Environment and Natural Resources Trust Fund

2026 Request for Proposal

General Information

Proposal ID: 2026-486

Proposal Title: Mitigating Short-Chain Forever Chemicals for a PFAS-Free Minnesota

Project Manager Information

Name: Peter Bruggeman

Organization: U of MN - College of Science and Engineering

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Project Basic Information

Project Summary: The project addresses the remediation of short-chain PFAS that are irreversibly accumulating in water streams and are largely inadequately removed by currently implemented PFAS mitigation processes.

ENRTF Funds Requested: $299,000

Proposed Project Completion: June 30, 2029

LCCMR Funding Category: Small Projects (G)

Secondary Category: Water (B)

Project Location

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

Region(s): Metro

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.

Contamination of water streams with per- and polyfluoroalkyl substances (PFAS), a large group of synthetic chemicals used in household and industrial products, are a global concern. Several PFAS chemicals have been measured in Minnesota water streams at concentrations sufficient to harmfully impact human health and the ecological environment. PFAS are also referred to as "forever chemicals" because they are not biodegradable and accumulate in the environment over time. Many reported PFAS of concern by the US Environmental Protection Agency, such as PFOA and PFOS, are long-chain molecules with eight or more carbon atoms that can be effectively removed from water streams with adsorbent material or membrane filtration technologies. However, there is an emerging concern about short-chain PFAS that are recently found to be irreversibly accumulating in water streams at concentrations an order of magnitude higher than PFOA. An example is trifluoroacetic acid (TFA), a nearly indestructible molecule and finds its origin in, for example, PFAS containing pesticides. TFA is attributed with reproductive toxicity and is by some researchers identified as a "planetary boundary threat with potential irreversible disruptive impacts on vital earth system processes". Currently implemented PFAS mitigation processes are largely inadequate in removing short-chain PFAS such as TFA.

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 proposed project aims to create a disruptive technology enabled by non-thermal plasma generated at the liquid surface that can efficiently treat both short and long-chain PFAS contaminated water streams and dissociate the PFAS into harmless byproducts. The surfactant nature of long-chain PFAS such as PFOA and PFOS causes the accumulation of PFAS at the liquid surface resulting in its effective decomposition by the plasma-generated reactive species at the liquid surface. This technology is also able to decompose short-chain PFAS but at significantly lower rates due to the slow transport of these compounds to the liquid surface. Nonetheless, by adding a (non-toxic) surfactant to the water to which the short-chain PFAS can attach, their decomposition can be as effective as long-chain PFAS. This was recently shown for PFBS (a PFAS with 4 carbon atoms). We will demonstrate this surfactant enhanced plasma decomposition for a broad range of short-chain PFAS and develop a scaled-up prototype reactor for energy efficient PFAS decomposition enabled by intimate contact between the plasma and the water. The vision is that the technology can be scaled up to treat PFAS contaminated water in wastewater treatment plants or at point emission sources.

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?

- Demonstration of proposed surfactants enhanced plasma decomposition for a broad range of short-chained PFAS (containing 4 or less carbon atoms) including PFBS, PFBA, PFHxS, and TFA.
- Optimized scaled-up prototype reactor.
- Preliminary economic analysis

Activities and Milestones

Activity 1: Demonstration of proposed surfactant enhanced plasma decomposition for a broad range of short-chained PFAS

Activity Budget: $100,000

Activity Description:
We hypothesize that a broad range of short-chain PFAS can electrostatically bind to cationic surfactants and is transported with the surfactant to the plasma-liquid interface. Activity 1 consists of assessing the enhancement of short-chain PFAS (including TFA, PFBA and PFHxS) decomposition by plasma upon the addition of different non-toxic surfactants. We will use hexadecyltrimethylammonium bromide (CTAB) as a reference surfactant as CTAB has recently been shown to be effective in increasing PFBS decomposition by Mededovic and co-workers. These experiments will be performed in plasma-liquid film and plasma-liquid jet reactors available at the High Temperature and Plasma Laboratory, directed by the PI. These reactors have very well-defined fluid flow characteristics that allow us to quantitatively assess the impact of the addition of surfactants on the decomposition rates. The analysis of the decomposition will be performed by nuclear magnetic resonance (NMR). Plasma can in principle decompose PFAS into water, CO2 and fluorine but often unmineralized fragments remain in solution. Hence, we will also assess major byproducts and determine the total amount of fluoride formed with as key goal to close the fluorine mass balance. The quantitative results obtained in these measurements will be leveraged to build a scaled-up reactor in Activity 2.

