Environment and Natural Resources Trust Fund

M.L. 2022 Approved Work Plan

General Information

ID Number: 2022-265

Staff Lead: Michael Varien

Date this document submitted to LCCMR: June 22, 2022

Project Title: Innovative Technology for PFAS Destruction in Drinking Water

Project Budget: $445,000

Project Manager Information

Name: Shaobo Deng

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Project Reporting

Date Work Plan Approved by LCCMR: June 27, 2022

Reporting Schedule: March 1 / September 1 of each year.

Project Completion: June 30, 2025

Final Report Due Date: August 14, 2025

Legal Information

Legal Citation: M.L. 2022, Chp. 94, Art. , Sec. 2, Subd. 04k

Appropriation Language: $445,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota for the Southern Research and Outreach Center to develop and demonstrate a treatment process based on continuous liquid-phase plasma discharge technology to destroy per- and polyfluoroalkyl substances (PFAS) in drinking water. This appropriation is subject to Minnesota Statutes, section 116P.10.

Appropriation End Date: June 30, 2025

Narrative

Project Summary: Develop and demonstrate a novel and efficient process based on continuous liquid-phase plasma discharge technology to decompose /destroy Perfluoroalkyl and Polyfluoroalkyl substances (PFAS) in drinking water.

Describe the opportunity or problem your proposal seeks to address. Include any relevant background information.

Per- and poly-fluoroalkyl substances (PFAS) are a group of anthropogenic chemicals, which are used in the production of fire-fighting foams, stain repelling agents, fluoropolymers, pesticides, lubricants, paints, and medicines for decades. PFAS are not biodegradable and can bioaccumulate, thus hazardous to humans and ecological systems. At relatively low concentrations, PFAS could lead to serious health effects such as kidney cancer, liver damage, immunotoxicity, neurotoxicity, and testicular cancer. In 2016, EPA has recommended a health advisory level of 70 ng/L (ppt) for combined Perfluorooctanoic acid (PFOA) and Perfluorooctanesulfonic acid (PFOS). In 2019, the Minnesota Department of Health (MDH) adopted values as low as 15 parts per trillion (ppt) for PFOS.

Managing and removing PFAS in drinking water is one of the most pressing issues facing the government and industry. The current ex-situ technologies such as sorption, reverse osmosis (RO), and nanofiltration are used to concentrate PFAS from very diluted water. These sorption-and membrane-based treatments do not really destroy PFAS and will need further in-situ destroying or land application. Most in-situ tests were conducted at a lab-scale using advanced oxidation processes (AOPs) such as UV/H2O2, Fenton reaction, zero-valent iron, photochemical, which showed mixed and unsatisfying results on PFAS decomposition.

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.

The lack of technologies to treat water contaminated by PFAS is extremely outstanding. To address this issue, we propose a novel and efficient solution based on liquid-phase plasma discharge technology to decompose PFAS in drinking water. The liquid phase plasma discharge is a patent-pending technology and was originally developed at the Southern Research and Outreach Center, University of Minnesota. It is currently in the stage of commercialization for biodiesel production. The preliminary research of liquid phase plasma discharge on destroying PFAS in water demonstrates a great promise with high conversion and process efficiencies.

The proposed solution spearheads a non-thermal, easy-to-operate process to destroy PFAS without producing hazardous byproducts. Liquid phase plasma has been proved to possess the effect of various reactive species, such as •OH, O•, and H2O2, UV radiation, shockwaves, or high electric field produced by electric discharge, which can independently and synergistically complete chemical reactions rapidly and efficiently. Thus, the liquid plasma process is deemed as a combined physical/chemical process that produces a much stronger effect than the conventional chemical oxidation/reduction processes used to degrade PFAS with multiple recalcitrant C-F bonds.

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 outcome of this project is expected to lead to a new and effective technology to eventually clean up PFAS in drinking waters. This endeavor could bring profound economic and environmental benefits, given the current situation that the problem of PFAS contamination is looming large with no effective treatment techniques available. The advantages of the proposed solution include 1) no chemical addition needed; 2) continuous process for various source streams with different PFAS concentrations; 3) no harmful byproducts produced and HF neutralized; 4) compact equipment size and easy operation and 5) low capital and maintenance costs.

Project Location

What is the best scale for describing where your work will take place?

