Final Abstract

Final Report Approved on March 16, 2026

M.L. 2022 Project Abstract

For the Period Ending June 30, 2025

Project Title: Innovative Technology for PFAS Destruction in Drinking Water

Project Manager: Xiaowen Chen

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Funding Source:

Fiscal Year:

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

Appropriation Amount: $445,000

Amount Spent: $445,000

Amount Remaining: -

Sound bite of Project Outcomes and Results

This project developed an innovative liquid-phase plasma technology to destroy PFAS in water. Both a benchtop and a pilot-scale systems were tested and successfully demonstrated. Key operating parameters were identified and optimized. Results show the technology is a practical and effective solution for protecting Minnesota's drinking water from PFAS contamination.

Overall Project Outcome and Results

Per- and polyfluoroalkyl substances (PFAS) are synthetic chemicals that are persistent, non-biodegradable, and prone to bioaccumulation, posing risks to human health and ecosystems. This project developed a new, effective technology to remove PFAS from drinking water, demonstrating strong potential with high conversion rates and process efficiency.

We first designed, built a benchtop-scale liquid-phase plasma system and successfully operated to generate plasma discharge in a flowing water stream. The conducted experiments identified critical factors for PFAS degradation, including initial concentration, water conductivity, water and gas flow rates, plasma power, and treatment time. Plasma power, treatment time, gas types, and initial PFAS concentration were most significant for efficient treatment. Both one-

pass and circulation modes were tested. The results demonstrated that the process reduced PFOA concentration by 91.0% within 30 minutes and by 93.4% within 1 hour, with a defluorination rate of 87.75 %. Shorter-chain byproducts accounted for 5.1%. The estimated energy efficiency per order (EEO) ranged from 1.33 to 2 kW/L per order.

Second, a pilot-scale plasma system capable of processing 10–30 gallons per hour was developed, installed, and tested. An extended run at a real wastewater treatment plant evaluated system reliability and failure rates, confirming stable PFAS removal performance. Results showed 97.5% destruction of PFOA and 95.6% destruction of PFOS in leachate wastewater.

Third, water quality and byproducts were analyzed, and a techno-economic assessment was conducted. The data indicate that the plasma system can treat various contaminated water sources, including drinking water, process wastewater, and leachate. Although some short-chain PFAS, such as PFBA, are more difficult to remove, long-chain PFAS like PFOA and PFOS showed significant reductions.

Overall, this project provides a practical and effective solution for PFAS treatment, and the technology is moving toward commercialization.

Project Results Use and Dissemination

Project results were shared through 11 conference and workshop presentations, including the AWWA Water Quality Conference, the Minnesota Water Resources Conference, and the Advancing PFAS Treatment and Remediation Solutions conference. Public demonstration and outreach included exhibits at the University of Minnesota Foundation's event, the Minnesota Farmfest, and a classroom demonstration for K12 students. The research data will support future research, technology implementation and commercialization.

