



Environment and Natural Resources Trust Fund

2027 Request for Proposal

General Information

Proposal ID: 2027-384

Proposal Title: Reducing PFAS Mass Loading to Minnesota Waters

Project Manager Information

Name: Juer Liu

Organization: U of MN - College of Food, Agricultural and Natural Resource Sciences

Office Telephone: (612) 404-9638

Email: liux3514@umn.edu

Project Basic Information

Project Summary: Evaluate continuous-flow CHIEF plasma technology for PFAS destruction in high-strength wastewaters, quantifying defluorination and energy performance to establish scalable approaches that reduce PFAS loading to Minnesota groundwater and surface waters

ENRTF Funds Requested: \$300,000

Proposed Project Completion: June 30, 2030

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?

Statewide

What is the best scale to describe the area impacted by your work?

Statewide

When will the work impact occur?

Narrative

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

PFAS are widely detected in Minnesota waste streams that influence surface water and groundwater quality. Monitoring by the MPCA has identified PFAS at 100 of 102 assessed closed landfills, with 62 sites exceeding MDH drinking water guidance values in downgradient groundwater. Landfill leachate monitoring has documented concentrations as high as 84,000 ng/L for PFOA and 31,000 ng/L for PFOS, along with elevated short-chain PFAS compounds. Municipal wastewater monitoring has also detected PFOS in influent (0.007–0.811 µg/L), effluent (0.007–1.51 µg/L), and sludge (4–861 µg/kg), indicating partitioning to solids and potential recirculation within treatment processes.

High-strength waste streams such as landfill leachate, sludge centrate, and certain industrial wastewaters contain elevated PFAS as well as high dissolved solids and chemical oxygen demand (COD). These conditions complicate treatment: elevated conductivity destabilizes electric-discharge systems, while organic constituents compete for reactive species in advanced oxidation processes. Most currently deployed technologies therefore rely on separation processes that transfer PFAS to secondary residuals requiring additional management.

Continuous-flow advanced oxidation systems remain poorly evaluated in Minnesota high-strength wastewaters, leaving decision-makers without matrix-specific data on PFAS destruction, fluoride release, and energy demand under realistic operating conditions.

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.

We will evaluate a continuous-flow Concentrated High-Intensity Electric Field (CHIEF) reactor for treatment of PFAS-containing wastewaters. The system operates as a non-thermal plasma reactor in which an electric field is concentrated through a dielectric capillary with a micro-orifice. As wastewater and injected gas pass through this region, a stable plasma–liquid interface forms without bulk heating, generating energetic electrons, ultraviolet emission, and short-lived oxidative species.

To address elevated conductivity and high COD, a heterogeneous photocatalyst will be positioned within the discharge region. Two configurations will be assessed: catalyst immobilized on the orifice surface and a rod-through-catalyst geometry placing the rod within the plasma region to guide flow across a plasma-activated surface. This will evaluate whether surface-mediated reactions improve defluorination efficiency, radical utilization, and operational stability under high-strength conditions.

Previous testing of the non-catalytic CHIEF system under synthetic conditions demonstrated 85–95% removal of PFOA and PFOS. The reactor will be evaluated using municipal sludge centrate primarily, with comparative testing in landfill leachate and industrial wastewater. Performance will be quantified using PFAS analysis, fluoride release, COD reduction, and energy monitoring to define operating boundaries, assess feasibility under Minnesota-relevant wastewater characteristics, and estimate potential reductions in PFAS mass loading to Minnesota waters.

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?

This project will deliver decision-ready technical criteria for plasma-based treatment of PFAS in high-strength Minnesota wastewaters that influence surface and groundwater quality. Outcomes include: Verified PFAS transformation and confirmed defluorination with mass balance; Energy-normalized treatment performance relative to contaminant loading; Defined operating boundaries under elevated conductivity and organic strength; Catalyst stability under continuous-flow operation; And estimated reduction in PFAS mass loading under Minnesota-relevant scenarios. These results establish feasibility thresholds to determine whether plasma treatment can reduce PFAS mass loading from

municipal sidestreams, landfill leachate, and industrial discharges before return to the water environment, supporting protection of Minnesota's natural water resources.

