Environment and Natural Resources Trust Fund

2027 Request for Proposal

General Information

Proposal ID: 2027-073

Proposal Title: Hybrid Deconstruction of Persistent PFAS Toward Complete Mineralization

Project Manager Information

Name: Xiaowen Chen

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

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Project Basic Information

Project Summary: This project aims to achieve complete PFAS destruction and mineralization while significantly reducing energy demand and costs through an innovative hybrid treatment train that integrates plasma, photocatalysis, and biological methods.

ENRTF Funds Requested: $470,000

Proposed Project Completion: June 30, 2030

LCCMR Funding 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?

During the Project and In the Future

Narrative

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

Per- and polyfluoroalkyl substances (PFAS) represent a persistent public health concern in Minnesota. PFAS can cause cancer and adverse liver, immune, neurological, and endocrine effects, even at parts-per-trillion levels, with similar toxicity observed in pets and wildlife. They are also acutely toxic to fish, undermining aquatic ecosystems and food chains. The persistence, bioaccumulation, and broad biological impacts of PFAS make contamination not merely an environmental issue, but a statewide health and ecological crisis. Removing PFAS from Minnesota's water supply has therefore become a high priority for both government and industry.

Meanwhile, the rapid growth of data centers in Minnesota is introducing new PFAS discharge pathways through fire suppression systems and cooling-water management, highlighting the urgent need for robust decontamination technologies.

We previously developed and demonstrated an LCCMR-funded pilot-scale continuous non-thermal plasma (NTP) technology to efficiently deconstruct PFAS directly in water, particularly long-chain compounds such as PFOA, PFDA, and PFOS. However, short-chain PFAS, including PFBA(S) and PFHxA(S), are inherently resistant to NTP due to their high hydrophilicity, requiring higher energy input and longer treatment times. These limitations necessitate complementary, energy-efficient pathways to pair with NTP for more complete PFAS deconstruction and mineralization.

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.

To achieve complete PFAS destruction and mineralization while reducing energy demand, we propose developing a novel treatment train technology by integrating our patented non-thermal plasma technology with photocatalytic and biological processes. In the first treatment step, we will apply the NTP procedure that exposes PFAS at the gas-liquid interface, generating reactive oxygen species and solvated electrons to activate and cleave C-C and C-F bonds in long-chain PFAS such as PFOA and PFOS. We have shown that NTP can trigger the degradation of long-chain PFAS, although the reaction slows as more short-chain products form, particularly PFBA. To address this limitation, we will employ a cooperative photocatalysis step to further leverage plasma-generated ultraviolet light, reactive species, and activated PFAS intermediates. We expect this step to enable stepwise reductive defluorination and C-C bond cleavage, thereby facilitating the conversion of short-chain PFAS into C2-C3 fluorinated intermediates. Lastly, to completely defluorinate and recycle fluorine from the C2-C3 intermediates, we will introduce a fungal processing step to treat the NTP-Photo reaction products for bio-defluorination under the ambient conditions. Concurrently, we will leverage fungal-aided mineral dissolution and reprecipitation to ultimately mineralize the released fluorine, thereby enabling fluorine recycling and preventing its spread into the environment.

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 success of this project will immediately benefit Minnesota through new technology innovation for more sustainable and reliable PFAS management. By reducing energy demands and treatment costs, the new technology would be particularly valuable for small and mid-size communities with limited financial resources. Broad deployment of this technology would effectively prevent Minnesota's communities from exposure to PFAS and associated health risks. Complete fluorine mineralization will safeguard Minnesota's lakes, rivers, and fisheries, preventing secondary contamination arising from PFAS concentration or partial deconstruction. Additionally, the project will educate the next generation of engineers and scientists in PFAS treatment technologies and environmental engineering.

