Environment and Natural Resources Trust Fund

2023 Request for Proposal

General Information

Proposal ID: 2023-191

Proposal Title: Understanding Plastic Pollution Beyond Microplastic in Minnesota Waters

Project Manager Information

Name: Boya Xiong

Organization: U of MN - College of Science and Engineering

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Project Basic Information

Project Summary: We will study how ubiquitous microplastic form potentially toxic chemicals during wastewater treatment or in Minnesota's waterways. The study will inform us to prevent toxic compounds from generating from microplastics.

Funds Requested: $424,000

Proposed Project Completion: June 30, 2026

LCCMR Funding 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.

About 25% of plastic leaks into Minnesota's waterways and soils, where it breaks down into small microplastic particles (less than 5 mm) via mechanical and sunlight-driven processes. We have evidence of the abundance of microplastics in Minnesota's water and wastewater, and the quantity of microplastic in Minnesota's water is likely to double in just 13 years. To fully assess impacts to environmental and human health, we need to understand how plastics breakdown and the products that form. Potential breakdown products are 1) toxic or endocrine disruptive polymer fragments and chemicals such as bisphenol S and styrene, 2) plastic additives, such as phthalates, which have suspected biological effects, or 3) non-toxic polymer fragments. Microplastics are also known to sorb other pollutants, thus altering the typical degradation pathways of these pollutants. The objective of this proposal is to understand the processes that occur in UV disinfection of wastewater treatment, oxidation ponds (i.e., rural wastewater lagoons), and natural systems that lead to the formation of toxic versus non-toxic byproducts from different types of plastic polymers. With this information, we will help inform the use and design choices of consumers and plastic manufacturers as well as our future regulations on microplastics.

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 fill this knowledge gap by detecting the unknown toxic compounds released from microplastic degradation. We will then measure the rate of release of those compounds driven by natural processes and under wastewater treatment conditions. We will also examine the degradation of pollutants that are sorbed onto microplastics. Specific goals are to:

- Identify toxic and non-toxic byproducts formed from microplastics during the wastewater treatment and natural processes, focusing on sunlight-driven processes.
- Determine treatment and natural conditions that dictate the rate of toxic product formation from microplastics
- Develop a model to predict the long-term leaching rate of chemicals and polymer fragments .
- Assess the degradation of co-pollutants (e.g., contaminants of emerging concern) that are sorbed onto the surfaces of microplastics.
- Disseminate the findings to water utilities, the MN Department of Health, MN plastic manufacturers, and the public.

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 work will identify the types of plastics that are likely to release toxic chemicals during their degradation, and in what engineered and natural processes are toxic chemicals forming at a faster rate. We will also identify microplastics that are "protectors" of co-pollutants sorbed onto microplastic surfaces from natural degradation processes. These finding will aid in identifying which materials and the processes that lead to release of any toxic byproducts, and whether additional treatment or regulatory steps are required. The ultimate outcome is to reduce the impact of microplastic pollution in Minnesota's waterways and natural resources.

Activities and Milestones

Activity 1: Identify toxic and non-toxic byproducts formed from microplastics during wastewater treatment and natural processes

Activity Budget: $142,014

Activity Description:
We will evaluate a wide range of single-use plastics, including shopping bags, packaging wraps, food-grade products (e.g., coffee cups and baby bottles), and plastic pipes (e.g., PVC and HDPE). Micro-scale plastic particles will be produced in the laboratory from these bulk plastic materials using a cryo-milling process. Laboratory-scale weathering experiments will be performed in water simulating UV processes in wastewater treatment and natural surface water. We will use high-resolution mass spectrometry instrumentation to identify byproducts formed. Because many of the byproducts have unknown biological effects, we will utilize standardized biological assays and toxicity tests to screen for potential toxic byproducts. The hypothesis to be tested is that microplastics that are made of a range of additives and polymers break down into smaller polymer fragments and byproducts that have the potential for environmental persistence and aquatic toxicity. The outcome of this activity will identify plastic materials that have the highest potential to form toxic byproducts.

