Environment and Natural Resources Trust Fund
2019 Request for Proposals (RFP)

Project Title: **ENRTF ID: 110-BH**

Plastic Debris Remediation in the Great Lakes

Category: H. Proposals seeking $200,000 or less in funding

Sub-Category: B. Water Resources

Total Project Budget: $ 199,979

Proposed Project Time Period for the Funding Requested: June 30, 2022 (3 yrs)

Summary:

The objective of this project is to improve the health of the Great Lakes by devising an engineering solution to extract the floating plastic debris that infiltrates our food chain.

Name: Sungyon Lee

Sponsoring Organization: U of MN

Title: Assistant Professor

Department: College of Science and Engineering/Department Mechanical Engineering

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Web Address

Location

Region: Statewide, Northeast

County Name: Statewide

City / Township:

Alternate Text for Visual:

Images show different types of hazardous plastic debris that are found in the lakes and the map of the regions surrounding the Great Lakes that are affected by this infestation.

_____ Funding Priorities	_____ Multiple Benefits	_____ Outcomes	_____ Knowledge Base
_____ Extent of Impact	_____ Innovation	_____ Scientific/Tech Basis	_____ Urgency
_____ Capacity Readiness	_____ Leverage	_____ TOTAL	_____%
____ If under $200,000, waive presentation?			

PROJECT TITLE: Plastic debris remediation in the Great Lakes

I. PROJECT STATEMENT

The objective of this project is to improve the health of the Great Lakes by devising an engineering solution to extract the floating plastic debris from water surfaces. An alarming amount of floating plastic debris that was first observed in the oceans is also shown to plague the Great Lakes. In particular, "microplastics" refer to plastic debris that are less than 5 mm in size and originate from multiple sources that include common household products (i.e. degraded Styrofoam and plastic bags), abrasive microbeads in cleaning products, and the spillage of pellets and powders. Owing to their size, microplastics are difficult to prevent and pose health threats to the water ecosystem that infiltrates our food chain, as the plastic particles are ingested by marine and freshwater organisms. In addition, plastic debris enable the accumulation of organic pollutants and often contain harmful chemical additives that are associated with cancer and birth defects.

The serious environmental implication of microplastics in the oceans and lakes has led to significant efforts to collect and analyze the field data. By contrast, no current studies focus on developing science-based microplastic remediation strategies. The major challenge in the safe microplastic collection is to remove floating particles gently from the water surface without disrupting the water body and causing the particles to sediment down. Therefore, it is crucial to first understand how floating particles respond to different flow conditions, in order to devise a cost-effective, energy-efficient engineering solution to clean them from the Great Lakes with minimal disturbance to aquatic life.

The project team led by Dr. Sungyon Lee (University of Minnesota) combines the strong background in fluid mechanics and engineering to uncover the fundamental dynamics of the microparticle transport along the water surface. They will conduct lab-scale experiments and develop the theoretical model to predict the aggregation and collective motion of floating microplastics on the water surface. Their experiments and modeling will culminate in the design of an engineering device that uniquely addresses the particle removal challenges. The final phase of the project will include working with the local Minnesota agencies, such as the Minnesota Pollution Control Agency, the Large Lakes Observatory, and the Coast Guard Marine Safety Unit at Duluth, to field-test the device in the natural environment.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: *Lab-scale experiments and mathematical model development.*

Description: Dr. Lee and her student will develop an experimental set-up (to be housed in her existing lab at University of Minnesota), which will allow them to probe the fundamental dynamics of particles on water surfaces in a systematic manner. She will also leverage her on-going collaboration with Dr. Takagi (University of Hawaii) and Dr. Jung (Virginia Tech) to discuss the experimental results and to develop a predictive, mathematical model that describes the particle dynamics on water surfaces under variable flow conditions. Together, the experimental results and mathematical model will provide a comprehensive physical picture of how floating plastic particles respond external conditions and what causes them to mix and sink into water.

