission. Instead of individually testing thousands of patients, collecting and testing wastewater is much more cost-efficient to obtain data, especially informative to regions with low clinical COVID-19 testing rates. Moreover, continual monitoring of wastewater can be used to estimate a trend of an outbreak, and to identify a new outbreak and prevalence.

Activities and Milestones

Activity 1: Design and fabrication of the low-cost continuous sampling device and the highly sensitive on-site detection device

Activity Budget: $99,588

Activity Description:
We will design and fabricate a low-cost, easy operation while highly sensitive device that consists of a sampling device and an on-site detection device for continuous motoring of COVID-19 in wastewater. The core functional module of the sampling device is FTA papers. Once the virus in the wastewater flows through the FTA paper, it will be lysed and the corresponding nucleic acids will be adsorbed onto the paper. The structure of the sampling device is designed to ensure that the wastewater will continuously flow through the FTA paper. The size of the sampling device and the detection device will also be carefully calculated and optimized to ensure that they will be well and easily integrated together for rapid result reading on site. The on-site detection device contains three functional modules: 1) the pre-packaged washing buffer for nucleic acid enrichment; 2) the pre-packaged reaction buffer for isothermal amplification; 3) LFA integrated for end point detection of isothermal amplicons with naked eyes. The tightness of the entire platform is carefully designed and ensured to avoid leakage of the testing samples and reaction buffers, otherwise it will affect the accuracy of detection and may cause contamination as well.

Activity Milestones:

Description	Completion Date
Develop an FTA paper-based sampling device for continuous sampling of COVID-19 virus in wastewater	December 31, 2023
Develop low-cost and highly sensitive on-site detection devices based on nucleic acid amplification method	June 30, 2024
Size optimization of sampling devices and on-site detection devices to ensure the overall functions	June 30, 2024

Activity 2: Integration of the sampling part and detection part, and optimization of the platform for high performance

Activity Budget: $100,412

Activity Description:
The sampling device and the on-site detection device will be integrated together for continuous monitoring of COVID-19 in wastewater. To obtain a better performance, the nucleic acid capture efficacy of the FTA paper on the sampling device is investigated and optimized. After a period of sampling, the sampling device is taken out and put directly into real-time quantitative PCR buffer for PCR reaction. The obtained threshold values are used to quantify the concentration of nucleic acids, to compare the extraction efficiency of FTA paper. The primer design and reaction parameters of isothermal amplification, including reaction temperature, concentration of enzymes, and reaction time have a significant impact on the sensitivity, specificity, and accuracy of the assay result. Targeting at the ORF1a/b gene, N gene, and E gene of COVID-19, several sets of primers and the corresponding reaction parameters will be designed and optimized. The optimized reactions will be fully integrated in the on-site detection device. By the end, the platform will be evaluated and improved by testing the real wastewater samples by comparing the results with the conventional testing methods.

Activity Milestones:

Description	Completion Date
Integration of the whole monitoring platform	December 31, 2024
Improvement of the whole monitoring device for high performance	December 31, 2024
Evaluation of the whole device in real wastewater tests	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 work be funded?

This project will provide low-cost, accurate, and continuous monitoring devices for detection of COVID-19 in wastewater. Upon completion, this project will realize distributed sensor monitoring for COVID-19 viruses. The knowledge learned throughout the project will provide a solid foundation for further research and development that will lead to the eventual implementation of this sensing technique, for broader monitoring viruses of wastewater in Minnesota. In addition, we plan to file patents on the proposed distributed COVID-19 sensor for commercialization in the future. If needed, we will apply for funding from NSF, EPA, USGS, and other funding agencies for further development.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
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: Distinguished McKnight University 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 Department of Electrical and Computer Engineering and Department of Biomedical 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, the University of Minnesota, National Laboratory of Metrology in Japan, and Louisiana Tech University. He was a Distinguished Visiting Fellow at the University of Cambridge in UK, and a Distinguished Visiting Professor at Gustave Eiffel University 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 360 archived papers, and he also holds 6 issued US patents. 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 Global Chair at the University of Bath, 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.

Dr. Cui will serve as the PI and the project manager, responsible for overseeing the project, all reports, and deliverables. He will supervise one graduate research assistant to work on design, fabrication, and characterization of the COVID-19 motoring device in wastewater. 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 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 Tianhong Cui is the director of TIAN Lab equipped with the state-of-the-art instruments and facilities to conduct the proposed research, with a variety of fabrication and characterization equipment and tools, sufficient for Professor Cui and his graduate research assistant to design, fabricate, characterize and analyze the proposed COVID-19 motoring device in wastewater.