Environment and Natural Resources Trust Fund

M.L. 2022 Approved Final Report

General Information

Date: April 13, 2026

ID Number: 2022-265

Staff Lead: Tom Dietrich

Project Title: Innovative Technology for PFAS Destruction in Drinking Water

Project Budget: $445,000

Project Manager Information

Name: Xiaowen Chen

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Project Reporting

Final Report Approved: March 16, 2026

Reporting Status: Project Completed

Date of Last Action: March 16, 2026

Project Completion: June 30, 2025

Legal Information

Legal Citation: M.L. 2022, Chp. 94, 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	$ Amount Spent	$ Amount Remaining
Personnel										
Professor		Co-Principal Investigator, coordinate and supervise the research efforts.			0%	0.15		-	-	-
Researcher 6		Principal Investigator, system development, experimental design and project reporting			36.5%	2.1		$188,570	-	-
Researcher 3		Scientific Staff, system operation and data collection			31.8%	0.9		$77,120	-	-
Post-Doctoral Associate,		Experiment conducting, samples testing, data analysis, report and paper draft.			37.1%	1		-	-	-
							Sub Total	**$265,690**	**$265,690**	**-**
Contracts and Services										
Minnesota Valley Testing Laboratories Inc.	Service Contract	Certified lab service for water sample and chemical analysis				0		$42,500	$42,500	-
CSE Shop, University of Minnesota	Service Contract	Machine shop for components and parts fabrication and assembling.				0		$5,000	$5,000	-
							Sub Total	**$47,500**	**$47,500**	**-**
Equipment, Tools, and Supplies										
	Tools and Supplies	Chemicals, tools, analysis kits, glassware, and personal protection supplies. Budget changes due to higher costs than expected	Tools, materials and supplies for lab experiments					$34,398	$34,398	-
	Equipment	The lab scale research system including plasma reactor, 2 high voltage transformers ($2000-3000/unit), and 2 inverters ($3100/unit) and testing instruments	Test and optimize the process and technology at lab scale.					$12,770	$12,770	-

							Sub Total	**$47,168**	**$47,168**	**-**
Capital Equipment										
		The pilot-scale system development and testing	Evaluate and demonstrate the technology and the system.	X				$73,250	$73,250	-
		Optical emission spectrometer	Detect and identify the active radicals and species generated by plasma discharge in water.	X				$6,667	$6,667	-
							Sub Total	**$79,917**	**$79,917**	**-**
Acquisitions and Stewardship										
							Sub Total	**-**	**-**	**-**
Travel In Minnesota										
	Other	Trips to site and testing lab using vehicles, standard rate applies. Budget increase due to identified additional application opportunities for the project.	Travel between site and analytical lab for collection and analysis of samples					$2,503	$2,503	-
							Sub Total	**$2,503**	**$2,503**	**-**
Travel Outside Minnesota										
	Conference Registration Miles/ Meals/ Lodging	One person travel to Schaumburg, IL for AWWA Water Quality Technology Conference WQTC 2024	The research paper on plasma PFAS treatment has been accepted and will be presented at the AWWA Water Quality Technology Conference on November 17-21 in Schaumburg, IL.	X				$2,222	$2,222	-
							Sub Total	**$2,222**	**$2,222**	**-**
Printing and Publication										

	Publication	Publication cost for three journal articles, We will use our own funding for publications.	Present research results in scientific journals					-	-	-
							Sub Total	**-**	**-**	**-**
Other Expenses										
							Sub Total	**-**	**-**	**-**
							Grand Total	**$445,000**	**$445,000**	**-**

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request
Capital Equipment		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.
Capital Equipment		Optical emission spectrometer	The optical emission spectrometer is the key instrument to measure the physical and chemical properties of plasma-treated water. The system quote at $8189.00, will be in the capital expenditure category. **Additional Explanation :** The optical emission spectrometer will be available for future research, outreach, and demonstration for the same program.
Travel Outside Minnesota	Conference Registration Miles/Meals/Lodging	One person travel to Schaumburg, IL for AWWA Water Quality Technology Conference WQTC 2024	Presenting research results and findings to the public is essential for the success of the LCCMR project. The proposed travel and conference activities will facilitate the dissemination and application of the technology, showcase Minnesota's leadership in addressing environmental challenges, build partnerships with experts across the country, and attract collaboration opportunities that can be applied locally, strengthening Minnesota's efforts to combat PFAS contamination and protect public health and the environment.

Non ENRTF Funds

Category	Specific Source	Use	Status	$ Amount	$ Amount Spent	$ Amount Remaining
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...

Supplemental Attachments

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

Title	File
UMN Authorization of Proposal	1d1c0a82-f36.pdf
Background Check Form	184c2787-fae.pdf
UMN BBE 2024 seminar	5cf871b7-0f3.png
MN-Farmfest-2024-1	0daca08c-c1b.jpe
MN-Farmfest-2024-2	93ab9fbd-280.jpe
The pilot plasma PFAS treatment system	ad19fbda-294.jpe
The pilot plasma PFAS treatment syste-2	9018d724-85e.jpe
The pilot plasma PFAS treatment system-3	782f1e3f-a23.jpe
MN Water Conference 2024 presentation	b8e79cff-907.pdf
AWWA 2024 poster presentation	a061e34b-cc4.pptx
ASABE 2023 annal meeting presentation	ef615a6a-d97.docx
U of M BBE 2024 spring seminar presentation	ec8612d7-62a.pdf

Media Links

Title	Link
MN Farmfest 2024	https://sroc.cfans.umn.edu/news/farmfest-2024

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 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?