Activity Milestones:

Description	Completion Date
Identify potentially toxic byproducts from microplastic weathering in natural surface water under sunlight.	June 30, 2024
Identify potentially toxic byproducts in leachate of microplastic weathering under advanced treatment conditions (UV disinfection).	June 30, 2024
Determine the relative biodegradability and toxicity of the byproducts formed during weathering of microplastics.	December 31, 2024

Activity 2: Measure and predict the rate of toxic byproduct formation under various treatment and natural conditions

Activity Budget: $143,038

Activity Description:
After identifying potential toxic byproducts from specific polymer products, it is important to learn which natural and treatment conditions will yield fast release of these products. Natural organic matter (NOM), which is abundant in all water sources, is well known to generate reactive species that trigger the degradation of organic pollutants. NOM may potentially accelerate the leaching of these byproducts from microplastics. In wastewater treatment, various intensities of oxidation and UV disinfection processes could also accelerate the leaching of toxic byproducts. Lastly, microplastics can continue to breakdown into smaller particles, exposing more surfaces to environmental conditions and increasing the potential to leach byproducts. We will measure the rates of byproduct leaching under these conditions so that we can build a predictive model to estimate the long-term release rate of these byproducts. This activity will identify which environmental and treatment processes have the greatest potential to quickly generate toxic byproducts and yield concentrations in our water that may pose a risk to human health and aquatic life. This activity will also generate a model that predict the releasing of toxic product in the long term.

Activity Milestones:

Description	Completion Date
Determine the effect of light, temperature, and natural organic matter on the releasing rate	June 30, 2025
Determine the effect of UV disinfection conditions during wastewater treatment on the leaching rate	December 31, 2025
Determine the effect of microplastic size on the leaching rate of toxic byproducts.	December 31, 2025

Develop a model to predict the potential long term release of toxic byproducts.	December 31, 2025

Activity 3: Assess whether microplastics suppress or enhance degradation of co-pollutants sorbed to the surface of microplastics.

Activity Budget: $138,948

Activity Description:

In addition to being a source of pollution, we know that microplastics can sorb a wide range of dissolved chemical pollutants from the surrounding water, such as pharmaceuticals, pesticides, and PFAS. It is less known, however, whether microplastics could affect the natural degradation and persistence of these co-pollutants in aquatic environments and during wastewater treatment. Microplastics are likely to affect the degradation of pollutants in complex ways: 1) microplastics could quench reactive species formed from NOM that otherwise could degrade the free, non-sorbed pollutants, 2) microplastics can generate reactive radicals themselves that could degrade pollutants sorbed onto the microplastic surface, and 3) microplastics can attract microbes to colonize their surfaces and allow faster biodegradation of the pollutants. Lastly, chemicals on a surface are known to have a different reactivity than their free state. We will measure the degradation and persistence of a few representative pollutants that are sorbed onto microplastics, under natural water and advanced treatment process. We will determine if the co-pollutants sorbed to microplastic are indeed more persistent or degrade faster, or if they could degrade into toxic products. We can gain insight on the role of microplastics on a wide range of organic pollutants in our waterways.

Activity Milestones:

Description	Completion Date
1. Determine reactive species generated by microplastics alone from sunlight exposure.	June 30, 2026
Compare the degradation rate of both free and microplastic-sorbed pollutants in various conditions	June 30, 2026
Compare the biodegradation rate of free and microplastic-sorbed pollutants in various conditions	June 30, 2026

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Bill Arnold	University of Minnesota; Dept. of Civil, Environmental, and Geo-Engineering	Dr. Arnold will lead the design of photochemistry experiments and analytical method of detecting chemicals.	Yes
Andrew McCabe	Barr Engineering	Dr. McCabe will assist and consult design on photochemical experiments that simulate Minnesota's condition and high-resolution mass spectrometry analysis.	Yes
Sara BinAhmed-Menzies	Barr Engineering	Dr. BinAhmed-Menzies will advise on plastic degradation characterization in various light and water conditions	Yes

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 will be disseminated to industry, MPCA, practitioners, and other state agencies through open access publications, direct meetings, and conference presentations. If additional work is needed, Dr. Xiong will seek funding at National science Foundation and polymer industry partners.

