Environment and Natural Resources Trust Fund

2023 Request for Proposal

General Information

Proposal ID: 2023-175

Proposal Title: Water Treatment Technology 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 aims to create a disruptive technology that can efficiently treat a broad spectrum of PFAS contaminated water, a growing health and environmental concern in Minnesota.

Funds Requested: $199,000

Proposed Project Completion: June 30, 2026

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?

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 chemicals of the PFAS family have been measured in Minnesota at concentrations sufficient to significantly 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. Industry has tried to remediate this issue by replacing traditional toxic PFAS chemicals by alternative chemicals that were believed to be more environmentally friendly. However, recent studies show that these so-called ‘GenX’ and PFBS chemicals are equally or even more toxic and persistent. The current challenge in removing PFAS from water streams is thus not only historical contamination remediation but also treatment of new emissions at the source. While treatment technologies for PFAS removal from wastewater are being implemented in Minnesota, the current processes are based on phase separation producing residual solid waste which requires expensive post treatment or could even reintroduce the compounds into the environment. Many state-of-the-art chemical treatments can selectively decompose specific PFAS chemicals but are unable to efficiently eradicate a broad range of PFAS compounds.

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 that can efficiently treat a broad spectrum of PFAS contaminated water streams and dissociate the PFAS including GenX and PFBS chemicals into harmless byproducts. The proposed technology exploits non-thermal plasmas as a source of highly reactive species produced from electricity and water that enable the dissociation of PFAS. Recent studies have shown effective decomposition of PFOA, a commonly used PFAS in industry, by non-thermal plasma. This project will develop an optimized reactor design for effective and energy efficient PFAS decomposition. This will critically rely on the innovative design of a water handling system that enables the efficient contact between the plasma and the water. In addition, we will assess the technology for the new GenX and PFBS chemicals and assess byproducts. The outcome of this project will be a laboratory prototype that can be scaled up to treat large quantities of water containing PFAS inspired by the plasma-based ozone water treatment facilities successfully used for many decades but unable to tackle the PFAS contamination. The vision is that the technology can treat PFAS contaminated water in wastewater treatment facilities, at emission sources or contaminated water sites.

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?

- Development of a laboratory prototype reactor that can be scaled to treat large quantities of water containing PFAS.
- Demonstrate the potential of the technology for PFAS decomposition including GenX and PFBS.
- Detailed analysis of the cost and efficiency of the proposed process.
- Preliminary economic analysis of the proposed process with scale up assessment.

Activities and Milestones

Activity 1: Development of benchtop size prototype reactor and preliminary optimization

Activity Budget: $68,653

Activity Description:
Activity 1 consists of developing a benchtop size protype reactor and optimizing the system. The optimization will critically depend on the innovative design of a water handling system that enables the efficient contact between the plasma and the water which will be explored in a variety of ways through innovative multiphase reactor designs informed by extensive research over the last decade at the High Temperature and Plasma Laboratory at the University of Minnesota. Previous investigations by the applicant suggest that treatment times as short as a few milliseconds is sufficient for (local) PFAS decomposition. This very fast decomposition shows promise for scale up and enhancing process efficiency. As detection of PFAS can be challenging and work intensive, the initial optimization of the reactor which will involve a large parametric study will be performed with Rhodamine B, which is like PFOA a surfactant and its decomposition can be easily measured even in situ by absorption. The outcome of this work will be a benchtop size prototype reactor that will be used to evaluate PFAS decomposition in Activity 2.

Activity Milestones:

Description	Completion Date
Benchtop size prototype reactor	December 31, 2023
Preliminary optimized reactor	June 30, 2024

Activity 2: Evaluation of the protype reactor for PFAS including the analysis of byproducts and economic viability

Activity Budget: $130,347

Activity Description:
Research in Activity 2 will be focused on assessing efficacy of plasma enabled decomposition of PFAS including GenX and PFBS starting from the preliminary optimized reactor conditions determined in Activity 1. The decomposition kinetics dependence on key operation parameters including liquid residence time, PFAS concentration and presence of other pollutants will be assessed. These investigations will allow to further optimize the prototype system and establish energy cost and decomposition efficiency of the proposed technology.

Plasma can in principle decompose molecules back to water, CO2 and fluorine. Nonetheless, a series of follow-up experiments will be conducted to evaluate the product composition of the optimized plasma treatment to confirm that no toxic decomposition products remain. A further optimization of the treatment conditions will be performed if required. The determined optimized conditions will be tested on selected PFAS contaminated water samples collected in Minnesota.

To assess the viability of the proposed technology, we will perform a preliminary economic analysis of the process using the energy and decomposition efficiency obtained in this activity. As plasma requires electricity to be generated, the technology can fully exploit renewable energy sources such as wind or solar energy.

Activity Milestones:

Description	Completion Date
Optimization of the reactor with PFOA and determine decomposition kinetics	December 31, 2024
Assessment of the decomposition efficiency of GenX and PFBS chemicals and their kinetics	June 30, 2025
Assessment of treatment byproducts	December 31, 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?