Activities and Milestones

Activity 1: Optimize long-chain PFAS degradation using NTP process

Activity Budget: $100,000

Activity Description:
The goal of this activity is to identify optimal operating conditions, including energy input, treatment time, and reactor configuration, that enable maximization of long-chain PFAS degradation while minimizing overall energy consumption. This step focuses on optimizing PFAS deconstruction by the NTP process, aiming to efficiently transform long-chain PFAS into shorter-chain intermediates that are more amenable to subsequent treatment steps, including photocatalysis, fungal-aided biodegradation, and fluoride mineralization. The research will involve using representative mixtures of long-, medium-, and short-chain PFAS to simulate typical PFAS-contaminated water. A response surface experimental design will be employed by systematically varying treatment time, energy input, and gas and liquid flow rates to optimize long-chain PFAS degradation. The treated effluent will be characterized for residual PFAS and transformation products with HR-MS, and then used as the feed to test the efficacy of hybrid NTP treatment combined with photocatalytic and biological processes in Activities 2 and 3.

Activity Milestones:

Description	Approximate Completion Date
Define the PFAS matrix, source representative contaminated water, and complete comprehensive baseline characterization.	October 31, 2027
Optimize NTP conditions to maximize long-chain PFAS degradation while minimizing energy input and treatment time	June 30, 2028
Provide sufficient volumes of NTP-treated water enriched in short-chain PFAS for subsequent photocatalytic-biological treatment	January 31, 2029

Activity 2: Develop hybridized use of photocatalysis for transformation product degradation

Activity Budget: $150,000

Activity Description:
The objective of this activity is to evaluate hybrid treatment strategies that integrate photocatalysis with NTP, applied sequentially or in a consolidated configuration, to further transform PFAS into shorter-chain intermediates and achieve extensive defluorination. We hypothesize that hybrid systems will outperform standalone NTP or photocatalytic treatments in degradation efficiency and energy utilization. This activity will focus on developing photocatalysts compatible with NTP operating conditions. Batch screening will first be conducted using representative short-chain PFAS mixtures, including PFBA, PFBS, PFHxA, and PFHxS, under UV irradiation. Emphasis will be placed on carbon-based nanostructured photocatalysts with high surface area to enhance PFAS adsorption and with heteroatom doping, particularly nitrogen, to induce defects, improve charge separation, and promote reactive species generation. Catalyst performance will be assessed using PFAS removal kinetics by LC-MS and 19F NMR, fluoride release quantified by ISE and ICP-MS, and transformation pathways characterized by HR-MS. One to two high-performing catalysts will be downselected for treating plasma-generated transformation products from Activity 1. Alternatively, catalysts will be integrated directly with NTP to evaluate potential synergistic effects on PFAS degradation pathways and energy efficiency. Effluents from NTP and hybrid treatments will be advanced to subsequent fungal-aided defluorination and mineralization for complete PFAS decontamination.

Activity Milestones:

Description	Approximate Completion Date

Evaluate and compare sustainable, inexpensive photocatalysts for PFAS degradation using visible and ultraviolet light sources.	June 30, 2028
Use top-performing, high-surface-area photocatalysts to evaluate PFAS removal and defluorination across chain lengths and water	December 31, 2028
Achieve over 80 percent long chain PFAS removal and over 50 percent short chain removal	December 31, 2029

Activity 3: Complete PFAS decontamination with the fungal-aided PFAS defluorination and mineralization

Activity Budget: $150,000

Activity Description:
This research activity aims to develop a fungal-aided biotreatment that complements and synergizes with plasma and photocatalytic treatments to achieve complete PFAS mineralization. This approach leverages the unique fungal defluorination capacity to degrade short-chain PFAS, as demonstrated in our previous work (Ayers and Zhang, 2025), and the fungal-mediated mineralization to sequester fluoride into stable mineral forms for fluorine recycling. Pre-grown, living fungal cells of Trametes versicolor will be employed to treat NTP and photocatalytic PFAS transformation products from Activities 1 and 2. Defluorination rates over the time course will be quantified by measuring the fluoride released using ISE and ICP-MS. Fluorine mass balance closure will be evaluated, and transformation products will be characterized using HR-MS and 19F NMR to confirm the complete C-F bond cleavage. Metal cations, including Ca^{2+} and Mg^{2+}, will be added at varying concentrations to assess their effects on fungal defluorination and fluoride mineralization. The physical and chemical properties of fluorine-containing mineral precipitates will be characterized using scanning electron microscopy (SEM), energy-dispersive X-ray spectroscopy (EDX), and X-ray diffraction (XRD) at the University of Minnesota Characterization Facility. Finally, low-cost calcite ($CaCO_3$) will be supplemented to fungal cultures to promote fluoride precipitation and recycling through fungal-mediated dissolution.