Yes, Sponsored Projects Administration

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

Not acknowledged

Work Plan Amendments

Amendment ID	Request Type	Changes made on the following pages	Explanation & justification for Amendment Request (word limit 75)	Date Submitted	Approved	Date of LCCMR Action
1	Amendment Request	• Budget - Capital, Equipment, Tools, and Supplies	As planned, an optical emission spectrometer will be purchased to detect and identify the active radicals and species generated by plasma discharge in water. The system, quoted at $8189.00, is the key instrument to measure the physical and chemical properties of plasma-treated water. This capital expenditure will be available for future research, outreach, and demonstration for the same program.	August 11, 2022	Yes	August 11, 2022
2	Amendment Request	• Other • Budget - Personnel • Budget - Professional / Technical Contracts • Budget - Capital, Equipment, Tools, and Supplies	1. The professor has retired and plans to hire a postdoc ($54840/year plus 37.1% figure benefits) for the project. 2. Updated the awarded contractor entities and funds be shifted between contracts (from $20000-$30000 to $40000 -$10000) because of high PFAS water sample testing costs. 3. Updated lab scale system category from the capital to equipment; description includes the high-frequency inverter and the cost, reducing the funds from $36800 to $12770.	March 13, 2024	Yes	April 10, 2024
3	Amendment Request	• Other • Budget - Personnel • Budget - Professional / Technical Contracts • Budget - Capital, Equipment, Tools, and Supplies • Budget - Travel and Conferences	1. The postdoc hiring has been postponed, and the workload reassigned to the current staff. 2. Request a $2,500 budget for one-time out-of-state travel and conferences to present results at AWWA meeting. 3. Remove $5000 from Professional/Technical Contracts - CSE shop, allocate $2500 to out-of-state travel, and $2500 to MN Valley Testing Lab because components fabrication has been done and testing tasks increased. 4.	October 10, 2024	Yes	October 15, 2024

			Updated the number of high-voltage transformers and inverters purchased.			
4	Amendment Request	• Project Collaborators - Project Manager Info • Budget - Personnel • Budget - Capital, Equipment, Tools, and Supplies • Budget - Travel and Conferences • Budget - Printing and Publication • Attachments	Request budget adjustments to match actual project expenses: 1. Personnel from $267930 to $265690. 2. Tools and supplies from $25000 to $34398 due to broken and worn-out parts needing replacement, and extra equipment for on-site demonstrations. 3. Pilot system from $75000 to $73250, optical spectrometer from $8200 to $6667. 4. Travel within Minnesota from $1800 to $2503 due to increased activities, and out-of-state travel from $2500 to $2222. 5. Remove the publications budget of $4300.	January 14, 2026	Yes	January 27, 2026
5	Project Manager	Previous Manager: Shaobo Deng (dengx007@umn.edu) New Manager: Xiaowen Chen (chen9858@umn.edu)	The current project manager has retired from the University of Minnesota, and a newly hired faculty member will continue the research program at SROC and assume responsibility for this project.	October 8, 2025	Yes	October 8, 2025

Status Update Reporting

Final Status Update August 14, 2025

Date Submitted: January 14, 2026

Date Approved: January 27, 2026

Overall Update
This project aims to develop continuous in-liquid plasma technology for destroying PFAS in drinking water. Following the expected outcomes of this research, the technology implementation path was identified. A benchtop-scale liquid-phase plasma system has been designed, built, and successfully operated to generate plasma discharge in the water stream. The one-pass and circulation modes have been tested. The experiments identified critical factors for PFAS degradation, including initial concentration, water conductivity, water and gas flow rates, plasma power, and treatment time. Plasma power, treatment time, gas types, and initial PFAS concentration are significant factors in efficient treatment. The experiments demonstrated that the process reduced PFOA concentration by 91.0% within 30 minutes and by 93.4% within 1 hour. The defluorination rate was 87.75 %, and the shorter-chain byproducts accounted for 5.1%. The estimated energy efficiency per order (EEO) ranged from 1.33 to 2 kW/L per order. A pilot-scale plasma system capable of processing 10-30 gallons per hour has been developed, installed, and tested. The results show that 97.5% of PFOA and 95.6% of PFOS were destroyed in real leachate wastewater. The planned three journal articles will be published in 2026 and updated as they become available.