Activity Milestones:

Description	Approximate Completion Date
Determination of enhancement of PFBS decomposition upon addition of a range of surfactants.	December 31, 2026
Assessment of the selected surfactant on a broad range of short-chain PFAS	June 30, 2027

Activity 2: Development of scaled-up prototype reactor

Activity Budget: $75,000

Activity Description:
The reactor used in activity 1 operates at electrical powers of the order of 1 W and typically treats less than half a liter of water per hour. Activity 2 consists of scaling up this technology to a protype reactor with a capacity to treat 0.5 to 1 liter water per minute. The efficiency of the reactor will critically depend on the innovative design of a water handling system that enables the intimate contact between plasma and the wastewater. We will explore a variety of approaches enabled by innovative multiphase reactor design and informed by extensive research over the last decade at the High Temperature and Plasma Laboratory. Studies by the PIs suggest that treatment times, as short as 10 milliseconds, are sufficient for (local) PFAS decomposition. This very fast decomposition is promising for scale up and enhancing process efficiency. As the detection of PFAS can be challenging, the preliminary optimization of the reactor, which will involve a large parametric study, will be performed with dye such as Rhodamine B as its decomposition can be easily measured even in situ by absorption. The outcome of this work will be a prototype reactor that will be optimized for PFAS decomposition

Activity Milestones:

Description	Approximate Completion Date
Scaled-up prototype reactor	December 31, 2027
Optimized reactor for Rhodamine B (model chemical)	June 30, 2028

Activity 3: Optimization of prototype reactor with preliminary economic analysis

Activity Budget: $124,000

Activity Description:

Research in Activity 3 will be focused on assessing the efficacy of plasma-enabled decomposition of PFAS starting from the preliminary optimized reactor conditions determined in Activity 2. We will measure the decomposition kinetics of both long-chain (PFOA and PFOS) and short-chain (PFBS, TFA, PFBA and PFHxS) with and without additional surfactant selected in activity 1. The decomposition kinetics dependence on key operation parameters including liquid residence time and PFAS concentration will be assessed. These investigations will allow us to further optimize the prototype system and establish energy cost and decomposition efficiency of the proposed technology. We will evaluate the product composition of the optimized plasma treatment to confirm that no toxic decomposition products remain and further optimize the treatment conditions if required. To assess the viability of the proposed technology, we will perform a preliminary economic analysis of the process using the measured energy cost and decomposition efficiency obtained in this activity. As plasma requires electricity to be generated, the developed technology can fully exploit renewable energy sources such as wind or solar energy.

Activity Milestones:

Description	Approximate Completion Date
Optimization of the reactor and determining decomposition kinetics to determine scaling laws for scale up	June 30, 2028
Assessment of the decomposition of short-chain PFAS chemicals and their kinetics	March 31, 2029
Preliminary economic analysis of the proposed process with scale up assessment	June 30, 2029

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Aditya Bhan	University of Minnesota	Professor Bhan is a Distinguished McKnight University Professor in Chemical Engineering and Materials Science at the University of Minnesota. He is an expert in chemical process and reactor engineering and will lead the effort on reactor design and analytics.	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 likely outcome at the conclusion of the project is the establishment of a start-up company focused on technology scale up and testing in partnership with stakeholders. This will enable us to pursue a variety of funding sources including private capital and grants from federal agencies such as the National Science Foundation and the Advanced Research Projects Agency-Energy (ARPA-e). The PI has levered initial previous support from LCCMR to land a $2.8M ARPA-e project for developing and scaling up plasma-enabled iron ore reduction. The proposed work will similarly position us to attract future funding while developing an out-of-the-box technology.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Environment-Friendly Decarbonizing of Steel Production with Hydrogen Plasma	M.L. 2023, , Chp. 60, Art. 2, Sec. 2, Subd. 07e	$739,000

Project Manager and Organization Qualifications

Project Manager Name: Peter Bruggeman

Job Title: Distinguished McKnight University Professor

Provide description of the project manager's qualifications to manage the proposed project.