Activity Milestones:

Description	Approximate Completion Date
Optimize the fungal culture for defluorinating PFAS products subjected to chemical treatments	June 30, 2028
Characterize the fungal defluorination products	October 31, 2028
Optimize the cationic conditions for fluoride mineralization	April 30, 2029
Measure the impacts of calcite on fungal defluorination and fluoride mineralization	October 31, 2029
Data compilations, paper write-up and submission for activity 3	December 31, 2029

Activity 4: Mid-scale demonstration with real-world samples and TEA/LCA analysis

Activity Budget: $70,000

Activity Description:
Activity 4 will focus on a mid-scale demonstration of the integrated treatment train system in collaboration with Plasma Blue. Scale-up activities will emphasize optimization of energy consumption, refinement of reactor design, and integration of the full treatment system. Insights generated in Activity 1,2, and 3 will directly inform this transition and de-risk scale up. The goal is to deliver a fully integrated hybrid treatment train demonstration by the end of the project. A techno-economic analysis (TEA) and life cycle assessment (LCA) will be conducted to quantify the economic and environmental performance of the proposed hybrid plasma–photocatalytic–biological PFAS treatment system. TEA will estimate capital and operating costs, including energy consumption, reactor construction, catalyst usage, and biological treatment inputs. We will benchmark costs against conventional PFAS treatment technologies such as activated carbon adsorption, ion exchange, and membrane filtration.
We will integrate life cycle assessment with techno-economic analysis using TRACI 2.1 to quantify environmental

impacts, including carbon and water footprints. This integrated approach provides a robust sustainability framework that balances detailed environmental metrics with system-level performance and cost considerations.

Activity Milestones:

Description	Approximate Completion Date
Demonstrate the hybrid treatment train system at mid-scale	March 31, 2030
Provide a comprehensive TEA and LCA analysis based on the mid-scale demonstration	June 30, 2030
Prepare a manuscript based on hybrid PFAS treatment system for publication	June 30, 2030

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Jiwei Zhang	University of Minnesota, CFANS	Dr. Jiwei Zhang will lead activity 3: Complete PFAS decontamination through fungal-aided PFAS defluorination and mineralization. He will oversee a postdoc to test a PFAS remediation method that consolidates fungal processes to achieve complete defluorination and mineralization of short-chain PFAS products generated by upstream chemical treatment.	Yes
Roger Ruan	University of Minnesota, CFANS	Dr. Ruan will oversee the design, optimization, and mid-scale demonstration of the NTP reactor system for long-chain PFAS degradation, ensuring that optimized NTP-treated effluents are suitable for downstream further photocatalytic and biological mineralization in subsequent project activities as needed.	Yes
Plasma Blue	Minnesota based start-up company	Plasma Blue will support the project through field demonstrations in collaboration with municipal water utilities.	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.
Achieving complete mineralization of PFAS using energy-efficient technology is essential for the successful commercialization of any PFAS treatment approach, particularly in Minnesota, where PFAS contamination has affected drinking water, landfills, and industrial sites. This project integrates multiple cutting-edge technologies to develop a cost-effective, safe PFAS destruction process well-suited for deployment in Minnesota communities. By targeting complete defluorination and mineralization, the proposed approach minimizes the formation of harmful byproducts and ensures strong protection of public health and Minnesota's environment.

The team will demonstrate and share this technology through workshops, technical presentations, and university showcase events across Minnesota, engaging key stakeholders, including county and municipal water utilities, data centers, landfills, and state and federal partners. Potential demonstration and outreach audiences include the Minnesota Department of Defense–related installations, such as Camp Ripley, where PFAS concentrations have exceeded regulatory standards. These activities will support informed decision-making and technology adoption for PFAS-impacted sites throughout the state.

