Environment and Natural Resources Trust Fund

2021 Request for Proposal

General Information

Proposal ID: 2021-170

Proposal Title: Minimizing Plastic Pollution Through Prediction Of Nano/Microplastic Generation

Project Manager Information

Name: Boya Xiong

Organization: U of MN - College of Science and Engineering

Office Telephone: (612) 625-5522

Email: bxiong@umn.edu

Project Basic Information

Project Summary: We will model the concentration of nano/microplastic generated from weathered bulk plastic, enabling accurate estimation of plastic pollution in Minnesota's waterways and informing what plastic products are harmful.

Funds Requested: $200,000

Proposed Project Completion: 2023-06-30

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?
In the Future

Narrative

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

Due to the disposable nature of many plastic products, 75% of plastic quickly turns into waste that is difficult to recycle. It therefore leaks into and pollutes Minnesota's water in the form of nano- and micro-size particles, called nano/microplastics. These particles threaten Minnesota's water resources because: 1) microplastic can be eaten by aquatic organisms that may lead to death, and 2) microplastic releases/ adsorbs unknown chemicals and toxic contaminants, creating "hotspots" of contaminants in waterways. Citizens can also consume microplastics via drinking plastic-tainted water and beverages in Minnesota. Looking forward, the quantity of microplastic in Minnesota's water will drastically increase in very near future due to 1) a recent collapse of international recycling markets; 2) the fact that the total plastic production in the next 15 years will outweigh all past production since 1960s. It is urgent for us to know how much nano/microplastic is and will be in Minnesota's water. However, field sampling is time-consuming and costly; more importantly, it is extremely difficult to capture nano size range plastic particles in natural samples, due to the challenge in separating plastic and natural nanoparticles. These size range particles are particularly believed to be harmful.

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 determine and model the size and concentration (rate) of nano/microplastic generated from common single-use plastics under weathering conditions consistent with Minnesota's climate and hydrology. Studies have shown the major fraction of nano/microplastic originates from the breakdown of weathered bulk plastics. Plastic material becomes brittle first by sunlight and then breaks down by abrasion when flowing with sediments in a stream or in a turbulent flow in the aeration tanks of wastewater treatment plants, forming nano/microplastics.
First, we will weather various plastic products using a customized solar simulator that can mimic Minnesota's climate. The photoweathered plastic will then be broken down under various flow conditions using customized flow cells, to simulate flow in rivers or mixing in wastewater treatment plants. We will use state-of-art nanoparticle analysis techniques to measure the size, concentration, and surface properties of nano/microplastics. Second, we will establish a new model that correlates particle generation with climate and hydrology, which will be validated with field experiments in the St. Anthony Falls Lab stream lab and a wastewater treatment plant. We will also compare the particles generated with different plastic types, and determine which plastic products generate more nano/microplastics.

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 can be used to estimate nano/microplastic pollution in Minnesota's waterways and quantity of human consumption. Identifying spatial and temporal hotspots of nano/microplastic in waterways will inform managers of Minnesota's water resources about when and where targeted pollution control is needed. The comparison of nano/microplastic generation potential of different plastic products can influence consumers' choice on plastic products and raise awareness regarding the need to reduce disposable plastic use. In the long term, these results provide criteria for plastic manufacturers to design plastic chemistries and processing methods with reduced particle formation.

Activities and Milestones

Activity 1: Determine the rate of nano/microplastic generation from photoweathered plastic under various flow conditions

Activity Budget: $107,120

Activity Description:
We will weather a variety of common single-use plastics with different chemistries, thicknesses, and shapes (i.e., film, sheet, and fiber) in a newly constructed large-scale solar simulator to simulate Minnesota's weather. We will then introduce the weathered plastic into two flow cells that simulate slow flow (e.g., streams) and bubbled turbulent flow (e.g., aeration tanks) with and without sand particles. We will employ microscopy and light scattering-based tools to measure a full size range of particles (from <100 nm all the way to mm size). In addition, plastic manufacturers rely on material properties to design and optimize plastic products. Thus the knowledge of what material properties are linked to generating microplastics is critical in guiding manufacturers to design future plastic products that do not generate microplastics. Therefore, we will also measure plastic chemical and mechanical properties of plastic during photoweathering. These material parameters will then be correlated with particle generation.