Region(s): SE

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

Activities and Milestones

Activity 1: Study the mechanism of effective remediation of typical PFAS substances (PFOA and PFOS) by the liquid-phase plasma discharge process.

Activity Budget: $198,500

Activity Description:
A lab-scale experimental system will be set up to study this new process. The system is composed of a high-voltage power supply, the liquid phase plasma reactor, a pump, and the instruments and control modules including plasma discharge detection, water/gas flow monitoring, and power measurement. A venturi injector will be added and introduce argon and other gases to the reactor to enhance the activated radical generation in the water. PFOA and PFOS will be used as the test chemicals. The system parameters, such as water and gas flow rate, input power, treatment time, and the PFAS concentration will be tested. The plasma properties during electric discharge in water will be characterized, and the formation of reactive species will be verified. The removal rate and efficiency for PFOA and PFOS as well as their degradation pathways will be analyzed to confirm the mechanism of PFAS remediation. The different operational modes, i.e., circulation, one-pass, and multi-reactors connected in series, will be compared for the PFOA/PFOS degradation. Finally, the process's significant operating and design parameters and the best operational model for PFAS removal efficiency and preservation of drinking water quality will be determined.

Activity Milestones:

Description	Approximate Completion Date
Design, improve and set-up a lab-scale plasma discharge experimental system for water/PFAS treatment	December 31, 2022
Investigate and Identify significant factors and parameters that influence the PFAS degradation and water quality	August 31, 2023
Determine the best operational mode for PFAS removal efficiency by the liquid plasma discharge process.	December 31, 2023
One journal article will be drafted and submitted	December 31, 2023

Activity 2: Develop an on-site demonstration pilot-scale system that will enable verification of the liquid plasma system and process.

Activity Budget: $201,500

Activity Description:
With the determination of operating and design parameters of the process and the best operational mode obtained in Activity 1, a 10-gallon per hour pilot-scale system will be designed, constructed, and installed. This pilot-scale demonstration system will be used to 1) confirm the lab-scale experimental results at a large treatment capacity. 2) test the plasma reactor and basic system reliability by conducting an extensive production run given the goal of operating the system for 8 hr/day for 5 days, 3) Identify failure points, if any, and characterize wear of reactor and system parts, Improve the plasma reactor and system design. 4) optimize the process and operating parameters to maximize the treatment efficiency under production-like conditions.

Activity Milestones:

Description	Approximate Completion Date
Design, construction and installation of a 10-gal/hr on-site pilot-scale treatment system.	June 30, 2024
Continuous operation and optimization of pilot-scale system treating PFAS contaminated water	December 31, 2024
One journal articles will be drafted.	March 31, 2025

Activity 3: Conduct a techno-economic assessment that estimates the implementation potential of the precess and technology

Activity Budget: $45,000

Activity Description:

During the optimization and extended run and demonstration of the pilot system, the data for the system performance, water quality, power consumption, and capital / operational cost will be synthesized and collected. A techno-economic assessment of the processing and technology will be conducted and reported. The technology implementation path and strategy should be identified.

Activity Milestones:

Description	Approximate Completion Date
Information about water quality, energy consumption and operational costs will be monitored and reported	March 31, 2025
A preliminary techno-economic assessment of liquid plasma system will be conducted and reported	June 30, 2025
A field day will be held for potential customers and a general audience	June 30, 2025
One journal article will be drafted and submitted	June 30, 2025

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Forrest Izuno	U of M - Southern Research and Outreach Cneter	Co-Project Manager	Yes

Dissemination

Describe your plans for dissemination, presentation, documentation, or sharing of data, results, samples, physical collections, and other products and how they will follow ENRTF Acknowledgement Requirements and Guidelines.
The research outcomes will be presented in both technical and non-technical formats, including refereed journal publications for professionals and other outlets for laypeople, aiming to distribute the information of this project not just in Minnesota but across the nation and world as well. Quantitatively, starting from the end of the project's first year, at least one manuscript will be generated and submitted for possible publication in a refereed journal annually. One presentation in a scientific, technical, or marketing venue will be given. A special field day for people in the concerned industries and the stakeholders will be organized at the end of the project to demonstrate the complete system. In the meantime, talks will be initiated with those interested in adopting the newly developed technology to benefit health and protect the environment.