Activities and Milestones

Activity 1: Reactor Configuration, Plasma Diagnostics, and Baseline Defluorination

Activity Budget: \$120,000

Activity Description:

The objective of this activity is to establish stable continuous-flow operation of the CHIEF reactor and quantify baseline PFAS defluorination and energy intensity in municipal sludge-processing sidestream. Reactor performance will be evaluated under controlled voltage, pulse characteristics, gas injection rate, and flow conditions to define discharge stability across conductivity ranges representative of the primary matrix. Influent will be characterized for PFAS composition, COD, dissolved solids, pH, and alkalinity prior to treatment. Treatment performance will be assessed as a function of flow rate and cumulative exposure time using continuous operation with controlled recirculation where appropriate. PFAS concentrations will be quantified using LC-MS/MS (EPA Method 1633A), and fluoride release will be measured via ion chromatography to construct fluorine mass balances. COD reduction and energy consumption will be measured to calculate energy intensity (kWh g^{-1} PFAS transformed). Optical emission spectroscopy and peroxide quantification will be used as diagnostic tools to interpret oxidative species generation and relate plasma discharge behavior and reaction pathways to observed defluorination and energy demand. Outcomes will define discharge stability limits, verified defluorination performance, and baseline energy requirements under Minnesota-relevant conditions.

Activity Milestones:

Description	Approximate Completion Date
Stable plasma discharge demonstrated across representative sidestream conductivity range	October 31, 2027
Verified PFAS transformation and fluorine mass balance closure achieved	January 31, 2028
Baseline energy intensity established under defined loading conditions	April 30, 2028
Diagnostic characterization completed to interpret discharge–performance relationships	June 30, 2028

Activity 2: Photocatalyst Selection, Integration, and Comparative Matrix Evaluation

Activity Budget: \$130,000

Activity Description:

The objective of this activity is to determine whether integrating photocatalyst improves defluorination efficiency, modifies transformation pathways, or alters energy demand under conditions of elevated organic loading and ionic strength. Candidate photocatalysts (e.g., TiO_2 , Fe-based oxides, or perovskite materials) will be selected based on band gap, surface hydroxyl density, and chemical stability under plasma exposure. Materials will be immobilized onto inert supports or directly onto the orifice surface using controlled deposition methods to prevent particulate release. Surface area and morphology will be characterized using BET analysis and electron microscopy, and surface chemistry will be evaluated before and after plasma exposure to assess active-site stability. Two configurations: (i) an orifice-coated catalyst and (ii) a rod-through-catalyst geometry will be evaluated under electrical and hydraulic conditions defined in Activity 1. Municipal sidestream will remain the primary matrix for performance evaluation. Landfill leachate from an anonymous Minnesota municipal solid waste landfill and industrial wastewater provided by Claros will be tested under defined operating conditions to determine tolerance limits with respect to conductivity and COD. Time-resolved sampling will quantify apparent kinetic, defluorination fractions, and energy-normalized performance. Continuous operation will be conducted to assess catalyst durability and discharge stability.

Activity Milestones:

Description	Approximate Completion Date
Photocatalysts selected, immobilized, and surface-characterized	October 31, 2028
Catalytic configurations integrated and reproducibly operated	January 31, 2029
Comparative performance quantified for leachate and industrial matrices	March 31, 2029
Catalyst stability and matrix tolerance boundaries defined	June 30, 2029

Activity 3: Matrix-Specific Performance Envelope and Screening TEA/LCA

Activity Budget: \$50,000

Activity Description:

The objective of this activity is to translate experimental results into quantitative feasibility thresholds for Minnesota implementation. Integrated datasets from Activities 1 and 2 will be used to define operating envelopes for conductivity, COD, flow regimes, and energy intensity for the primary municipal sidestream, with sensitivity limits derived from landfill leachate and industrial wastewater testing. Reproducibility will be verified through sustained steady-state operation under representative loading conditions. Energy-normalized PFAS transformation (including defluorination) will be summarized as matrix-specific performance envelopes rather than single-point removal values. A screening-level techno-economic analysis will be conducted using measured energy demand, observed electrode and catalyst longevity, and projected scaling relationships for treatment capacity. A streamlined life-cycle assessment will compare energy use and secondary residual generation against adsorption-based baseline scenarios using empirical data generated during the project. Sensitivity analyses will evaluate how influent PFAS concentration and conductivity influence projected treatment burden. Outcomes will define advancement thresholds indicating when pilot-scale validation is technically justified for protection of Minnesota surface and groundwater resources.

Activity Milestones:

Description	Approximate Completion Date
Reproducible steady-state performance demonstrated across all matrices	October 31, 2029
Matrix-specific operating envelopes defined for conductivity and COD	January 31, 2030
Screening-level TEA completed using measured performance data	March 31, 2030
LCA comparison and advancement thresholds finalized	June 30, 2030

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Roger Ruan	University of Minnesota	Co-PI	Yes
Zekun Liu	Claros Technologies Inc	Collaborator	No

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.