Activity Milestones:

Description	Completion Date
Weather a diversity of plastic samples in a solar simulator that simulates Minnesota's weather	2022-06-30
Determine what chemical and mechanical properties of plastics that are critical to nano/microplastic generation	2022-12-31
Determine the rate and size of nano/microplastic from photoweathered bulk plastic by shear flow	2022-12-31

Activity 2: Construct a model to predict nano/microplastic generation and validate with field experiments

Activity Budget: $92,880

Activity Description:
We will use the data in activity 1 to develop a predictive model that describes the size and concentration of particles for given a plastic type, as a function of weathering conditions (e.g., light intensity, temperature, and shear rate). To validate the lab-scale model, we will measure particle generation of outdoor weathered plastics that will be mounted into the stream facilities at the Saint Anthony Falls Laboratory and aeration tanks in a wastewater treatment plant over one to two month. Nano/microplastics will be generated under various flow rates and mixing intensities, and analyzed to generate data for model validation. To quantify nano/microplastic in actual stream and wastewater samples, we will first concentrate plastic nanoparticles in a large sample volume using membrane filtration, followed by fractionating particles by their size, and identifying particle chemistry using mass spectrometry. Particle size and concentration will be used to validate the lab model.

Activity Milestones:

Description	Completion Date
Construct a linear regression model that correlates nano/microplastic generation with weathering and flow conditions	2022-12-31
Validate the model with field experimental data	2023-06-30
Measure nano/microplastics generated in stream facilities and wastewater treatment plants	2023-06-30

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?

I will disseminate the research results that describes the predicted concentration of nano/microplastic in wastewater effluent and surface waters to the Minnesota Pollution Control Agency. I plan to submit a proposal to the National Science Foundation to further study the mechanisms and dynamics of abrasion, erosion, and fragmentation of photoweathered plastic. I will also deliver the findings of this work to local plastic industries (e.g., 3M), and seek funding and collaboration to investigate how changing polymer chemistry and processing conditions can tune plastic with controllable weathering and nano/microplastic generation properties.

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 currently a post-doctoral research associate at the Massachusetts Institute of Technology. She will begin her appointment in August 2020 as an assistant professor at the University of Minnesota in the Department of Civil, Environmental, and Geo- Engineering. Her research primarily focuses on polymer degradation and advanced organic chemical analysis to guide sustainable municipal and industrial treatment process and materials design. In particular, she designed a novel high-pressure reactor to simulate the mechanical degradation of polymer, and is developing advanced mass spectrometry based tools to identify polymer fragments. She has 14 manuscripts published in the peer-reviewed technical literature.

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								
Principle Investigator		Lead the project, design experiment, supervision of graduate students			27%	0.1		$18,348
Graduate student		Design experimental details, perform weathering, and shearing experiments, material and particle characterization			43%	1		$102,444
Undergraduate student		Assist solar simulator and flow cell construction, particle counting, and field experiments			0%	0.18		$5,460
							Sub Total	**$126,252**
Contracts and Services								
OceanInsights	Professional or Technical Service Contract	OceanInsights provide calibration service to the spectraradiometer so we can measure solar irradiance accurately.				-		$1,000
University of Minnesota, Characterization facility	Internal services or fees (uncommon)	The characterization facility provides service and shared instruments so that we can characterize the property of plastic change during photodegradation.				-		$12,792
Minnesota Nano Center	Internal services or fees (uncommon)	Minnesota Nano Center provides instruments and services so that we can characterize the size and concentration of generated microplastic.				0		$15,656
Mass spectrometry lab in Department of Chemistry	Internal services or fees (uncommon)	Mass spectrometry lab provides service to specifically identify the chemistry of plastic particles in natural stream and wastewater samples, where other non plastic particles are also present as interferences.				0		$5,000
							Sub Total	**$34,448**
Equipment, Tools, and Supplies								

	Equipment	Radiospectrometer	to measure irradiance of solar simulator and the actual solar output in Minnesota					$4,000
	Tools and Supplies	Solar simulator and the supplies, including frame, reflector, light bulbs, thermometer, light housing, humidifier	To simulate sunlight that cause photodegradation of plastic					$6,300
	Tools and Supplies	Plastic samples	Plastic samples are the object of this study					$1,000
	Tools and Supplies	Regular lab consumables (filters, analytical standards, chemicals, particle standards, and beakers)	To maintain regular experiments in a wet lab					$4,000
							Sub Total	**$15,300**
Capital Expenditures								
		flow cell and pumps	To simulate waves and flows that breaks down plastic in nature					$10,000
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							Sub Total	**$20,000**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
							Sub Total	**-**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
	Publication	publications	Publication charges to make the journal article publication open access					$4,000
							Sub Total	**$4,000**
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				
In-Kind	University of Minnesota	facilities/administratve costs (55% of direct costs excluding permanent equipment and graduate student tuition) are provided in-kind	Potential	$80,931
			State Sub Total	**$80,931**
Non-State				
			Non State Sub Total	**-**
			Funds Total	**$80,931**

Attachments

Required Attachments

Visual Component

File: 898efb49-91c.pdf

Alternate Text for Visual Component

Predicting plastic breakdown into nano/microplastics help us estimate the true plastic pollution in Minnesota's waterways

Administrative Use

Does your project include restoration or acquisition of land rights?