Some fabrication work will be partially done in Minnesota Nano Center, 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 the NNCI network, 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 on nanomaterials and nanotechnology.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Tianhong Cui		Principal Investigator			33.5%	0.16		$50,774
Post Doctoral Associate		Researcher			23.6%	2		$121,505
							Sub Total	**$172,279**
Contracts and Services								
							Sub Total	-
Equipment, Tools, and Supplies								
	Tools and Supplies	Silicon wafers, polymer substrates, papers, reagents, chemicals, and components for experiments for testing set-up.	Materials and supplies for fabrication and characterization of the monitoring device and for testing set-up.					$18,721
							Sub Total	**$18,721**
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								
		Lab services	University of Minnesota's Minnesota Nano Center for fabrication costs of the portable covid-19 motoring device and the University of Minnesota's Characterization facility for characterization of the portable covid-19 motoring device					$9,000
							Sub Total	**$9,000**
							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				
			State Sub Total	**-**
Non-State				
In-Kind	Unrecovered F&A of 55% MTDC	Unrecovered F&A of 55% MTDC	Secured	$110,000
			Non State Sub Total	**$110,000**
			Funds Total	**$110,000**

Attachments

Required Attachments

Visual Component

File: 95dcf1ed-27f.pdf

Alternate Text for Visual Component

One page visual: Comparison of current and new technologies; Future applications of proposed new technology....

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?

No

Does the organization have a fiscal agent for this project?

