

**Environment and Natural Resources Trust Fund**

# 2022 Request for Proposal

## **General Information**

**Proposal ID:** 2022-265

**Proposal Title:** Innovative Technology for PFAS Destruction in Drinking Water

## **Project Manager Information**

**Name:** Shaobo Deng

**Organization:** U of MN - Southern Research and Outreach Center

**Office Telephone:** (507) 835-1495

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## **Project Basic Information**

**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.

**Funds Requested:** $500,000

**Proposed Project Completion:** June 30 2025

**LCCMR Funding Category:** Water Resources (B)

## **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

## **Narrative**

**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? i.e. What are you seeking funding to do? You will be asked to expand on this in Activities and 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 originally developed in 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 solution recently wins the EAP's "Innovative Ways to Destroy PFAS" challenge award.

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.

## **Activities and Milestones**

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

**Activity Budget:** $193,635

**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. Four different operational modes, i.e., circulation, one-pass, two-pass, one-pass with two reactors connected in series, will be compared for the PFOA/PFOS degradation. Finally, the significant operating and design parameters of the process and the best operational mode for PFAS removal efficiency and preservation of drinking water quality will be determined.

**Activity Milestones:**

|  |  |
| --- | --- |
| **Description** | **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 |

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

**Activity Budget:** $306,365

**Activity Description:**With the determination of operating and design parameters of the process and the best operational mode obtained in Activity 1, a 50 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 30 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, 5) monitor the energy consumption and derive an initial estimate of CAPEX and OPEX and comparison. 6) demonstrate the process and technology to potential customers and investors. After the successful demonstration, a techno-economic assessment of the processing system will be conducted and the implementation path and strategy should be identified.

**Activity Milestones:**

|  |  |
| --- | --- |
| **Description** | **Completion Date** |
| Design, construction and installation of a 50-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 |
| Techno-economic assessment of liquid plasma system including CAPEX/OPEX estimation and comparison | June 30 2025 |

## **Long-Term Implementation and Funding**

**Describe how the results will be implemented and how any ongoing effort will be funded. If not already addressed as part of the project, how will findings, results, and products developed be implemented after project completion? If additional work is needed, how will this be funded?**The purpose of this project is to thoroughly 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 |

## **Project Manager and Organization Qualifications**

**Project Manager Name:** Shaobo Deng

**Job Title:** Researcher 6

**Provide description of the project manager’s qualifications to manage the proposed project.**Shaobo Deng is a researcher at Southern Research and Outreach Center, University of Minnesota, Leading the plasma technology research and development for agricultural and food process, waste treatment, renewable energy production; designing and scale-up the process from concept to lab-scale and pilot-scale; conducting experiments for process evaluation and validation. Mr. Deng is the inventor of the patent-pending technology for plasma discharge in the liquid and in charge of the environmental engineering and renewable energy research lab at the SROC. He was the Project Manager of the LCCMR project” Clean Water and Renewable Energy from Beet Processing Wastewater and Manure” and the Principle Investigator of three MSR&PC-funded projects on liquid phase plasma discharge technology for biodiesel production and water treatment.

Forrest Izuno will serve as co-Project Manager for this project. Dr. Izuno is the head of SROC and the professor at the bioproducts and biosystems engineering department, University of Minnesota. With active research experience in water management and sustainable system development, he leads the SROC working on a base 1.7 million dollar per year allocation, annual budgets grow to over $4 million through grants and businesses. Recently he heavily involved in the development and commercialization of liquid phase plasma discharge technology. In this project, Dr. Izuno will be responsible for overall project coordination, ensuring the necessary resources, and supervising all the activities.

**Organization:** U of MN - Southern Research and Outreach Center

**Organization Description:**Southern Research and Outreach Center, located in Waseca, MN, is one of the ten University of Minnesota’s Research and Outreach Center and dedicate to conduct innovative basic and applied research for broad dissemination and education in the areas of agricultural and food production system, human health, renewable energy, and the environment, and provide extension service and research-based educational information to our clientele about crop production, animal nutrition, horticulture, renewable energy, and waste treatment techniques. The center has a 1,500 sqft laboratory for renewable energy, environmental engineering, and wastewater treatment research, equipped with all the necessary lab equipment and instruments for the proposed project. A lab-scale liquid phase plasma reactor has been built and yielded good preliminary results for PFAS destruction. Gas chromatography with both a TCD and an FID detector is available for the project. The university also has analytical facilities that can be accessed with payment, such as soil, water, and climate research analytical laboratory.

## **Budget Summary**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Category / Name** | **Subcategory or Type** | **Description** | **Purpose** | **Gen. Ineli gible** | **% Bene fits** | **# FTE** | **Class ified 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 for water sample analysis, machine shop for components and parts fabrication. |  |  |  | 0 |  | $15,000 |
|  |  |  |  |  |  |  | **Sub Total** | **$15,000** |
| **Equipment, Tools, and Supplies** |  |  |  |  |  |  |  |  |
|  | Tools and Supplies | Chemicals, analysis kits, glassware and personal protection supplies | Materials for lab experiments |  |  |  |  | $25,000 |
|  | Equipment | Build a lab scale system for research and a pilot scale system for demonstration | Test and demonstrate the process and technology |  |  |  |  | $210,000 |
|  |  |  |  |  |  |  | **Sub Total** | **$235,000** |
| **Capital Expenditures** |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  | **Sub Total** | **-** |
| **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** | **$500,000** |

### **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: [e25420a3-9e9.pdf](https://lccmrprojectmgmt.leg.mn/media/map/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](https://lccmrprojectmgmt.leg.mn/media/attachments/1d1c0a82-f36.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