Project results will also be published in high-impact, peer-reviewed journals and presented at professional conferences, building on the team's strong publication record. Together, these efforts will increase the visibility of Minnesota-based PFAS solutions, support technology transfer, and accelerate the deployment of energy-efficient PFAS treatment technologies to protect Minnesota's water resources. We will ensure that the Environment and Natural Resources Trust Fund is acknowledged by using the trust fund logo or attribution language on project print and electronic media, publications, signage, and other communications, per the 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?
The results of this project will be implemented through pilot-scale demonstrations in real-world operating environments. In partnership with Plasma-Blue, municipal utilities, and landfill facilities, the developed system will be evaluated using a range of PFAS-contaminated water sources. Findings and breakthroughs from this novel integrated

system will be disseminated through peer-reviewed publications, technical reports, high-impact conferences, and stakeholder workshops to support broader implementation. If additional funding is required for long-term field validation or further scale-up, we will seek funding and support through programs such as LCCMR, EPA, and the DoD ESTCP.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Methods to Destroy PFAS in Landfill Leachates	M.L. 2022, , Chp. 94, Art. , Sec. 2, Subd. 04a	$200,000
PFAS Fungal-Wood Chip Filtering System	M.L. 2022, , Chp. 94, Art. , Sec. 2, Subd. 08f	$189,000
Preventing PFAS and Microplastics Contaminants across Minnesota	M.L. 2024, , Chp. 83, Art. , Sec. 2, Subd. 08k	$656,000

Project Manager and Organization Qualifications

Project Manager Name: Xiaowen Chen

Job Title: Assistant Professor

Provide description of the project manager's qualifications to manage the proposed project.
Dr. Xiaowen Chen, Project Manager, is an Assistant Professor in the Department of Bioproducts and Biosystems Engineering (BBE) at the University of Minnesota. Dr. Chen leads the overall technical vision, project integration, and execution of this effort. Building on prior LCCMR funding, the University of Minnesota has developed a patented, non-thermal plasma (NTP)-based, pilot-scale mobile PFAS treatment trailer that has demonstrated high efficiency in degrading long-chain PFAS from contaminated water. Leveraging this established platform, Dr. Chen developed the consolidated PFAS treatment concept and assembled and coordinated a multidisciplinary team to further optimize, extend, and scale the technology. Dr. Chen has led more than 10 DOE–funded projects with cumulative funding exceeding $10 million, demonstrating a strong track record in managing complex, multi-institutional research programs and translating laboratory innovations for pilot- and field-scale deployment.

Dr. Jiwei Zhang will serve as a Co-Project Manager. Dr. Zhang is an Associate Professor in the BBE department and leads research on fungal and microbial biodegradation pathways for PFAS management, with a focus on PFAS-contaminated biosolids and compliance with state regulations. His laboratory has developed extensive expertise and analytical capabilities relevant to this project, including 19F-NMR, fluoride ion-selective electrode measurements, and fungal-mediated PFAS transformation studies.

Dr. Roger Ruan, Professor in the BBE department and a member of the National Academy of Engineering, is an inventor of NTP systems for PFAS degradation and provides critical expertise in NTP reactor design, optimization, and scale-up.

Tom Slunecka will lead the demonstration effort for this project. He has been the Chief Executive Officer of Minnesota Soybean since August 2012. He currently serves as CEO of Plasma Blue LLC and is heavily involved in the development and commercialization of liquid-phase plasma technology. In this project, Tom will be responsible for coordinating demonstration efforts with the UMN research team.

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

Organization Description:
In the College of Food, Agricultural, and Natural Resources Sciences (CFANS) at the University of Minnesota, we look at the bigger picture. When we envision a better tomorrow, it includes disease-resistant crops, products that protect our health, lakes free from invasive species, and so much more. We use science to find answers to Minnesota and the world's grand challenges and solve tomorrow's problems. Almost 93 percent of students who earn CFANS