Upon the successful completion of the project, we will actively work on the scale up of the technology with industrial partners and water treatment facilities and test the device in different relevant operational environments to address customer needs and overcome implementation challenges. We will actively work to promote our newly proposed technology through our contacts in companies and explore the broadest possible implementation and market opportunities. A likely outcome of the project is the establishment of a start-up company which will allow to acquire funding through a variety of funding sources including private capital and national grant agencies.

Project Manager and Organization Qualifications

Project Manager Name: Peter Bruggeman

Job Title: Professor and Associate Head

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

Peter Bruggeman is Professor and Associate Department Head of Mechanical Engineering at the University of Minnesota. Professor Bruggeman is an expert in plasma science and engineering who brings nearly two decades of experience in plasma-liquid multiphase reactor studies and design. Bruggeman's leadership experience includes his role as Director of the High Temperature Plasma Laboratory, currently consisting of 3 faculty and 25 researchers, Associate Head of Mechanical Engineering, a department comprising more than 40 faculty, 40 staff members, and ~300 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 and a Growing Convergent Research Grant from the National Science Foundation involving 5 research groups with expertise ranging from microbiology to manufacturing and biochemistry. He has published over 130 papers in peer-reviewed journals, delivered invited keynote lectures at over 80 international meetings. His research has been recognized by several awards including the 2012 Hershkowitz Early Career Award, the 2013 Institute of Pure and Applied Physics Young Scientist Medal and Prize in Plasma Physics, the 2016 US Department of Energy Early Career Award, the 2018 Peter Mark Memorial Award of the American Vacuum Society and the 2020 George W. Taylor Award for Distinguished Research of the College of Science and Engineering of the University of Minnesota. He also served on the committee charged by the National Academies with the Decadal Study of Plasma Science and co-edited the "2017 and 2022 Plasma Roadmap" giving directions for the future development of the field of low temperature plasma.

Organization: U of MN - College of Science and Engineering

Organization Description:

The University of Minnesota offers world-class infrastructure for this project. Professor Bruggeman directs the High Temperature and Plasma Technology lab, which consists of 3 faculty members and over 20 researchers and is one of the best equipped plasma technology laboratories in the world. The team has access to many shared facilities at the University of Minnesota including the Research Analytical Laboratory for water analysis and the Waters Center of Innovation Laboratory with state-of-the-art analytical capabilities.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Professor		Project director			25%	0.12		$28,708
Research Assistant		Researcher			78%	1.2		$129,742
							Sub Total	**$158,450**
Contracts and Services								
TBD	Internal services or fees (uncommon)	PFAS and byproduct analysis				0.3		$21,000
							Sub Total	**$21,000**
Equipment, Tools, and Supplies								
	Tools and Supplies	Reactor components, chemicals, power supplies, optical components, electrical components	reactor construction and daily operation expenditures					$19,550
							Sub Total	**$19,550**
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								
							Sub Total	**-**
							Grand Total	**$199,000**

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				
			Non State Sub Total	**-**
			Funds Total	**-**

Attachments

Required Attachments

Visual Component

File: bd7d4626-2f0.pdf

Alternate Text for Visual Component

Map of measured PFAS levels in Minnesota and visualization of proposed technology...

Optional Attachments

Support Letter or Other

Title	File
Letter of Commitment	925fff22-3ee.pdf

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?

