Environment and Natural Resources Trust Fund

2024 Request for Proposal

General Information

Proposal ID: 2024-254

Proposal Title: Novel Laundry Filters to Reduce Microfiber Pollution

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 make a novel and effective laundry filter that can capture all types of microfibers to reduce plastic pollution in Minnesota's waterways.

Funds Requested: $230,000

Proposed Project Completion: August 31, 2027

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?

In the Future

Narrative

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

Minnesota's water, such as the Mississippi River and Lake Superior, has been polluted with microplastics. These tiny particles (<5 mm) are of critical concern because they have known and suspected ecological and human health impacts and can ultimately enter our food chain. These health effects are complexed by toxic contaminants that can be adsorbed by or leached from microplastics. Microplastics in the form of fibers (i.e., micro- and nano-fibers) are the most prevalent type found in environments across the globe, including Minnesota. This is evidenced by microplastic sampling at the Lake Superior water column and fish body collected in the Mississippi River. The primary source of microfiber pollution is from household apparel washing. Daily, laundry wastewater tainted with billions of microfibers enters wastewater systems from which they leak into water bodies and farmlands. Luckily, a recent study highlighted that removing microfibers before entering the wastewater system is the most effective strategy. In particular, installation of in-line filters in washing machines will reduce microfiber pollution by 79%. Compared to other strategies that require significant capital investments on recycling infrastructures, installing laundry filters could be a cheap, tangible, and yet highly effective at mitigating a large fraction of the plastic pollution.

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.

A novel, effective, green filter that captures all types of microfibers from laundry wastewater will be developed to stop microfiber pollution in Minnesota's water at its source. Current commercial products for reducing microfibers such as Cora Ball can only remove 20-50% microfibers. We propose to incorporate two types of coating onto a cellulose filter that could capture all types and sizes of microfibers. One of the coatings will be a positively charged protein layer that is targeted towards microfibers with negative charges at all sizes (e.g., polyester fibers). A similar approach using a synthetic polymer coating was found to remove >95% nanoplastics in 40 minutes. The other coating will be a pressure sensitive adhesive (a similar adhesive used in sticky notes) that is targeted towards all other microfibers with little surface charge (e.g., nylon). A similar coating on large beads can stick and remove 100% microplastics in only 5 minutes. Furthermore, both coatings are nontoxic and will be made from plants or polymer waste, innovating materials to address pollution without creating new pollution. This novel dual coating filter will be tested with simulated laundry wastewater containing different size microfibers and real-life laundry wastewater.

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?

Microfiber pollution poses an urgent and growing problem in Minnesota's environment. The leak of microfibers from households threatens fishery, agriculture industry, and our ecosystem and human health. Since microfibers are a major type of microplastic pollution, reducing their leak into the environment will effectively manage the overall pollution. Instead of burdening wastewater treatment systems, stopping microfiber leakage at its source could be a simple solution that leads to significant microfiber reduction in short-term. This work will create such a cheap, effective, and green filter to better protect and enhance Minnesota's resources, environment, and benefits to human health.

Activities and Milestones

Activity 1: Develop a novel filter to capture synthetic microfibers in lab.

Activity Budget: $74,522

Activity Description:
To remove negatively charged microfibers, we will extract a naturally abundant and nontoxic protein with strong positive charges from the seeds of a plant called Moringa Oleifera, using our previously published methods. With this protein, we successfully created a highly adsorptive sand filter to remove 99.999999% pathogens (including nanosized viruses). To remove nanofibers with near neutral surface charge, we will incorporate pressure sensitive adhesive coating into our filter. The adhesive polymer coating will be synthesized via a one-step reaction using polyacrylic acid which is a main ingredient of waste diaper. Protein and adhesive polymer coating will be applied separately onto cellulose filter substrate and stacked to create the final filter. To test the efficiency of removing microfibers, microfibers from nanometer to micrometer size will be prepared via cryomilling of commercial fabrics. We will include negatively charged microfibers, such as polyester and acrylic, and near neutral charge fibers, such as nylon, polypropylene, silk, and wool. Microfibers < 1 µm will be quantified using nanoparticle tracking analysis; microfibers at 1-100 µm and >100 µm will be quantified using optical microscopes. We expect both charges and all sizes can be effectively removed up to 99% by dual adsorptive filter.