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?
The purpose of this project is to research this new application of liquid phase plasma discharge and develop it into a viable technology. Upon the expected outcome from this research, the technology implementation path and business model will be identified and developed. Minnesota Soybean Research and Promotion Council is the strategic partner to commercialize liquid phase plasma technology for renewable energy and other new applications. If an additional study is needed, funding may be pursued through MSR&PC. The Ecolab, 3M, or other water treatment entities could be the potential investor or users for the implementation of the technology.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Clean Water and Renewable Energy from Beet Processing Wastewater and Manure	M.L. 2014, Chp. 226, Sec. 2, Subd. 08f	$400,000

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Professor		Co-Principal Investigator, coordinate and supervise the research efforts.			36.5%	0.15		$30,810
Researcher 6		Principal Investigator, system development, experimental design and project reporting			36.5%	1.8		$163,090
Researcher 3		Scientific Staff, system operation and data collection			31.8%	0.6		$50,000
							Sub Total	**$243,900**
Contracts and Services								
TBD	Professional or Technical Service Contract	Certified lab service for water sample and chemical analysis				0		$20,000
TBD	Professional or Technical Service Contract	Machine shop for components and parts fabrication and assembling.				0		$30,000
							Sub Total	**$50,000**
Equipment, Tools, and Supplies								
	Tools and Supplies	Chemicals, tools, analysis kits, glassware, and personal protection supplies	Tools, materials and supplies for lab experiments					$25,000
							Sub Total	**$25,000**
Capital Expenditures								
		The lab scale research system and equipment development	Test and optimize the process and technology.	X				$45,000
		The pilot-scale system development and testing	Evaluate and demonstrate the technology and the system.	X				$75,000
							Sub Total	**$120,000**

Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Other	Trips to site and testing lab using vehicles, standard rate applies	Travel between site and analytical lab for collection and analysis of samples					$1,800
							Sub Total	**$1,800**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
	Publication	Publication cost for three journal articles	Present research results in scientific journals					$4,300
							Sub Total	**$4,300**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$445,000**

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request
Capital Expenditures		The lab scale research system and equipment development	The system will be composed of a high-voltage power supply, a plasma reactor, a column for liquid/gas reactant circulation/contacting/reaction, a water pump and a vacuum or gas pump, and the instruments and control modules including plasma discharge characterization, water/gas flow monitoring, and power measurement. Some instruments, equipment, and assembling will be in the capital expenditure category. **Additional Explanation :** The lab-scale system will be available for future research and education for the same program
Capital Expenditures		The pilot-scale system development and testing	The large-scale system will be built with a high-voltage power supply, the plasma reactors, a column or tank for liquid/gas reactant circulation/reaction, a water pump and a vacuum or gas pump, and the instruments and control modules including plasma discharge and properties monitoring, water/gas flow controlling, and power measurement. Some equipment and assembling will be in the capital expenditure category. **Additional Explanation :** The pilot-scale system will be available for future research, outreach, and demonstration for the same program.

Non ENRTF Funds

Category	Specific Source	Use	Status	$ Amount
State				
			State Sub Total	**-**
Non-State				
			Non State Sub Total	**-**
			Funds Total	**-**

Attachments

Required Attachments

Visual Component

File: e25420a3-9e9.pdf

Alternate Text for Visual Component

1. The mapping of PFAS contamination sites in US
2. News: 3M pay the city of Bemidji, Minn., $12.5 million to help fund operations of a new water treatment facility capable of removing PFAS from city well water, 2021
3. News: Biden administration looks set regulation to target PFAS, 2021
4. Ecolab seeks treatment solutions that can significantly reduce the amount of PFAS, 2020
5. EPA's challenge for Innovative Ways to Destroy PFAS, 2020
6. Liquid phase plasma discharge solution process diagra...

Optional Attachments

Support Letter or Other

Title	File
UMN Authorization of Proposal	1d1c0a82-f36.pdf
Background Check Form	184c2787-fae.pdf

Difference between Proposal and Work Plan

Describe changes from Proposal to Work Plan Stage

Revised to include all the suggested changes. Recalculated and changed the pilot system flow from 50 gallons/hour to 10 gallons/hour. Changed production goal of operating the system from 30 days to 5 days. increased the budget of the professional and technical service from 15000 to 50000. Reduced the costs of the lab and pilot-scale systems. Listed the techno-economic assessment as a separate activity with 4 milestones including reporting. Added "Generally Ineligible Expenses Justification" for Capital Expenditures.