No

Does your project have patent, royalties, or revenue potential?

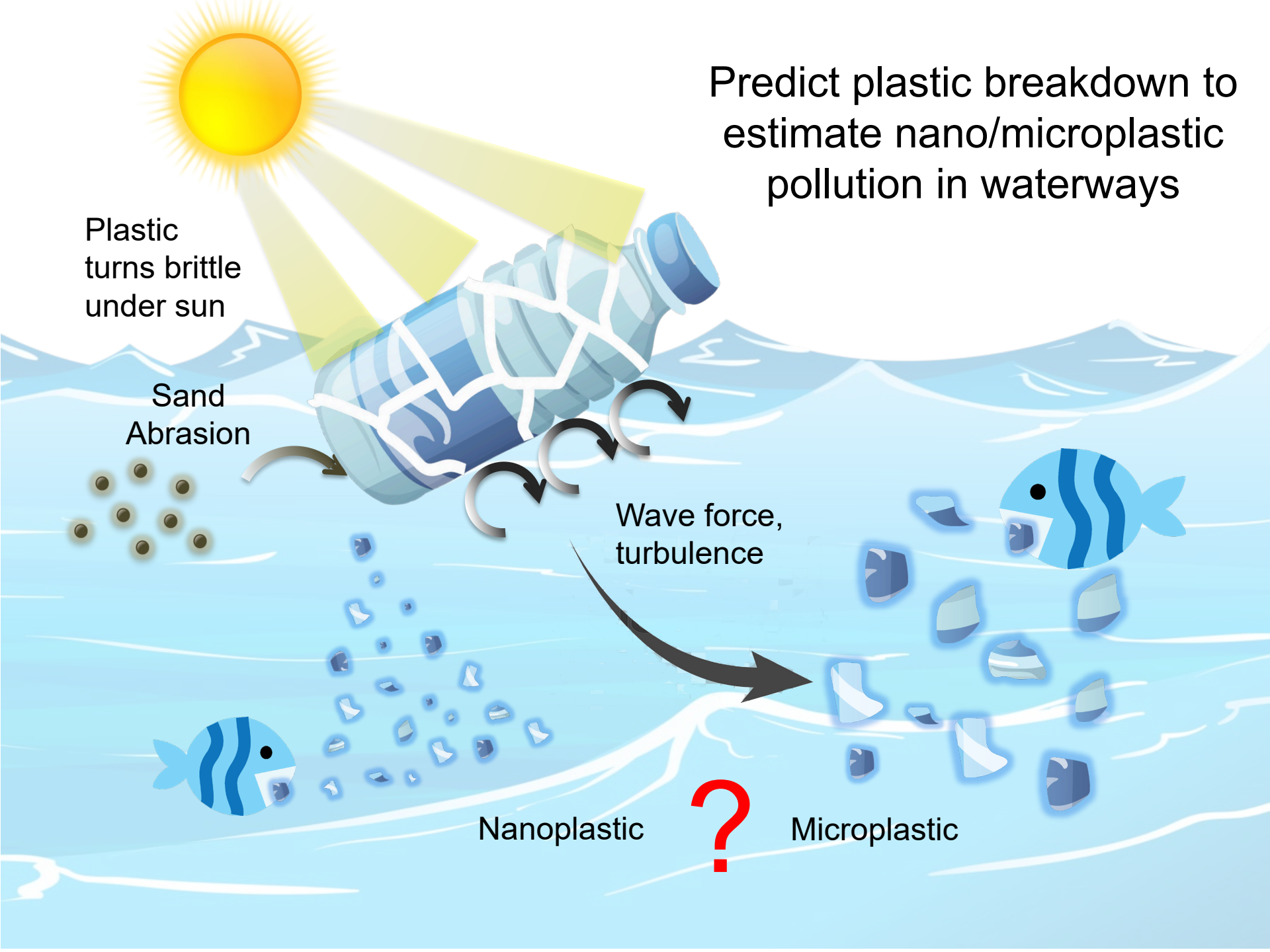
No

Does your project include research?

Yes

Does the organization have a fiscal agent for this project?

Yes, Sponsored Projects Administration


Predict plastic breakdown to estimate nano/microplastic pollution in waterways
Plastic turns brittle under sun
Sand Abrasion
Wave force, turbulence
Nanoplastic
?
Microplastic