Environment and Natural Resources Trust Fund

2022 Request for Proposal

General Information

Proposal ID: 2022-049

Proposal Title: Destruct per/polyfluoroalkyl substances (PFAS) in landfill leachates

Project Manager Information

Name: Roger Ruan

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

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Project Basic Information

Project Summary: Develop and examine physical, biological, thermochemical, and photochemical methods for destruction of per- and polyfluoroalkyl substances (PFAS) in landfill leachate.

Funds Requested: $200,000

Proposed Project Completion: June 30 2025

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?

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) have been manufactured and used in a variety of industries in the United States and around the globe. They have broad applications in industry and society, such as food packaging, non-stick stain repellent, waterproof products, industrial applications, and firefighting chemicals. PFAS can enter the environment through production or waste streams and can be very persistent in the environment and the human body because they resist heat, harsh chemical conditions, or moisture, creating a challenge when it comes time for disposal. EPA guidance on PFAS management recommends three disposal methods, namely, incineration, landfill, and injection into deep wells. However, all these methods have many significant unknowns and facilities with these required capabilities are lacking. As PFAS is becoming more and more problematic with increasing awareness, it has recently been the focus of regulatory attention. There is a significant need to develop effective methods to treat PFAS in waste streams.

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.

We propose to develop and study processes to treat leachate from landfill. The landfill method recommended by EPA is only effective if leachate is properly treated to prevent PFAS from entering the surface and ground water and atmosphere. Four different approaches will be investigated: 1) separation: ion exchange and membranes will be used to separate and remove PFAS from the leachate; 2) filtration/absorption, resin, biochar, or other absorbents will be used to filter leachate and retain PFAS; 3) degrading: breaking down PFAS through photocatalysis; and 4) flocculation: growing algae on leachate, flocculating to remove algal biomass and PFAS, and thermochemically processing harvested mass to destruct PFAS and produce biofuel and biochar.

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 specific project outcome will include the understanding of how PFAS in landfill leachate respond to the proposed treatments and the potential of these treatments to become technically and financially viable for preventing PFAS from entering Minnesota waters, protecting the state's water resource, aquatic lives, and human safety.

Activities and Milestones

Activity 1: Develop and examine the effectiveness of physical, biological, and photochemical methods

Activity Budget: $150,000

Activity Description:
We will work with landfill facilities to develop sampling protocols. The PFAS levels in the raw samples will be analyzed using standard methods. Samples will then be subjected to four treatments: 1) ion exchange and membranes separation (nanofiltration and reverse osmosis membranes), 2) filtration/absorption by resin, biochar, or other absorbents, 3) photocatalysis, and 4) algae cultivation and flocculation. Algae cultivation is designed to utilize nutrients in leachate and help flocculation using polyacrylamide (PAM) to remove PFAS. The harvested biomass together with PFAS will be microwave-pyrolyzed to decompose PFAS and produce biofuel and biochar. The biochar will be used as one of the absorbents used in the project. Experiments will be carried out under different process conditions including flow rate and pH for separation and filtration/absorption, light and nutrient supplements for algae cultivation, and type and loading of catalysts (including doped photocatalysts) and light for photocatalysis. Combinations of these treatments (treatment train) will also be investigated. The PFAS levels during and after the treatments will be monitored.

Activity Milestones:

Description	Completion Date
Sampling protocols are developed	December 31 2022
Processes and experimental apparatuses are set up	March 31 2023
Individual treatments are examined	December 31 2023
Combined treatments are examined	December 31 2024

Activity 2: Study kinetics and conduct preliminary evaluation of environmental impacts

Activity Budget: $50,000

Activity Description:
Data acquired under different conditions and treatment times will be analyzed and used to develop and verify kinetic models which will be used to predict the performance of the treatments beyond the experimental conditions and provide information useful for scale up and environmental impact assessment.

Activity Milestones:

Description	Completion Date
Data are compiled and analyzed, mathematical models are established	March 31 2025
Preliminary assessment of environmental impacts is carried out	June 30 2025

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Paul Chen	University of Minnesota	Co-PI	No

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 scientific knowledge acquired through this exploratory research will help guide further research and development, raise awareness and interests, and attract industrial partnerships and public funding for further research and development, and eventual implementation of new PFAS technologies. We believe Metropolitan Council Environmental Services will be interested in the proposed technologies. EPA has provided tens of millions of dollars grants for research on PFAS management.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Demonstrating Innovative Technologies to Fully Utilize Wastewater Resources	M.L. 2014, Chp. 226, Sec. 2, Subd. 08c	$1,000,000
Development of Innovative Sensor Technologies for Water Monitoring	M.L. 2016, Chp. 186, Sec. 2, Subd. 04j	$509,000