ENRTF BUDGET: $ 110,762

Outcome	Completion Date
1. Lab experiment design and set-up	December 31, 2019
2. Lab experiment data collection to visualize and quantify particle motion	June 31, 2020
3. Theoretical model to describe the particle dynamics on water surface	March 31, 2021

Activity 2: *Designing the remediation strategy.*

Description: Fundamental understanding of the particle dynamics will directly guide the development of a simple and cost-effective strategy to extract particles while minimizing the disruption to water. Dr. Lee and her student

will work closely with Dr. Jung in the second phase of the project to design engineering devices that can mobilize particles along the water surface. The initial design phase will include continuous modifications and testing of a small-scale design in the laboratory, before manufacturing a full-scale prototype. Dr. Lee will leverage existing facilities at University of Minnesota that include the state-of-art 3D printer, laser cutter and access to the machine shop to realize their design. The final part of the project will culminate in field-testing of the prototype on Lake Superior in Duluth, MN, by directly partnering with the Large Lakes Observatory and other local environmental agencies. In parallel, Dr. Takagi will apply the engineering solution developed as a result of their collaboration to microplastic remediation in marine environment in Hawaii; this ensures the far-reaching impact of the proposed project beyond Minnesota borders.

ENRTF BUDGET: $ 89,217

Outcome	Completion Date
1. Development of the science-based clean-up device	September 31, 2021
2. Device prototype and lab-testing	March 31, 2022
3. Field-testing of the prototype	June 30, 2022

III. PROJECT PARTNERS:

A. Partners receiving ENRTF funding

Name	Title	Affiliation	Role
Sungyon Lee	Assitant Professor	Department of Mechanical Engineering; Univeristy of Minnesota at Twin Cities	Project lead in charge of lab experiments and fluid mechanics modeling of microparticles in lakes

B. Partners NOT receiving ENRTF funding

Name	Title	Affiliation	Role
Sunny Jung	Associate Professor	Department of Biomedical Engineering and Mechanic; Virginia Tech	Designing and producing cost-effective particle removal device
Daisuke Takagi	Assistant Professor	Department of Mathematics; University of Hawaii at Manoa	Mathematical modeling of microplastic dynamics in marine environment

IV. LONG-TERM- IMPLEMENTATION AND FUNDING:

The proposed research will be tied in with the on-going research team's effort to understand microparticle transport and clean-up in the marine environment, as well as the bio-inspired design. The team's combined expertise in fluid mechanics, applied mathematics and engineering design will be leveraged to apply for federal grants from National Science Foundation (Fluid Dynamics and Environmental programs), as well as Department of Energy. Specifically, Dr. Takagi's position at University of Hawaii will allow him to apply for additional state funding to investigate the microplastic epidemic in the region surrounding the Hawaiian Islands.

V. TIME LINE REQUIREMENTS:

This project will be conducted over a 3-year period from July 1, 2019 to June 30, 2022.

2019 Proposal Budget Spreadsheet

Project Title: Plastic debris remediation in the Great Lakes

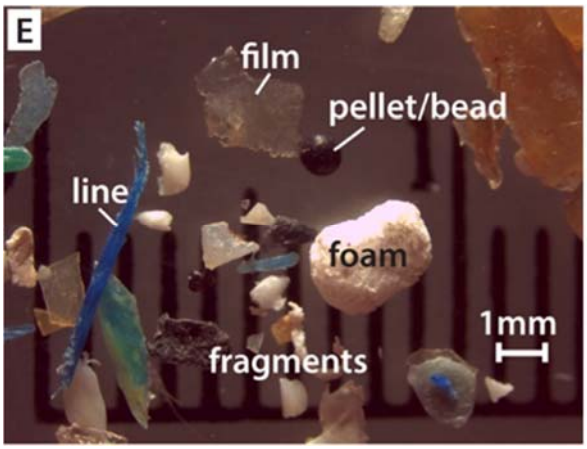
IV. TOTAL ENRTF REQUEST BUDGET : 3 years

BUDGET ITEM (See "Guidance on Allowable Expenses")	**AMOUNT**
Personnel:	$ 189,579
Dr. Sungyon Lee, project manager and laboratory measurement and modeling study (75% salary, 25% benefit); 7.67% FTE (i.e., 4 weeks of salary) for each of 3 years. ($41,476)	
Graduate Student Research Assistant, experiment and modeling research (59.8% salary, 40.2% benefit); 100% FTE for each of 3 years. ($148,103)	
Professional/Technical/Service Contracts: *N/A*	$ -
Equipment/Tools/Supplies: Cost of setting up a lab-scale experiment ($5000) and purchasing the camera/light source ($2000) and incidentals that include plastic particles ($1900).	$ 8,900
Acquisition (Fee Title or Permanent Easements): *N/A*	$ -
Travel: Tranportation within Minnesota state for field testing and research meetings. Estimated cost for 3 years: Mileage $0.535/mile x 1000 miles =$535; Incidental expense during travel $165;	$ 1,500
Additional Budget Items: *N/A*	$ -
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$ 199,979