Activity 1
This activity was previously marked complete.
(This activity marked as complete as of this status update)

Activity 2
This activity was previously marked complete.
(This activity marked as complete as of this status update)

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

Milestone 1: All experimental and system-generated data have been collected and analyzed. Water quality, PFAS treatment, and byproducts have been tested and evaluated. The data indicate that the plasma system can treat various contaminated water sources, including drinking water, process wastewater, and leachate. Although some short-chain PFAS, such as PFBA are difficult to treat, long-chain PFAS like PFOA and PFOS experience significant reductions.

Milestone 2: The pilot demonstration unit was tested on-site at a Cottonwood County wastewater plant to evaluate its technical and economic performance. The results show that 97.5% of PFOA and 95.6% of PFOS were destroyed in the actual leachate wastewater, with energy efficiency per order (EEO) estimated to be around 2 kW/L per order. The potential implementation of a plasma system at the plant is currently under consideration.

Milestone 3: An information session and demonstration on liquid plasma technology were held at Advancing PFAS Treatment and Remediation Solutions in Minneapolis on May 13 to 15, 2025.
(This activity marked as complete as of this status update)

Dissemination
1. A platform presentation and demonstration of liquid plasma technology took place at Advancing PFAS Treatment and

Remediation Solutions in Minneapolis from May 13 to 15, 2025.

2. The liquid plasma technology for PFAS destruction was presented at the University of Minnesota Foundation 2025 Heritage Society donors' dinner on June 10, 2025

3. An exhibition and demonstration of plasma PFAS treatment was held at Minnesota Farmer's Innovative Environmental Stewardship at FarmAmerica on June 18, 2025.

Status Update Reporting

Status Update March 1, 2025

Date Submitted: February 26, 2025

Date Approved: March 11, 2025

Overall Update
This project aims to develop continuous in-liquid plasma technology and processes for decomposing and destroying PFAS in drinking water. Following the expected outcomes of this research, the technology implementation path and business model will be identified and developed. The work accomplished so far has focused on Activities 1 and 2. A benchtop-scale liquid-phase plasma system has been designed, built, and successfully operated to generate plasma discharge in the water stream. The one-pass and circulation modes have been tested. The experiments identified critical factors for PFAS degradation, including initial concentration, water conductivity, water and gas flow rates, plasma power, and treatment time. Plasma power, treatment time, gas types, and initial PFAS concentration are significant factors in efficient treatment. The experiments demonstrated that the process reduced PFOA concentration by 91.0 % in 30 minutes and 93.4 % in an hour. The defluorination rate was 87.75 %, and the shorter-chain byproducts accounted for 5.1%. The estimated energy efficiency per order (EEO) was 1.33 to 2 kW/L/order based on different concentrations. A pilot-scale plasma system capable of processing 10-30 gallons per hour has been developed, installed, and tested. More system and water quality evaluations are conducted.

Activity 1
This activity was previously marked complete.
(This activity marked as complete as of this status update)

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

Milestone 1: Design, construction, and installation of a 10-gal/hr on-site pilot-scale treatment system.
A pilot-scale in-liquid plasma PFAS treatment system has been developed, installed, and tested. The system features two high-voltage transformers rated at 6 kV and 4 kVA, two power inverters operating at a frequency of 1.2 kHz, two water pumps with a flow rate of 30 gallons per hour, and two plasma reactors that can operate in series or parallel, along with all necessary monitoring and control equipment. The total treatment capacity ranges from 10 to 30 gallons per hour, depending on the operating model of the reactors. The series model extends the treatment time, while the parallel model doubles the treatment volume of PFAS-contaminated water. Furthermore, the system can operate in a circular model if additional treatment time is required.

Milestone 2: Continuous operation and optimization of the pilot-scale system treating PFAS-contaminated water.
The system has been tested, and an extended run was conducted to evaluate its failure rates and reliability, confirming the PFAS removal efficiency.