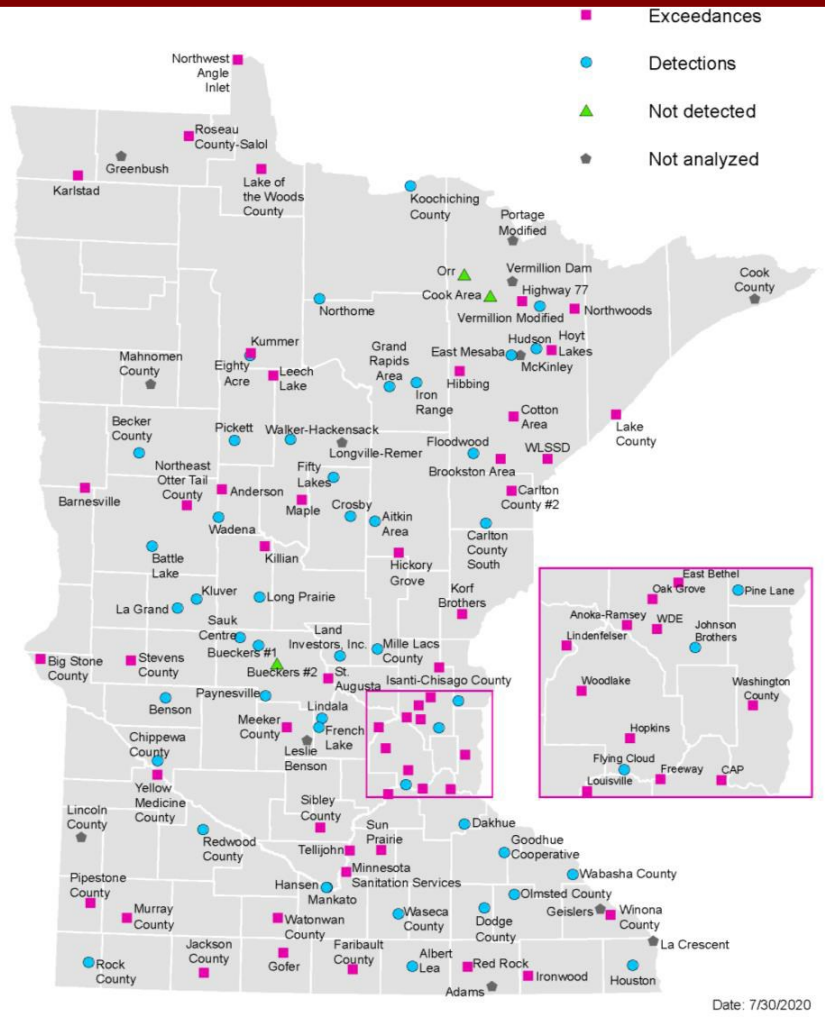
Yes

Does the organization have a fiscal agent for this project?

Yes, Sponsored Projects Administration

Water Treatment Technology for a PFAS-Free Minnesota

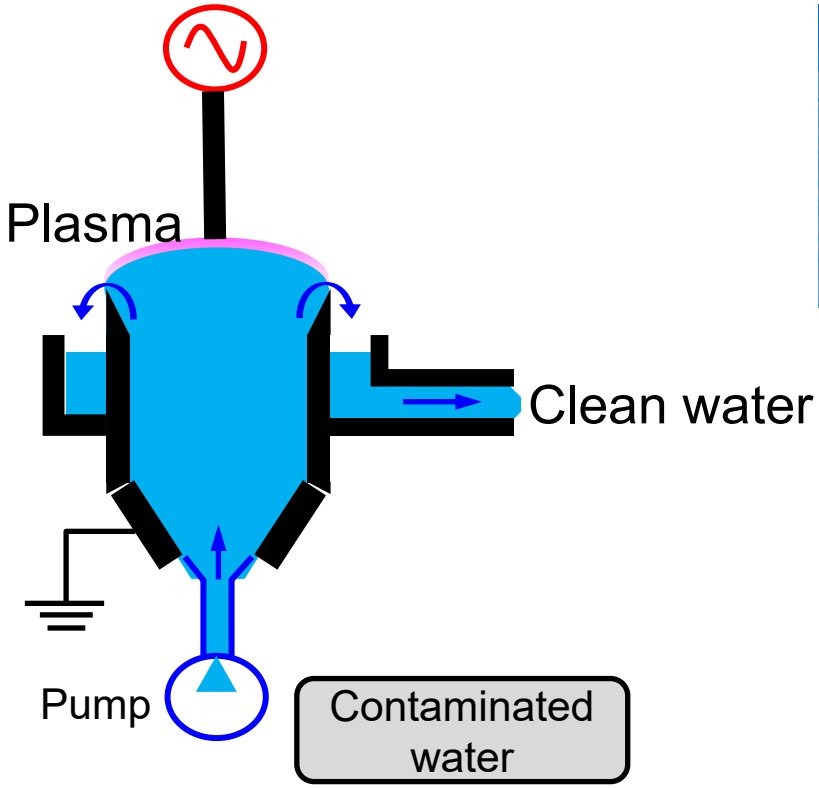
Opportunity/Problem to Solve



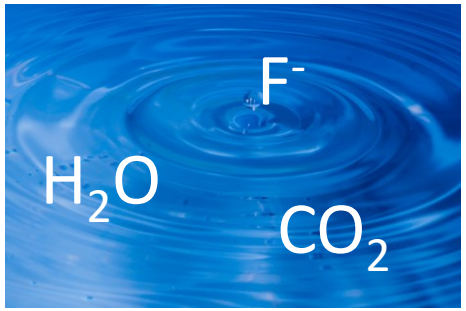
PFAS concentrations in down-gradient ground-water wells at Closed Landfill Program (CLP) sites

Minnesota's PFAS Blueprint 2021

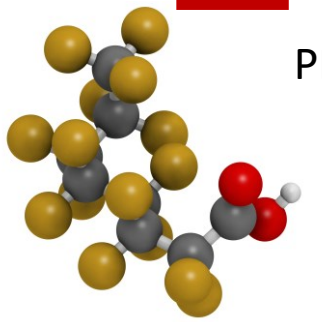
Proposed Solution



https://www.ci.stcloud.mn.us/331/Wastewater-Services



www.publicdomainpictures.net



PFAS

Molekuul/Getty Images