Project outcomes will be shared with Minnesota regulators, wastewater utilities, landfill operators, and the broader scientific community so that the results can inform strategies to reduce PFAS loading to surface waters and groundwater. Key technical outputs including verified PFAS transformation, fluorine mass balance confirming defluorination, energy-normalized treatment performance, and operating boundaries under elevated conductivity and organic loading, will be compiled into a final technical report. This report will be provided to the MPCA Municipal Wastewater Program, Industrial Stormwater Program, and PFAS Monitoring and Assessment Program, which oversee PFAS monitoring and wastewater discharge management across the state. Technical summaries will also be distributed to municipal wastewater utilities and landfill operators managing high-strength waste streams such as sludge centrate and landfill leachate.

Project findings will additionally be discussed through targeted informational briefings with wastewater utilities operating sludge-processing sidestream systems, including facilities within the Metropolitan Council Environmental Services network and other regional wastewater treatment plants in Minnesota. Landfill operators managing PFAS-containing leachate will also be included in these briefings. Where appropriate, results will be shared with water treatment technology developers and industrial partners interested in emerging PFAS destruction technologies for high-strength wastewaters.

Results will also be communicated through peer-reviewed publications and conference presentations addressing water treatment and PFAS remediation. Target journals include Environmental Science & Technology, Water Research, Journal of Hazardous Materials, and Environmental Science: Water Research & Technology. Findings will be presented at technical meetings such as the Water Environment Federation Technical Exhibition and Conference (WEFTEC) and the Association of Environmental Engineering and Science Professors (AEESP) Conference.

Experimental datasets including PFAS transformation measurements, fluoride release data, COD reduction, and energy consumption metrics, will be archived through the University of Minnesota Digital Conservancy to ensure long-term access for researchers and regulatory professionals evaluating PFAS treatment technologies.

Plain-language summaries describing the project objectives and major findings will be shared through University of Minnesota CFANS and Center for Biorefining web platforms, allowing Minnesotans to better understand how ENRTF-supported research contributes to protecting the state's water resources from persistent contaminants.

All reports, presentations, publications, and other outreach materials will acknowledge support from the ENRTF using the required attribution language and logo in accordance with ENRTF Acknowledgment Guidelines.

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?

Project findings will be shared with Minnesota wastewater utilities, landfill operators, and the MPCA through technical memoranda and targeted briefings focused on treatment feasibility under high-strength conditions. If defined advancement criteria including energy demand, fluorine mass balance closure, and stable operation within conductivity limits are met, the results will support development of a pilot-scale unit at a partner facility. Follow-on work, including extended-duration field validation, would be pursued through subsequent ENRTF proposals, federal water research programs (e.g., EPA, NSF), or cost-shared pilot agreements with participating utilities. Pilot advancement will proceed if performance benchmarks demonstrate practical applicability for Minnesota water.

Project Manager and Organization Qualifications

Project Manager Name: Juer Liu

Job Title: Research Professional 5

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

Dr. Juer Liu is a Researcher V and Associate Director at the Center for Biorefining in the Department of Bioproducts and Biosystems Engineering at the University of Minnesota. She holds a Ph.D. in Food Science with a minor in Bioproducts and Biosystems Science, Engineering, and Management. Dr. Liu has extensive experience managing interdisciplinary research projects focused on sustainable materials processing, waste valorization, and advanced thermal and non-thermal conversion technologies. She has contributed to more than 18 peer-reviewed publications, one book chapter, and over 650 citations, with research spanning microwave-assisted processing, plasma-based systems, and catalytic conversion technologies for waste-to-value applications. Her work includes studies on advanced processing systems, biomass conversion, and contaminant transformation relevant to emerging environmental challenges. She has successfully managed and supported multiple externally funded research projects from federal agencies including USDA, DOE, and NSF, as well as industry partners and commodity organizations. Dr. Liu has extensive experience coordinating multidisciplinary research teams, managing laboratory and pilot-scale experiments, and translating research findings into practical technologies. In addition to her research leadership, Dr. Liu has taught courses such as Renewable Energy Technologies and Food Process Engineering and actively mentors graduate and undergraduate researchers. She has received several professional recognitions, including the IFT Student Leadership Award and multiple national research poster awards. Her experience managing complex research programs, coordinating industry and municipal partners, and overseeing pilot-scale technology evaluation positions her well to manage the proposed project and ensure successful execution.