Activity Milestones:

Description	Approximate Completion Date
Create a dual layer adsorptive filter	June 30, 2025
Prepare microfiber samples with various sizes, surface charges, and concentrations	August 31, 2025
Test adsorptive filter via filtration of microfibers	December 31, 2025

Activity 2: Optimize the filter with real laundry conditions and wastewater.

Activity Budget: $82,698

Activity Description:
Using lab prepared microfibers, we will test removal under different flow rates and microfiber concentrations of that are relevant to actual laundry condition. To ensure the filter removal efficiency is consistent across different wastewater quality, filtration will also be performed using microfibers suspended in different amounts and types of laundry detergent and temperature. We anticipate both protein and adhesive coatings are stable under surfactants and elevated temperature. Furthermore, the breakthrough point (lifetime) of the filter would be determined as when the leakage of microfibers elevates by 10-20%. Lastly, we will test our adsorptive filter with three real laundry wastewaters, generated via rigorous washing modes from a household laundry machine in volunteered homes. Microfiber type and concentration in raw and filtered water will be determined using optical microscopy, µFTIR, and mass-based measurements. A longer and thicker filter and more protein and adhesive coating can be used to enhance filter capacity. A regeneration protocol for both coatings will be established after the collected microfibers from used-up filters can be carefully collected and disposed. We anticipate our filter can outcompete the lifetime of current commercial product such as Planetcare, which lasts around 20 wash cycles before a replacement is required.

Activity Milestones:

Description	Approximate Completion Date
Measure filter efficiency under actual laundry conditions (flow rate, temperature, and surfactant concentration)	June 30, 2026

Determine filter capacity and lifetime by continuous filtration and revise filter to achieve desirable capacity	June 30, 2026
Test filters with actual laundry wastewater	August 31, 2026
Develop a clean-up and regeneration protocol for used-up filters	December 31, 2026

Activity 3: Calculate reduction of microfibers into Minnesota's water with and without filter installation.

Activity Budget: $72,780

Activity Description:
We will use literature values, a process flow model, and our experimental removal results to inform relevant stakeholders about the effectiveness of applying such filter at reducing microplastic pollution in Minnesota's environment. We will first calculate Minnesota's annual synthetic fiber production and apparel consumption based on Minnesota's population and per capita fiber consumption data for North America. The fraction of the fiber will be calculated as the product of apparel lifetime estimates, washing frequency, and literature reported microfiber shedding rates from apparel washing. Lastly, the fraction of this fiber that is captured from leakage will be estimated based on our determined removal efficiency, frequency of replacement, and fraction of population that uses the filter. We will disseminate the quantity of microfiber reduction per year with the adoption of filters to wastewater professionals, consulting firms, local municipalities, and wastewater department at the Minnesota Pollution Control Agency. We will also present the results to laundry filter manufacturers and discuss potential commercialization of this technology.

Activity Milestones:

Description	Approximate Completion Date
Determine annual release rate of microfiber from apparel washing in Minnesota	June 30, 2027
Calculate annual quantity of microfiber reduction upon use of our adsorptive laundry filter	August 31, 2027
Disseminate results to stakeholders	August 31, 2027

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?

As mentioned in Activity 3, we will disseminate the research results to the wastewater department at the Minnesota Pollution Control Agency, wastewater practitioners, local municipalities, apparel companies (e.g., Adidas and Patagonia), and laundry machine manufacturers, through open access publications, direct meetings, and conference presentations. We will seek partners to produce the filters that can be installed at households. Additional funding from the state and/or private companies will be sought to implement this technology.

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.