Milestone 3: The second journal article is currently being drafted.
(This activity marked as complete as of this status update)

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

Milestone 1:Information about water quality, energy consumption, and operational costs will be monitored and reported
All the experimental and system-run information and data have been collected and analyzed. More water quality and PFAS treatment residual and byproducts will be tested and evaluated.

Milestone 2: A preliminary techno-economic assessment of the liquid plasma system will be conducted and reported
Not started yet.

Milestone 3: A field day will be held for potential customers and a general audience
A possible information session or field day is discussed.

Milestone 4: One journal article will be drafted and submitted
Not started yet.

Dissemination
1. On October 15, 2024, an invited speech titled "Plasma Systems to Destroy PFAS in Drinking Water" was delivered at the Minnesota Water Resources Conference.

2. The paper "Continuous Flow In-Liquid Plasma Discharge for PFAS Destruction in Drinking Water" was presented at the AWWA Water Quality Technology Conference in Schaumburg, Illinois, from November 17 to 21, 2024.

3. Published Conference Proceedings: "Evaluating a Continuous Liquid-Phase Plasma Discharge Process for Destroying PFAS in Water." American Society of Agricultural and Biological Engineers, 2024. doi: 10.13031/aim.202401483

4. Hosted lab visits for the Minnesota Aquaculture Association, Blue Earth County Wastewater Treatment, RockLeaf Water Environmental LLC, Houston Engineering Inc., and the University of North Dakota's Environment and Energy Research Center group regarding PFAS plasma treatment and water quality.

5. A presentation on plasma PFAS treatment technology is scheduled for March 11, 2025, at the Minnesota Solid Waste Administrators Association Winter Training.

6. A presentation was submitted and accepted to the Advancing PFAS Treatment and Remediation Solutions conference, hosted by the Air and Waste Management Association (A&WMA) from May 13 to 15 in Minneapolis, MN.

7. The Science Museum of Minnesota collected the plasma PFAS project information, photos, and videos.

Status Update Reporting

Status Update September 1, 2024

Date Submitted: August 26, 2024

Date Approved: October 1, 2024

Overall Update
This project aims to develop continuous in-liquid plasma technology and process for the decomposition/destruction of PFAS in drinking water. Upon the expected outcome of this research, the technology implementation path and business model will be identified and developed. The work accomplished so far has been focused on Activities 1 and 2. A benchtop-scale liquid-phase plasma system has been designed, built, and successfully operated to generate plasma discharge in the water stream. The one-pass and circulation modes have been tested. The experiments identified critical factors for PFAS degradation, including initial concentration, water conductivity, water and gas flow rates, plasma power, and treatment time. Plasma power, treatment time, gases, and original PFAS concentration are significant factors in efficient treatment. The experiments demonstrated that the process was able to reduce the PFOA concentration by 91.0 % in 30 minutes and 93.4 % in an hour. The defluorination rate was 87.75 %, and the shorter chain byproducts accounted for 5.1%. The estimated energy efficiency per order EEO was 1.33 – 2 kW/L/order based on different concentrations. A10-30 gallon per hour pilot-scale plasma system is currently in development and under construction, with an expected completion and delivery date of November.

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

Milestone 1: The bench-scale liquid plasma system has been built and set up at the University of Minnesota Southern Research and Outreach Center and has been successfully operated to generate plasma discharge in the water stream for PFAS remediation.

Milestone 2: The factors and process parameters influencing PFAS degradation, including initial PFAS concentration, water conductivity, water and gas flow rate, plasma power (voltage and frequency), and treatment time, were investigated. The study shows that plasma power, treatment time, and gases significantly affect plasma treatment efficiency.

Milestone 3: The experiments demonstrated that the process reduced the PFOA concentration by 91.0 % in 30 minutes and 93.4 % in an hour. The defluorination rate was 87.75 %, and the shorter chain byproducts accounted for 5.1%. The estimated energy efficiency per order EEO was 1.33 – 2 kW/L/order based on different concentrations.