Project Manager and Organization Qualifications

Project Manager Name: Boya Xiong

Job Title: Assistant professor

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

Dr. Xiong is an expert on polymer science and plastic pollution, particularly advanced material and chemical analysis to understand polymer degradation, in particular how nano- and micro-scale plastics are generated from bulk plastic materials. She is also developing advanced mass spectrometry-based tools to identify polymer fragments that could potentially be toxic. She has 23 manuscripts published in the peer-reviewed technical literature on polymer degradation, materials research related to environmental applications.

Organization: U of MN - College of Science and Engineering

Organization Description:

The University of Minnesota is one of the largest, most comprehensive, and most prestigious public universities in the United States, leading research areas including water quality and material science (http://www1.umn.edu/twincities/01_about.php). The laboratories of the PI and/or core facilities at the University of Minnesota contain the entire essential fixed and moveable instrumentation needed for the proposed studies.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Project manager		Dr. Xiong will supervise all activities including detecting toxic pollutants in activity 1, characterizing plastic degradation in activity 1 and 2, and evaluate the role of microplastics on other pollutants in activity 3			33.5%	0.06		$30,031
Co-investigator		Dr. Arnold will oversee photochemical experimental design and determining the releasing rates of toxic compounds in all activities			33.5%	0.06		$52,864
Graduate student		Perform plastic degradation, biodegradation and toxicity, and analytical chemistry experiments in all activities			23.6%	1.5		$157,933
Undergraduate student		assist graduate student			0%	0.18		$21,840
							Sub Total	**$262,668**
Contracts and Services								
Barr Engineering	Professional or Technical Service Contract	Dr. McCabe will assist and consult design on photochemical experiments that simulate Minnesota's condition in activity 1 and 2 and high-resolution mass spectrometry analysis in activity 1.				0.03		$22,500
Barr Engineering	Professional or Technical Service Contract	Dr. BinAhmed-Menzies will advise on plastic degradation and microplastic characterization in various sunlight and water conditions in all activities.				0.03		$22,500
							Sub Total	**$45,000**
Equipment, Tools, and Supplies								
	Tools and Supplies	Laboratory Supplies	Chemicals, solvents, materials, and labware necessary to perform the experiments					$51,000
	Tools and Supplies	Toxicity assay	To measure the toxicity of degraded chemicals					$10,000

	Tools and Supplies	Instrument maintenance	repair and upkeep of laboratory instruments needed for the project					$15,000
	Tools and Supplies	Instrument time	Hourly fees for use of high resolution mass spectrometry instrumentation and EPR for detecting radicals					$28,332
							Sub Total	**$104,332**
Capital Expenditures								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Conference Registration Miles/ Meals/ Lodging	conference attendance by graduate students (3 conferences for one student) and PI	disseminate results					$3,000
							Sub Total	**$3,000**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
	Publication	Open access journal fees	maximize dissemination of results of the project					$9,000
							Sub Total	**$9,000**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$424,000**

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: 3239d331-e27.pdf

Alternate Text for Visual Component

Microplastics are ubiquitous pollutants in Minnesota waterways. Toxic pollutants have been found during some plastic breakdown. We will screen a broad range of pollutants and determine and predict which plastic and environment will release toxic product the quickest. Use and design of plastic can be less harmful to Minnesota's water....

Optional Attachments

Support Letter or Other

Title	File
LOC 1078441	6ad79ce2-5a0.doc
Letter of support_MP_barr	6270a1be-b41.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?

No

Do you understand and acknowledge IP and revenue-return and sharing requirements in 116P.10?

N/A

Do you wish to request reinvestment of any revenues into your project instead of returning revenue to the ENRTF?

N/A

Does your project include original, hypothesis-driven research?

Yes

Does the organization have a fiscal agent for this project?

Yes, Sponsored Projects Administration

Beyond microplastic: toxic byproduct releasing from plastic breakdown in waterways and wastewater treatment