Environment and Natural Resources Trust Fund

M.L. 2022 Approved Work Plan

General Information

ID Number: 2022-049

Staff Lead: Corrie Layfield

Date this document submitted to LCCMR: May 31, 2022

Project Title: Methods to Destroy PFAS in Landfill Leachates

Project Budget: $200,000

Project Manager Information

Name: Roger Ruan

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Project Reporting

Date Work Plan Approved by LCCMR: June 27, 2022

Reporting Schedule: March 1 / September 1 of each year.

Project Completion: June 30, 2025

Final Report Due Date: August 14, 2025

Legal Information

Legal Citation: M.L. 2022, Chp. 94, Art. , Sec. 2, Subd. 04a

Appropriation Language: $200,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to develop and examine methods for destruction of per- and polyfluoroalkyl substances (PFAS) in landfill leachate. This appropriation is subject to Minnesota Statutes, section 116P.10.

Appropriation End Date: June 30, 2025

Narrative

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

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? 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 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.

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

Activities and Milestones

Activity 1: Evaluate separation/sorption processes methods

Activity Budget: $60,000

Activity Description:

Activity Description:

Two separation methods and one sorption method will be evaluated. For ion exchange treatment, organic scavenger resin and PFAS-specific resin will be used to remove PFAS. The resin dosage of 0.04–2 mL in 1 L of leachate will be examined. After the mixing, the resin is separated from the treated leachate by filtering through a 0.45 µm filter. The concentration of PFAS in the filtrate will be analyzed and the resin is regenerated by mixing with NaCl (10%). For nanofiltration (NF) treatment, commercial NF membranes will be used to separate PFAS from leachate. For sorption using biochar, we will use the biochar produced in-house as a byproduct of our microwave assisted pyrolysis of biomass and sludge. A wastewater treatment protocol described in a previous study will be adapted to the experiments in this project. For bioflocculation, we will cultivate microalgae on leachate. Microalgae use nutrients in leachate. The harvested biomass together with PFAS will be pyrolyzed to decompose PFAS and produce biofuel and biochar using the catalytic microwave assisted pyrolysis developed in our lab as mentioned above. The biochar will be used as the absorbent used in the sorption process described above.

Activity Milestones:

Description	Approximate Completion Date
Sampling protocols are developed	September 30, 2022
Processes and experimental apparatuses are set up	March 31, 2023
Removal of PFAS by individual treatments is examined	June 30, 2023

Activity 2: Develop and evaluate destruction methods

Activity Budget: $60,000

Activity Description:

Photocatalysis will be investigated alone and in combination with other processes, namely Intense pulsed light (IPL) and Non-thermal plasma (NTP). A photocatalytic reactor will be fabricated in-house and loaded with commercial photocatalysts with UVC illumination at 254 nm to activate the photocatalysts. Photocatalyst dosage of 10-100 gram is mixed with 1 L of leachate and placed in the reactor with UVC lamp on and off for 1-24 hours. IPL is expected to degrade PFAS directly as well as create synergy with the photocatalysts. A protocol described in our previous study will be followed for the treatment of leachate that is pre-mixed with known dosage of photocatalyst. NTP is normally generated in gaseous condition. Our lab has developed a unique reactor that generates concentrated high intensity electric field (CHIEF) and NPT in liquid when gas bubbles are present in the liquid. This novel technology has not been used to destruct PFAS in liquid. In our study, we will treat leachate that is pre-mixed with known dosage of photocatalysts and other NPT specific catalysts in this CHIEF reactor. The PFAS levels will be determined periodically during the treatments.

Activity Milestones:

Description	Approximate Completion Date
Photocatalytic reactor is set up	September 30, 2023
Removal of PFAS by photocatalysis alone is examined	December 31, 2023
Removal of PFAS by catalytic IPL is examined	March 31, 2024
Removal of PFAS by catalytic NTP is examined	June 30, 2024

Activity 3: Evaluate Combined process/treatment train

Activity Budget: $50,000

Activity Description:
After individual treatments are evaluated in Activities 1 and 2, top performing treatments and conditions will be selected and a treatment train will be designed, tested, and optimized for maximal PFAS destruction at minimal cost. Synergetic effects will be examined.