Milestone 4: The first draft of the journal article has been completed and is ready for submission.
(This activity marked as complete as of this status update)

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

Milestone 1: Design, construction, and installation of a 10-gal/hr on-site pilot-scale treatment system.
An in-liquid plasma PFAS treatment system on a pilot scale was designed and is under construction. The system required a high-voltage transformer and high-frequency power inverter, which were ordered from Plasma Technics Inc. A high-

flow plasma reactor was constructed and tested. The manufacturing service contract for the entire system is being processed by Plasma Blue LLC, and The pilot system is expected to be completed in November 2024.

Milestone 2: Not started yet.

Milestone 3: The second journal article is being drafted.

Activity 3

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

Not started yet.

Dissemination

1. The liquid plasma system for PFAS destruction was presented and demonstrated at Minnesota Farmfest on August 6-8, 2024, showcasing the University of Minnesota's research. Please refer to the attached pictures and links.

2. An invited speech titled "Plasma Systems to Destroy PFAS in Drinking Water" will be presented at the Minnesota Water Resources Conference on October 15, 2024.

3. The paper "Continuous flow in-liquid plasma discharge for PFAS destruction in drinking water" has been accepted and will be presented at the AWWA Water Quality Technology Conference in Schaumburg, Illinois, November 17-21, 2024.

Status Update Reporting

Status Update March 1, 2024

Date Submitted: February 28, 2024

Date Approved: March 11, 2024

Overall Update
This project aims to develop a continuous in-liquid plasma technology and process to decompose/destroy PFAS in drinking water without producing hazardous byproducts. Upon the expected outcome of this research, the technology implementation path and business model will be identified and developed. The work accomplished so far has been focused on Activities 1 and 2 and followed the schedule as planned. A benchtop-scale liquid-phase plasma system has been designed, built, and successfully operated to generate plasma discharge in the water stream. The one-pass and circulation modes have been tested. The experiments identified critical factors for PFAS degradation, including initial concentration, water conductivity, water and gas flow rates, plasma power, and treatment duration. Plasma power, treatment time, gases, and original PFAS concentration are significant for efficient treatment. The experiments demonstrated that the process was able to reduce the PFOA concentration by 91.0 % in 30 minutes and 93.4 % in an hour. The defluorination rate was 87.75 %, and the shorter chain byproducts accounted for 5.1%. The estimated energy efficiency per order EEO was 1.33 – 2 kW/L/order based on different concentrations. A 10-gal/hr pilot-scale plasma treatment system is under construction.

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

Milestone 1: The bench-scale liquid plasma system has been built and set up at the University of Minnesota Southern Research and Outreach Center and has been successfully operated to generate plasma discharge in the water stream for PFAS remediation.

Milestone 2: The factors and process parameters influencing PFAS degradation, including initial PFAS concentration, water conductivity, water, and gas flow rate, plasma power (voltage and frequency), and treatment time, were investigated. The study shows that plasma power, treatment time, and gases significantly affect plasma treatment efficiency.

Milestone 3: The experiments demonstrated that the process was able to reduce the PFOA concentration by 91.0 % in 30 minutes and 93.4 % in an hour. The defluorination rate was 87.75 %, and the shorter chain byproducts accounted for 5.1%. The estimated energy efficiency per order EEO was 1.33 – 2 kW/L/order based on different concentrations.

Milestone 4: One journal article is drafted and will be submitted for publication soon.

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

Milestone 1: Design, construction, and installation of a 10-gal/hr on-site pilot-scale treatment system.
An in-liquid plasma PFAS treatment system on a pilot scale was under development. The system required a high-voltage transformer and high-frequency power inverter, which were ordered from Plasma Technics Inc. A high-flow plasma

reactor was constructed and tested. The manufacturing service contract for the whole system was being discussed with Plasma Blue LLC, and the purchase process is underway.

Activity 3

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

Not yet started.

Dissemination

1. "Continuous flow in-liquid plasma discharge for biodiesel production and PFAS destruction in water" was presented during the Spring Seminar Series of the Bioproduct and Biosystem Engineering Department at the University of Minnesota on January 24, 2024. see the flyer on the Attachments page.

2. The abstract "Continuous flow in-liquid plasma discharge for PFAS destruction in drinking water" has been submitted to the AWWA Water Quality Technology Conference.