Organization: U of MN - College of Food, Agricultural and Natural Resource Sciences

Organization Description:

The Center for Biorefining is a University of Minnesota research center affiliated with the College of Food, Agricultural and Natural Sciences and helps coordinate the University efforts and resources to conduct exploratory fundamental and applied research and provide education on science and technology for environment protection and circular economy; stimulate collaboration among the University researchers, other public sector investigators, and private investigators involved in biobased production technology development; promote technology transfer to industries; and foster economic development in rural areas. The Center's research programs are funded by DOE, USDA, DOT, DOD, LCCMR, IREE, Xcel Energy, and other federal and state agencies, NGOs, and private companies. The Center is equipped with state of the arts analytical instruments, and processing facilities ranging from bench to pilot scale.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	\$ Amount
Personnel								
Professional Researcher		PI - contract faculty (funding dependent) - oversee experimental design, coordinate research activities, supervise personnel, manage project reporting, and ensure integration of analytical results across treatment testing and performance evaluation.			36.6%	0.3		\$28,051
Professor/Faculty		Co-PI - 9 month appointment (2 weeks summer salary) - technical oversight for reactor design and plasma-based treatment evaluation, guide system configuration, interpret treatment performance data, and contribute to analysis of PFAS transformation and reactor operation.			36.6%	0.15		\$37,533
Postdoctoral Researcher		Conduct day-to-day research activities including operation of the CHIEF reactor system, wastewater treatment experiments, sample preparation, PFAS degradation analysis, fluoride quantification, COD measurement, energy monitoring, and data interpretation.			26.1%	1.5		\$124,917
Graduate Research Assistant		Assist with reactor operation, wastewater matrix preparation, analytical measurements, sampling, and data processing. They will also assist in compiling experimental datasets and preparing technical reports.			24.2%	0.75		\$47,082
							Sub Total	\$237,583
Contracts and Services								
Laboratory Analytical Services	Internal services or fees (uncommon)	Internal analytical service charges and instrument use fees with internal rates needed to quantify PFAS treatment performance. Analyses will include PFAS quantification by LC-MS/MS, fluoride measurement, and related analytical verification.				-		\$8,000
							Sub Total	\$8,000

Equipment, Tools, and Supplies								
	Tools and Supplies	Catalyst materials, reagents for PFAS extraction and analysis, calibration standards for fluoride and COD analysis, solvents, gases, filtration media, tubing, vials, pipette tips, sample bottles, personal protective equipment, and other routine laboratory consumables.	Consumable materials required for plasma treatment experiments and analytical testing					\$28,417
	Equipment	High-voltage plasma power supply (laboratory-scale) – \$4,200; Mass flow controllers for process gas delivery (2 units × \$1,450) – \$2,900; Plasma voltage/current monitoring module – \$1,400; Laboratory peristaltic pump for wastewater feed control – \$1,500	Support stable plasma generation and controlled wastewater and gas flow through the dielectric capillary reactor					\$10,000
	Equipment	Inline conductivity and temperature sensors for wastewater monitoring (2 units × \$950) – \$1,900; Digital pressure regulators and gas manifold assembly – \$2,100; Reactor support frame and insulation components – \$2,600; Replacement dielectric capillary reactor assemblies (2 units × \$1,700) – \$3,400	Support continuous-flow reactor operation and monitoring under varying wastewater conductivity and organic loading conditions.					\$10,000
	Equipment	Effluent sampling and filtration manifold system – \$1,800; Laboratory adsorption column assemblies for treated effluent testing (2 units × \$950) – \$1,900; Additional reactor electrodes, fittings, and spare components – \$1,300	Support sample collection, treated effluent testing, and continued reactor operation during matrix comparison experiments.					\$5,000
							Sub Total	\$53,417
Capital Equipment								
							Sub Total	-
Acquisitions and Stewardship								
							Sub Total	-
Travel In Minnesota								
	Miles/ Meals/ Lodging	Approximate 10 round trips (~100 miles each) between the UMN and anonymous facilities for wastewater sample collection and stakeholder	Collection of representative wastewater matrices (e.g., landfill leachate or treatment sidestreams)					\$1,000

		coordination. Travel will be conducted by the PI, postdoctoral researcher, or graduate student at the federal mileage rate (~\$0.67 per mile).	and engagement with Minnesota wastewater stakeholders supporting the project.					
							Sub Total	\$1,000
Travel Outside Minnesota								
							Sub Total	-
Printing and Publication								
							Sub Total	-
Other Expenses								
							Sub Total	-
							Grand Total	\$300,000

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	-

Total Project Cost: \$300,000

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: [a4b147ac-33f.pdf](#)

Alternate Text for Visual Component

Evaluation of a continuous-flow CHIEF plasma reactor for PFAS destruction in high-strength wastewaters. The project quantifies PFAS transformation, fluorine mass balance, catalyst integration, and energy performance to determine feasibility for reducing PFAS mass loading from municipal and industrial wastewaters to Minnesota surface waters and groundwater....

Supplemental Attachments

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

Title	File
Claros Letter of Support	7e218f72-6bd.pdf
Letter of Authorization to Submit	7de2a5f4-2dd.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?

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?

No

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:

Wendy Moylan, Department Finance and Riana Fletcher, 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

N/A