undergraduate degrees find jobs in their career field or enter graduate school within six months of graduation. The Department of Bioproducts and Biosystems Engineering (BBE) in CFANS discovers and teaches solutions for the sustainable use of renewable resources and environmental enhancement. We discover innovative solutions to address challenges in the sustainable production and consumption of food, feed, fiber, materials, and chemicals by integrating engineering, science, technology, and management into all degree programs. We have a public impact through community engagement and extension efforts. We develop and deliver high-quality, regionally and nationally recognized research-based programs to meet the current and emerging needs of industry and communities. We also have a long-standing tradition of close partnerships with alumni, industry professionals, organizations, government agencies, donors, and community members.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Project Manager, PI Chen - 9 month appointment, seeking summer salary		Dr. Chen will oversee overall project management, supervise and mentor students/postdocs, design and execute the research activities, and coordinate project logistics. He will also be responsible for reporting project progress to LCCMR and identifying opportunities for technology translation and commercialization.			36.6%	0.18		$32,784
Co-PD Zhang, 9-month appointment, seeking summer salary		Dr. Zhang will support project management, focusing on the biological degradation and mineralization of PFAS. He will work on fungal processing optimization for complete mineralization of PFAS.			36.6%	0.18		$32,784
Postdoctoral researcher 1		The postdoc researcher will work on PFAS degradation using NTP and photocatalyst in Activities 1 and 2. The researcher will design and conduct the NTP experiment, design, synthesize, characterize, and test the photocatalysts for PFAS degradation.			26.1%	2		$159,696
Postdoctoral researcher 2		The researcher will focus on developing the biotreatment for complete PFAS mineralization in Activity 3. The researcher will work on the characterization and cultivation of the fungal species, the optimization of fungal processing, and the analysis of results. The researcher will also report data and write the report for the PIs.			26.1%	2		$165,284
							Sub Total	**$390,548**
Contracts and Services								
Plasma-Blue	Service Contract	Plasma-Blue will lead field demonstration activities using its proprietary, modular scale-up plasma systems. The company has extensive experience deploying plasma technologies at operating landfills for leachate treatment, with proven capability in				0.9		$61,650

		system integration, on-site commissioning, and reliable scale-up from pilot to field conditions, making them essential to successful translation.						
							Sub Total	**$61,650**
Equipment, Tools, and Supplies								
	Equipment	One homemade photoreactor for UV and visible light degradation of PFAS using photocatalysts, including material - $3500, service to fabricate the reactor -$2500	NTP modification to accommodate photocatalysts with UV lights					$6,000
	Tools and Supplies	1. Chemical and lab supplies for NTP and fungal cultures: PFAS chemicals, $500; analytical bottles x 50, $302; culture flasks x 40, $400; petri dishes x 6 packs, $500; gloves x 2 packs, $200; paper towels x 4 packs, $100; fungal media, $600; mineral salts, $200. 2. Analysis service costs: HR-MS or LC-MS PFAS analysis, ~$30/sample x 80 samples = $2,400; 19F NMR and ISE analysis, ~$20/sample x 50 samples = $1,000; SEM, XDS, and mineral crystal analysis at UMNChar, ~$20/sample x 50 samples = $1000. 3. Chemicals for catalyst synthesis: TiO2, lignin, silver nitrate, etc. $600.	The lab supplies, chemicals, and services will be purchased to conduct the proposed project research to detect PFAS degradation via NTP/Photocatalysis and biotreatment, and to measure fungal-aided F mineralization.					$7,802
							Sub Total	**$13,802**
Capital Equipment								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
							Sub Total	**-**
Travel Outside Minnesota								

							Sub Total	**-**
Printing and Publication								
	Publication	This will support the publications on open sourced peer reviewed journals.	Publish on peer review journals, e.g. Chemical Engineering Journal, or Environment Engineering Science					$4,000
							Sub Total	**$4,000**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$470,000**

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	Waived U of Minnesota overhead	The U of Minnesota waives the indirect costs/overhead and allows the project to use the public shared resources from the U.	Secured	$235,000
			Non State Sub Total	**$235,000**
			Funds Total	**$235,000**

Total Project Cost: $705,000

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: ea8f4cc9-470.pdf

Alternate Text for Visual Component

This diagram outlines a PFAS treatment train integrating four activities: nonthermal plasma degradation, photocatalytic degradation, fungal biodegradation, and field demonstration. The system aims to remove existing PFAS contamination in Minnesota while preventing future impacts from increased data center water use and wastewater discharge across regional water systems....

Supplemental Attachments

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

Title	File
Letter of Approval to Submit	b1a6418b-4f6.pdf
Supporting Letter from Minnesota Farmers' Union	57d822e6-c03.pdf
Supporting Letter from Saint Louis County	965a7a1e-7fd.pdf
Supporting Letter from Rock Leaf Water Environmental	8548b1e7-e92.pdf
Supporting Letter from MSR&PC	7d7accdd-d22.pdf
Supporting Letter from Plasma Blue	75992192-678.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?

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:

Jiwei Zhang

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

Yes, I understand