Project Manager and Organization Qualifications

Project Manager Name: Roger Ruan

Job Title: Professor and Director

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

Dr. Roger Ruan, Professor and Director of Graduate Studies, Department of Bioproducts and Biosystems Engineering, and Director of Center for Biorefining at University of Minnesota, is a Fellow of ASABE and a Fellow of IFT. Dr. Ruan's research focuses on renewable energy and environment technologies for sustainable development and circular economy. Specifically, he has conducted research and published his findings in the areas of municipal, agricultural, and industrial wastewater treatment and utilization through novel anaerobic digestion, microalgae cultivation, and hydroponic cultivation, biomass and solid wastes (including plastics) pyrolysis and gasification, airborne and other pathogen disinfection and pollutant control, catalysis, non-thermal plasma, and nitrogen fixation, etc. He is a top-cited author with an h-index of 69, i10-index of 301, and over 19,000 citations. He has supervised over 75 graduate students, 140 post-doctors, research fellows, and other engineers and scientists, and 21 of his Ph.D. students and post-doctors hold university faculty positions. He has also been invited to give over 300 keynote lectures, invited symposium presentations, company seminars, and short courses. Professor Ruan has received and managed over 200 projects totaling over $45 million in various funding for research, including major funding from USDA, DOE, DOT, DOD, LCCMR, and industries. He has served as guest editor or editorial board member of Bioresource Technology, Renewable Energy, Engineering, Applied Catalysis and Chemical Engineering, Journal of Food Process Engineering, The Open Plasma Physics Journal, and Associate Editor of Transactions of ASABE, Engineering Applications in Agriculture, and Transactions of CSAE, and Chairman of Editorial Board and Editor-in-Chief of International Journal of Agricultural and Biological Engineering, etc. His earlier LCCMR funded projects have resulted in several patented technologies which have been

successfully licensed to the industry. Therefore, he has the technical expertise and project management experience to ensure the execution of proposed projects.

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 help 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 founded 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								
Professor/faculty		PI - summer salary only			36.5%	0.12		$23,622
Professor/faculty		Co-PI - contract faculty member			36.5%	0.24		$33,460
1 Graduate Research Assistant		Researcher			45%	2.25		$126,289
							Sub Total	**$183,371**
Contracts and Services								
University of Minnesota	Internal services or fees (uncommon)	Lab services				-		$5,000
							Sub Total	**$5,000**
Equipment, Tools, and Supplies								
	Tools and Supplies	Purchase ion exchange and membrane separation devices, absorbents, photocatalysts, and supplies for algae cultivation	For setting up experimental devices and conducting experiments in labs.					$10,243
							Sub Total	**$10,243**
Capital Expenditures								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Miles/ Meals/ Lodging	9 one-day 2-person trips, 100 miles each round trip ($0.56/mile), meals @$49/person	Travel to landfill sites to collect samples and conduct on-site testing					$1,386

							Sub Total	**$1,386**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
							Sub Total	**-**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$200,000**

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

Optional Attachments

Support Letter or Other

Title	File
Institutional Approval for Submission	b68c5140-c24.pdf
Visual graphic	51703b83-b14.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

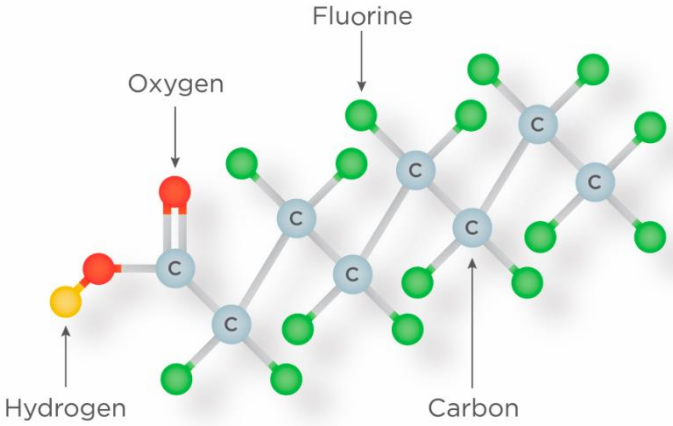
Does your project include original, hypothesis-driven research?