Assistant professor, Department of Civil, Environmental, and Geo- Engineering, University of Minnesota, Twin Cities
Postdoctoral scholar, 2020, Massachusetts Institute of Technology, Cambridge, MA.
Ph.D., Environmental Engineering, 2018, Pennsylvania State University, University Park, PA.
M. S., Agricultural and Biological Engineering, 2014, Pennsylvania State University, University Park, PA.
B. S., Biotechnology, 2011, East China University of Science and Technology, Shanghai, China.

Dr. Boya Xiong will be responsible for overall project supervision. Dr. Xiong is an expert on polymer and materials science, plastic pollution, and membrane filtration for water and wastewater treatment. She has 23 manuscripts published in the peer-reviewed technical literature on fate and degradation of polymer, and membrane materials design and processes for contaminant removal. Recently she leveraged her expertise in polymer degradation to explore how nano- and micro-scale plastics are generated from bulk plastic degradation via advanced microplastic analysis. Dr. Xiong is also the inventor of Moringa seed protein coated sand filter, where she developed simple protein extraction, coating, and recoating protocols for a variety of surfaces and substrates, for highly effective drinking water pathogen removal.

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 College of Science and Engineering is one of the premier public institutes in the country for graduate and undergraduate education and research. 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								
Assistant professor		Principal investigator: coordinate and supervise project			36.8%	0.15		$27,464
Graduate student		Perform filter manufacturing and filtration experiments			24.12%	1.25		$142,670
undergraduate researcher		Assist graduate to perform microfiber counting experiments and assist laundry wastewater collection			0%	0.19		$6,000
							Sub Total	**$176,134**
Contracts and Services								
							Sub Total	**-**
Equipment, Tools, and Supplies								
	Tools and Supplies	supplies and chemicals for preparing filter coating, filter substrate. Supplies for optical microscopy analysis and microfiber sample extraction from wastewater.	To prepare the dual layer coating and final filter product					$9,566
	Tools and Supplies	nanoparticle tracking analysis instrument time ($35.4/hour) for a total of 140 hours for 430 hundreds samples	analyzing concentration of nanofibers					$5,000
	Tools and Supplies	optical analyzer instrument time ($35.4/hour) for a total of 140 hours for 430 hundreds samples	to analyze the concentration and size of microfibers					$5,000
	Tools and Supplies	micro-FTIR instrument time ($26.5/hour and session charges) for a total of 650 hours for 10 samples	To analyze the chemistry and size of microfibers in real laundry wastewater					$25,000
							Sub Total	**$44,566**
Capital Expenditures								
							Sub Total	**-**

Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Miles/ Meals/ Lodging	Cost estimated as rental of sedan at $40 per day with 5 days per trip (5 x $40 =$200), an average 150 miles per trip with a UMN mileage rate of $0.17 per mile (100 x $0.17=$17) . Total per diem for two long trips estimated as $83	To collect and set up laundry wastewater collection					$300
							Sub Total	**$300**
Travel Outside Minnesota								
	Conference Registration Miles/ Meals/ Lodging	attend AEESP conference and MN-AWWA in 2026 for PI and graduate student.	To present the research outcome and disseminate to stakeholders and wastewater practitioners.					$4,000
							Sub Total	**$4,000**
Printing and Publication								
	Publication	open access journal fees	maximize dissemination of results of the project					$5,000
							Sub Total	**$5,000**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$230,000**

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: 53b754a1-4e7.pdf

Alternate Text for Visual Component

A simple dual layer filter capturing all type microfibers can significantly reduce microplastic pollution in Minnesota's water. The protein layer that removes negatively charged polyester fibers is extracted from plant seeds. The adhesive polymer layer that remove neutral microfibers is made from waste diaper....

Optional Attachments

Support Letter, Photos, Media, Other

Title	File
1101551 Xiong LOC	a74dcef6-6a1.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?

No

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 design, construction, or renovation of a building, trail, campground, or other capital asset costing $10,000 or more?

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?

No