Status Update Reporting

Status Update September 1, 2023

Date Submitted: August 29, 2023

Date Approved: October 24, 2023

Overall Update
The purpose of this project is to develop a continuous in-liquid plasma technology and process to decompose/destroy PFAS in drinking water without producing hazardous byproducts. Upon the expected outcome of this research, the technology implementation path and business model will be identified and developed. The work accomplished so far has been focused on Activity 1 and followed the schedule as planned. A benchtop-scale liquid-phase plasma system has been designed, built, and successfully operated to generate plasma discharge in the water stream. The one-pass and circulation modes have been tested. The experiments identified key factors for PFAS degradation, including initial concentration, water conductivity, water and gas flow rates, plasma power, and treatment duration. Plasma power, treatment time, and original PFAS concentration are particularly important for efficient treatment. Currently, 99% PFOA removal is achievable under specific conditions, with further optimization and testing underway.

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

Milestone 1: The bench-scale liquid plasma system has been built and set up at the University of Minnesota Southern Research and Outreach Center. It consists of a plasma reactor and two high-voltage power supplies, one with 60 Hz and another has a high frequency from 10 to 25 kHz, providing a voltage from 1 to 10 kV to the reactor. A venturi gas injector with two mass flow controllers introduces air, argon, and other gases to the plasma reactor. The system circulates the water sample at 100 to 500 ml/minute for a certain time based on the experimental design. The system has been successfully operated to generate plasma discharge in the water stream at low and high frequencies.

Milestone 2: The factors and process parameters that influence PFAS degradation, including initial PFAS concentration, water conductivity, water and gas flow rate, plasma power (voltage and frequency), and treatment time were investigated. The study shows that plasma power, treatment time and original PFAS concentration significantly affect the plasma treatment efficiency. Optmization and best condition testing are ongoing.

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

Milestone 1: Design, construction, and installation of a 10-gal/hr on-site pilot-scale treatment system.
The pilot scale liquid plasma PFAS treatment system was being designed. The 16 kW high voltage transformer and high-frequency power inverter were ordered from Plasma Technics Inc.. The high-flow plasma reactor was under construction.

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

Not yet started.

Dissemination

1. At the 2023 Mini Land-Grant University Conference, a presentation and demonstration showcased the liquid plasma technology for biodiesel production and water treatment.

2. At the 2023 ASABE Annual International Meeting, a paper 2301504 (doi:10.13031/aim.202301504) titled "Destroying perfluorooctanoic acid in water by continuous liquid-phase plasma discharge" was presented.

Status Update Reporting

Status Update March 1, 2023

Date Submitted: February 28, 2023

Date Approved: March 20, 2023

Overall Update
This project spearheads a non-thermal, easy-to-operate, in-liquid plasma process to destroy PFAS without producing hazardous byproducts. it is expected to lead to a new and effective technology to clean up PFAS in drinking waters. The work accomplished so far has been focused on Activity 1 and followed the schedule as planned. A benchtop-scale liquid phase plasma system has been designed, built, and successfully operated to generate plasma discharge in water samples. The one-pass and circulation modes have been tested. The experiments for treatment parameter evaluation are on the way.

Activity 1
Milestone 1: Design, improve, and set up a lab-scale plasma discharge experimental system for water/PFAS treatment
A bench-scale liquid phase plasma experimental system has been built and set up at the University of Minnesota Southern Research and Outreach Center, to study this new process. This benchtop system consists of a plasma reactor, which has two discharge plates in the chamber. Two high-voltage power supplies from Plasma Technics Inc., one with 60 Hz and another has a high frequency from 10 to 25 kHz, provide a voltage from 1 to 10 kV to the reactor. A high-voltage probe and scope meter was used to monitor the power voltage and frequency. A venturi gas injector with two mass flow controllers (Sierra C100L, flow rate 1-36 LPM) introduces air and argon to the reactor. The system circulates the water sample at 100 to 300 ml/minute for a certain time based on the experimental design. Plasma active radicals were detected by an optic emission spectrometer (OCEAN-HDX-XR) purchased from Ocean Optics. A computer was used to control the gas flow meters, and record the water-plasma status. The system has been successfully operated to generate plasma discharge in the water stream.

Activity 2
Not yet started.

Activity 3
Not yet started.

Dissemination
No update at this time.