Yes

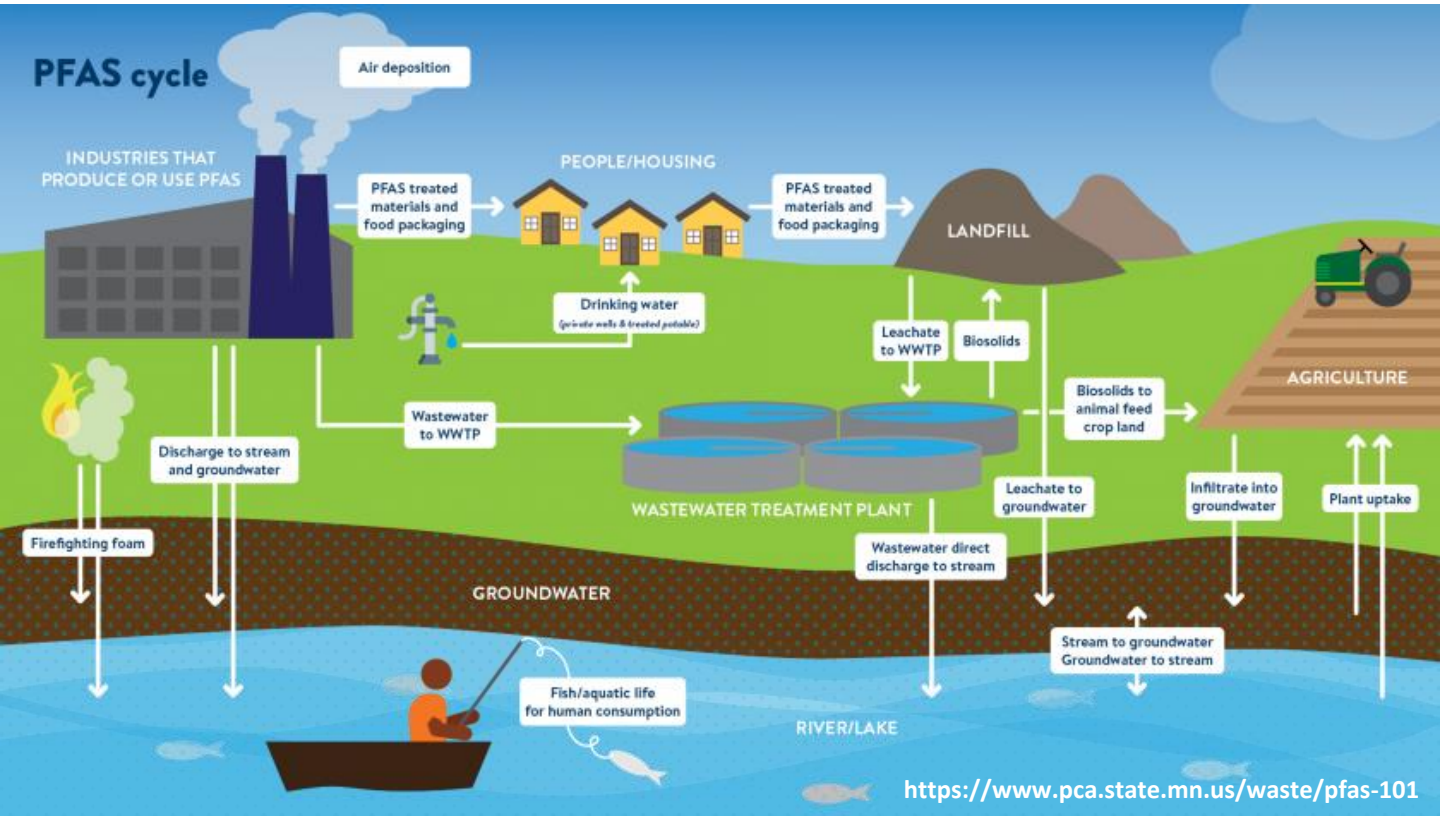
Does the organization have a fiscal agent for this project?

No

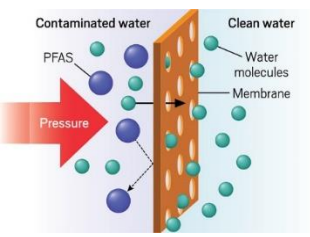
https://www.defence.gov.au/Environment/pfas/PFAS.asp



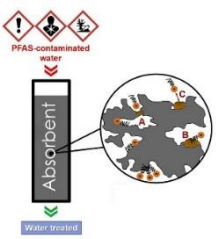
https://www.pfasfacts.com/



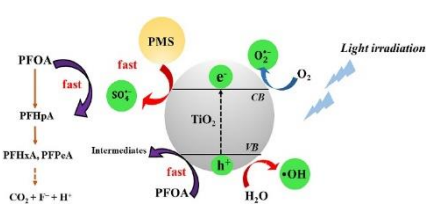
Proposed Methods to Destruct PFAS



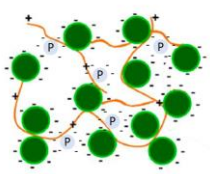
Separation



Absorption



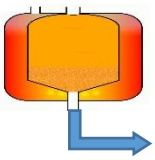
Photocatalysis



P - PFAS

- Algae

- Flocculants



- Pyrolysis

- biofuel, biochar