Additional Acknowledgements and Conditions:

The following are acknowledgements and conditions beyond those already included in the above workplan:

Do you understand and acknowledge the ENRTF repayment requirements if the use of capital equipment changes?

Yes

Do you agree travel expenses must 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 agree to the UMN Policy.

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?

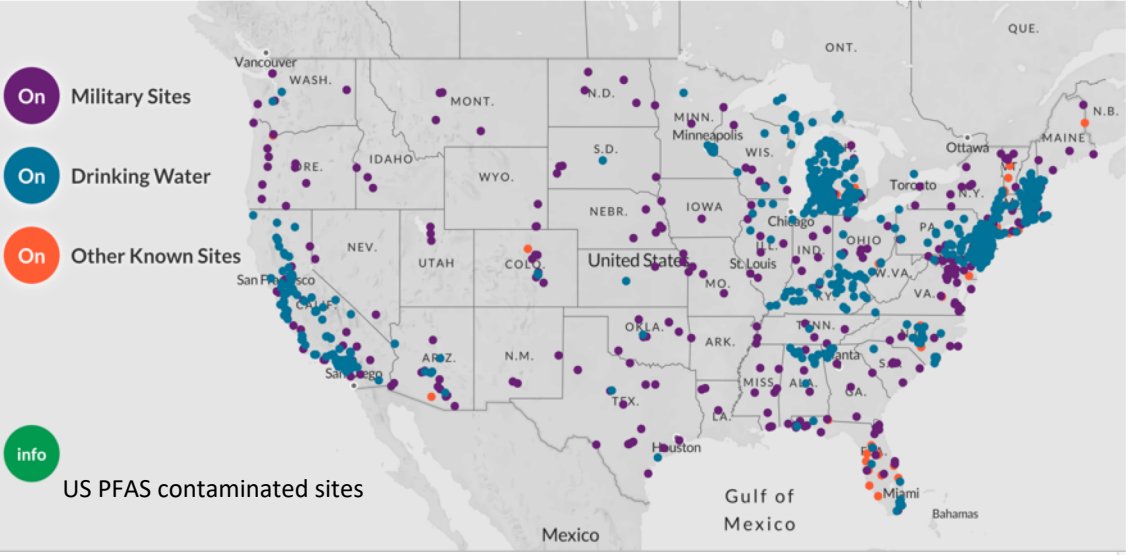
No

Does your project include original, hypothesis-driven research?

Yes

Does the organization have a fiscal agent for this project?

Yes, Sponsored Projects Administration



US PFAS contaminated sites

TODAY'S NEWS

3M to pay $12.5M to support Minn. water treatment facility

3M has agreed to pay the city of Bemidji, Minn., $12.5 million to help fund operations of a new water treatment facility capable of removing PFAS from city well water. The plant is scheduled to open this month. **Full Story:** Duluth News Tribune (Minn.) (free registration) (3/10)

PFAS Drinking Water Issues

Medill News Service

Biden administration looks set to target 'forever chemicals,' as 3M warns about 'onerous regulation'

Last Updated: Jan. 27, 2021 at 4:10 p.m. ET
First Published: Jan. 25, 2021 at 2:59 p.m. ET

By Dalia Faheid

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Environmentalists optimistic about increased PFAS regulation under new administration

EPA Innovation Home
Innovation at EPA
Innovation News
Science and Technology

Treatment of Perfluoroalkyl Substances

Ecolab presented a challenge entitled "Treatment of Perfluoroalkyl Substances (PFAS)" which looks to identify treatment solutions that can significantly reduce the amount of Perfluoroalkyl substances (PFAS) in water entering food and beverage manufacturing facilities.

Despite PFAS production being phased-out in many countries, its persistence in the environment will result in these compounds continuing to be a concern for many years to come. Water is often used within the food and beverage industry as an ingredient, so ensuring this water is PFAS-free is an important food safety consideration.

Innovative Ways to Destroy PFAS Challenge

On this page:

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Challenge

Background

Industry Demands

Liquid Plasma Solution