Activity Milestones:

Description	Approximate Completion Date
Treatment train is designed	September 30, 2024
Removal of PFAS by the treatment train is examined	March 31, 2025

Activity 4: Study kinetics and conduct preliminary evaluation of environmental impacts

Activity Budget: $30,000

Activity Description:
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	Approximate 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	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.
The purpose of this dissemination plan is to solicit input of relevant industries, build awareness of problems and solutions, and educate stakeholders with the findings from the project. Key stakeholders landfill operators, manufacturers who dump wastes containing PFAS, entities who provide environment mitigation and restoration services, state environmental control agencies, students, and researchers. To build awareness, we will communicate with the stakeholders and general public through holding zoom brief meetings, website, and presentations at meetings organized by trade groups and professionals. To educate the stakeholders, public information on the demonstration project will be designed and delivered to both technical and non-technical audiences. We will encourage active participations of others such as personnel from UMN outreach centers, animal waste management firms, etc. We will welcome visits to project site by stakeholders throughout the project period. A final demonstration will be held on UMN St. Paul campus. The announcement of the demonstrate event will be sent to stakeholders including LCCMR members and staff in advance. Technical findings will be presented in conferences and published on peer-reviewed journals. Through these activities, we hope to promote the changes in behavior of the stakeholders and general public to reduce PFAS emissions and support research and development that mitigate the problems caused by PFAS. In all the activities, we will acknowledge the Environment and Natural Resources Trust Fund through use of the trust fund logo or attribution language on project print and electronic media, publications, signage, and other communications and outreach.

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 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

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 for analysis of complex PFAS compounds, characterization of physical and chemical properties of catalysts				0		$5,000
							Sub Total	**$5,000**
Equipment, Tools, and Supplies								
	Tools and Supplies	No capital equipment over $5,000 will be purposed. The requeste funds are for purchase of small equipment and components such as ion exchange and membrane separation devices, absorbents, photocatalysts, and supplies for algae cultivation.	Setting up ion exchange and membrane separation experimental devices, fabricating photocatalytic reactor, modification of existing IPL and NTP reactors, 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				
Cash	University of Minnesota Budget	Waived overhead	Secured	$81,234
			Non State Sub Total	**$81,234**
			Funds Total	**$81,234**

Attachments

Required Attachments

Visual Component

File: f3f65acc-8f5.pdf

Alternate Text for Visual Component

The visual graphics illustrate the source of PFAS, representative molecular structure, PFAS cycle in the environment, and the proposed methods to be examined....

Optional Attachments

Support Letter or Other

Title	File
Visual graphic	51703b83-b14.pdf
Institutional Approval for Submission	b68c5140-c24.pdf
Background check	79bc2b33-e31.pdf
Research Addendum	53994cf6-8db.pdf

Difference between Proposal and Work Plan

Describe changes from Proposal to Work Plan Stage

No major changes to the proposal. The Activities and Milestones have been rearranged according to the comments; more specific details were added; however the technical approach has not been modified.

Additional Acknowledgements and Conditions:

The following are acknowledgements and conditions beyond those already included in the above workplan:

Do you understand and acknowledge the ENRTF repayment requirements if the use of capital equipment changes?

N/A

Do you agree travel expenses must 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 agree to the UMN Policy.

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

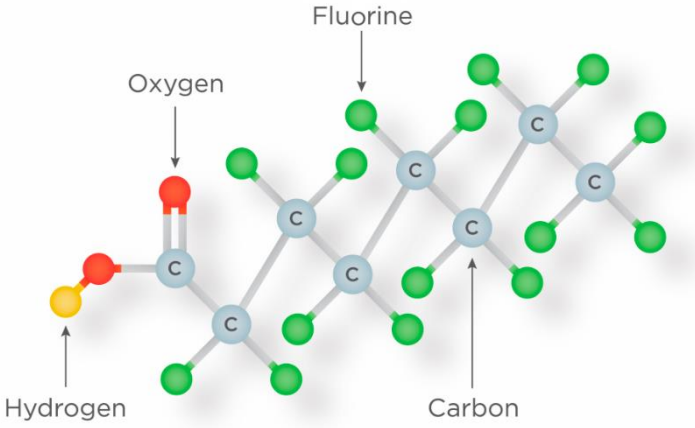
Does your project include original, hypothesis-driven research?