Peter Bruggeman is a Distinguished McKnight University Professor and the Ernst Eckert Professor of Mechanical Engineering at the University of Minnesota. He directs the High Temperature and Plasma Laboratory currently consisting of 3 faculty and 25 researchers, that focuses on developing innovative plasma processes for health, sustainability and materials processing. Bruggeman brings two decades of experience in plasma-liquid multiphase reactor studies and design. Bruggeman's leadership experience includes his role as Director of Graduate Studies of Mechanical Engineering, a program with more than 200 graduate students and Associate Director of the Department of Energy Center on Plasma Interactions with Complex Interfaces and a research center involving 8 institutions and 11 principal investigators. He also directs an Army Research Office funded Multidisciplinary University Research Initiative project, involving partners at the University of Minnesota, University of Michigan and Northwestern University. His group's research has been recognized by several awards including the 2016 US Department of Energy Early Career Award, the 2018 Peter Mark Memorial Award of the American Vacuum Society, the 2020 George W. Taylor Award for Distinguished Research of the College of Science and Engineering of the University of Minnesota and the Inaugural 2023 University of Michigan Prize for Excellence in Plasma Science and Engineering. He is a fellow of the International Plasma Chemistry Society and served on their board of directors from 2013 to 2024. He is the co-founder and co-organizer of the US Low Temperature Plasma Summer School, served on the committee charged by the National Academies with the Decadal Study of Plasma Science (Plasma 2020), and co-edited the 2017 and 2022 Plasma Roadmap contributing to shape research directions for the field of plasma science and engineering in the US and globally.

Organization: U of MN - College of Science and Engineering

Organization Description:
The College of Science and Engineering at UMN houses 12 departments and a multitude of research centers and posted $162.9 million in research expenditure in FY2024. The University of Minnesota has spun out more than 260 startups since the formation of the Venture Center within UMN Technology Commercialization in 2006 and is the largest single source of startups in Minnesota, placing UMN within the top 3 of public universities in the US. The University of Minnesota offers world-class infrastructure for this project. Professor Bruggeman directs the High Temperature and Plasma Technology Laboratory, which consists of 3 faculty members and over 25 researchers and is one of the best equipped plasma technology laboratories in the world. The Characterization Facility and the Waters Center of Innovation Laboratory housed in the College of Science and Engineering provide state-of-the-art materials and analytical capabilities for UMN researchers that are maintained and upgraded by experts.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Peter Bruggeman		Principal Investigator			26.79%	0.09		$39,032
Aditya Bhan		Co-PI			26.79%	0.09		$40,165
Graduate Research Assistant		Researcher/Engineer			43.01%	1.5		$186,760
							Sub Total	**$265,957**
Contracts and Services								
							Sub Total	-
Equipment, Tools, and Supplies								
	Tools and Supplies	Laboratory supplies (e.g., glassware), gases, chemical reagents and solvents	The laboratory supplies, gases, chemical reagents and solvents are essential to conduct the proposed work.					$14,043
	Tools and Supplies	Parts to construct scaled up reactor	Parts needed to construct scaled-up reactor as described in Activity 2					$10,000
							Sub Total	**$24,043**
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								
		Scientific Services	PFAS analysis in NMR and analytics facility at the University of Minnesota					$9,000
							Sub Total	**$9,000**
							Grand Total	**$299,000**

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request

Non ENRTF Funds

Category	Specific Source	Use	Status	Amount
State				
			State Sub Total	**-**
Non-State				
In-Kind	Unrecovered F&A calculated at 54% MTDC	Support of ME facilities where research will be conducted.	Secured	$131,413
			Non State Sub Total	**$131,413**
			Funds Total	**$131,413**

Total Project Cost: $430,413

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: 4428f405-afd.pdf

Alternate Text for Visual Component

Mitigating short-chai forever chemicals for a PFAS-Free Minnesota: visualization of problem to solve and proposed solution....

Supplemental Attachments

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

Title	File
authorization letter	692691aa-ac2.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

Do you understand that travel expenses are only approved if they follow the "Commissioner's Plan" promulgated by the Commissioner of Management of Budget or, for University of Minnesota projects, the University of Minnesota plan?

N/A

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

No

Do you understand and acknowledge IP and revenue-return and sharing requirements in 116P.10?

N/A

Do you wish to request reinvestment of any revenues into your project instead of returning revenue to the ENRTF?

N/A

Does your project include original, hypothesis-driven research?

Yes

Does the organization have a fiscal agent for this project?

Yes, Sponsored Projects Administration

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:

Alex Sullivan

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

N/A