No

PI/PD: Tianhong Cui, University of Minnesota

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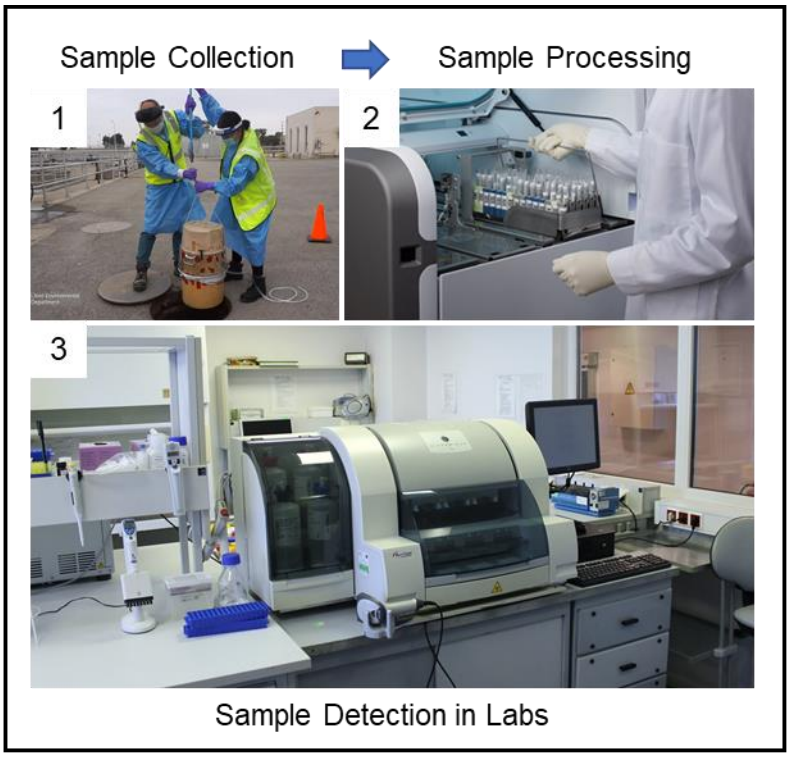
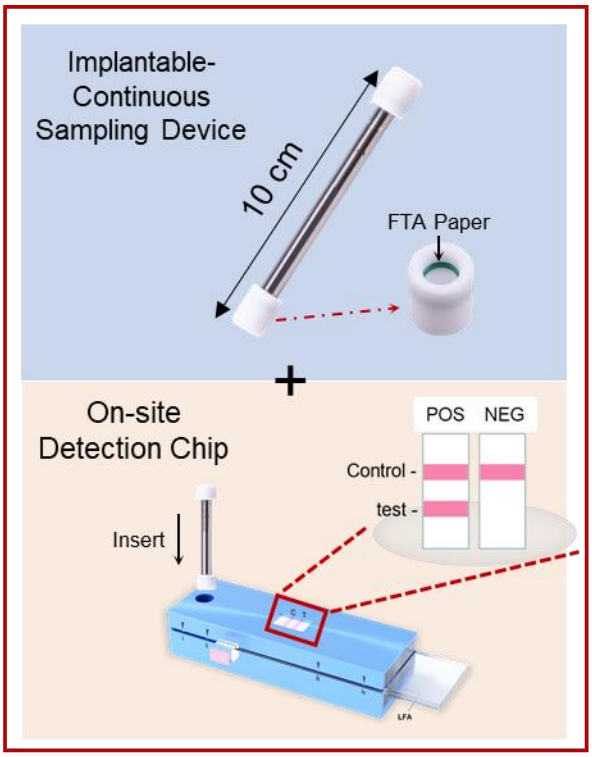
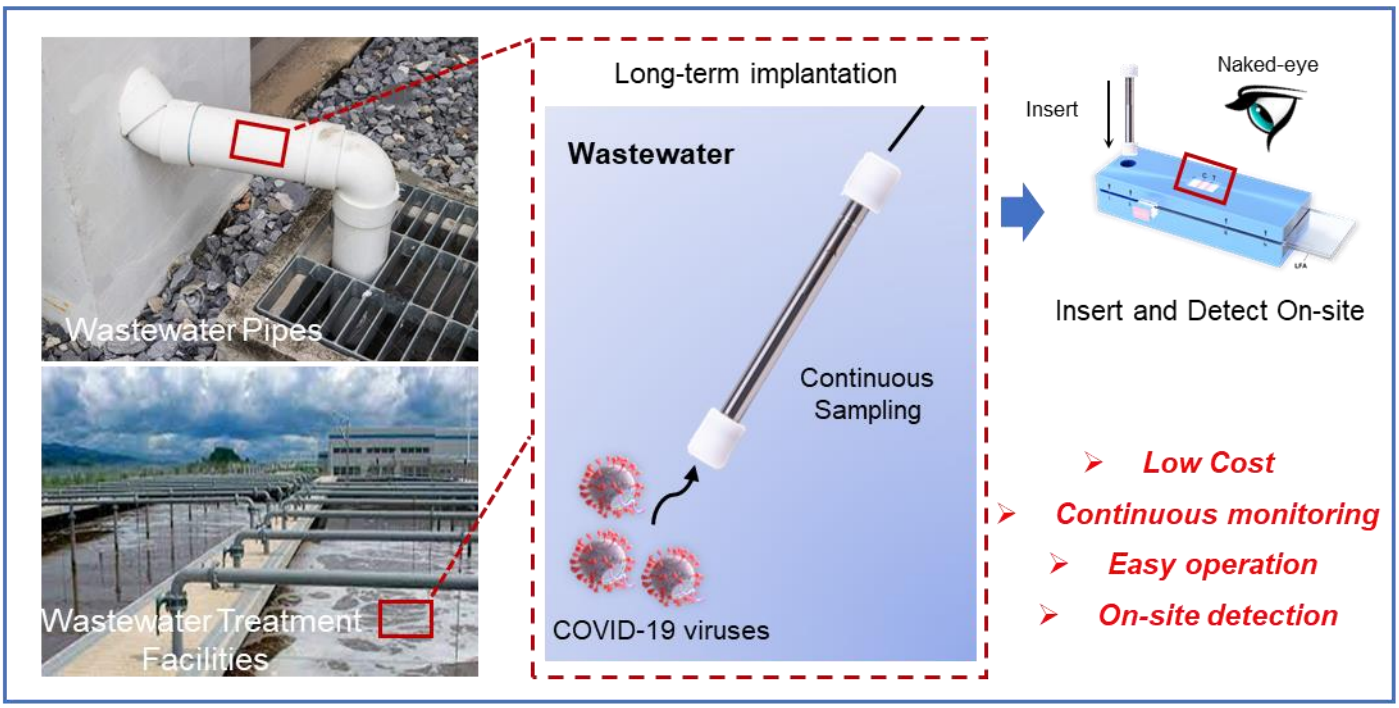




Current Technology ***New Technology Proposed***



Future applications to continuous monitoring of COVID-19 in Minnesota wastewaters