Yes

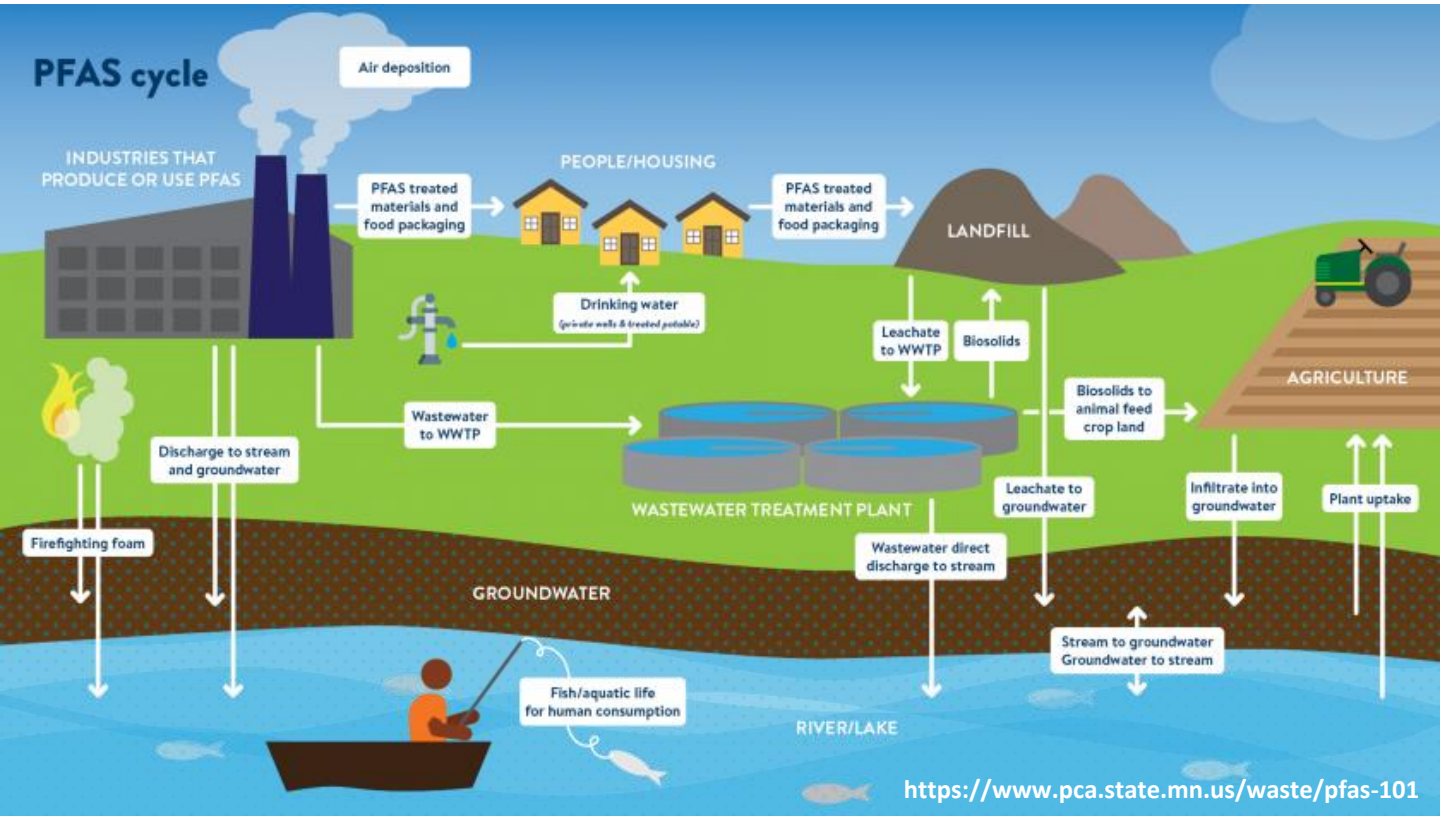
Does the organization have a fiscal agent for this project?

No

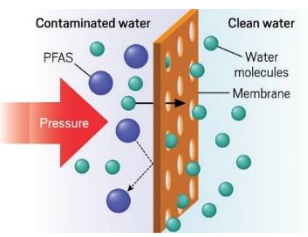
https://www.defence.gov.au/Environment/pfas/PFAS.asp



https://www.pfasfacts.com/

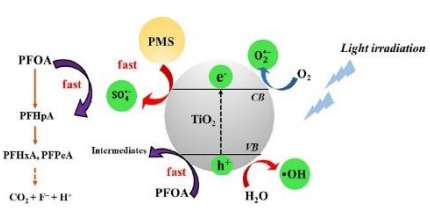


Proposed Methods to Destruct PFAS

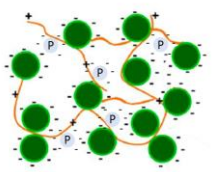


Separation

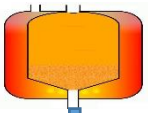
Absorption



Photocatalysis



- PFAS
- Algae
- Flocculants



- Pyrolysis
- biofuel, biochar