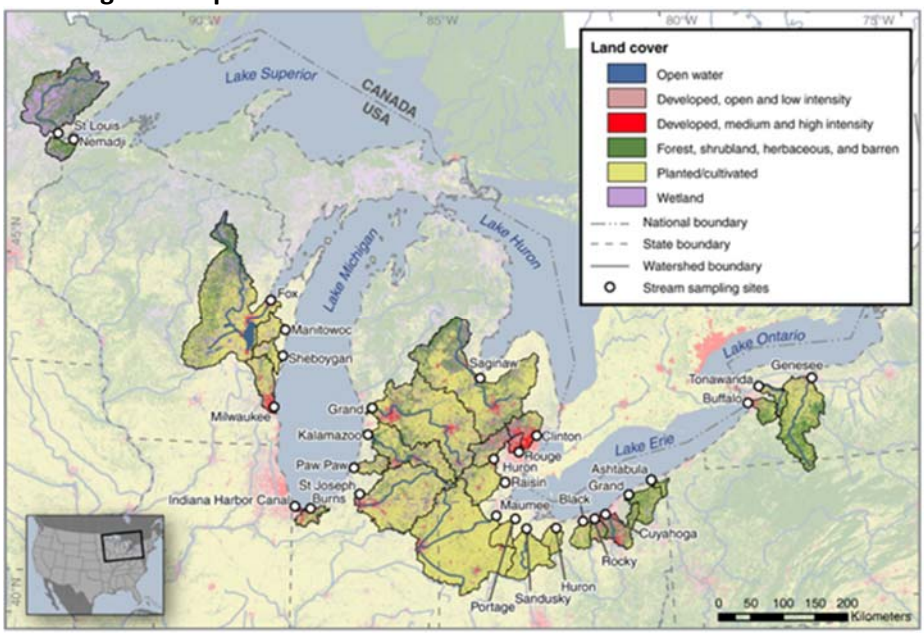
V. OTHER FUNDS *(This entire section must be filled out. Do not delete rows. Indicate "N/A" if row is not applicable.)*

SOURCE OF FUNDS	**AMOUNT**	**Status**
Other Non-State $ To Be Applied To Project During Project Period: *N/A*	$ -	*N/A*
Other State $ To Be Applied To Project During Project Period: *N/A*	$ -	*N/A*
In-kind Services To Be Applied To Project During Project Period: *N/A*	$ -	*N/A*
Past and Current ENRTF Appropriation: *N/A*	$ -	N/A
Other Funding History: *N/A*	$ -	*N/A*

1. Small plastic debris – known as "microplastics"- are found in large quantities in the marine environment and consist of various household items, including microbeads used in cleaning products. They pose a serious hazard to the aquatic ecosystem and to the human health.



2. In the recent years, microplastics have been observed in large quantities on the surface of the Great Lakes, including Lake Superior in Minnesota.



3. Currently, there exist no science-based strategy for removing floating microplastics without disrupting the body of water. The research team proposes to combine their strong background in fluid mechanics and nature-inspired design to devise the cost-effective clean-up solution.

PROJECT MANAGER QUALIFICATIONS

The overall project will be led by Dr. Sungyon Lee, an assistant professor in the Department of Mechanical Engineering at the University of Minnesota. Having completed her doctorate degree at Massachusetts Institute of Technology, Lee started her academic career in the Department of Mechanical Engineering at Texas A&M University from 2013 to 2017, before joining UMN in Fall 2017. Her overarching vision in research is to uncover fundamental physical mechanisms that govern complex engineering applications and natural processes. Consistent with that vision, her research group identifies fundamental fluid mechanics phenomena that are motivated by important challenges in nature and in industry and rationalizes them through simple experiments and reduced mathematical modeling. Lee's current research topics constitute interfacial, multiphase flows, such as drops, bubbles and suspensions, with the special interest in the particle dynamics on fluid-fluid interfaces. Her research has been published in top journal publications and is being supported by the National Science Foundation as well as the UK Royal Society Exchange Program.

Dr. Sunny Jung is an associate professor in the Department of Biomedical Engineering and Mechanics at Virginia Tech. He is one of the leading researchers in experimentation and modeling of bio-fluid mechanics; he also specializes in developing effective and sustainable nature-inspired engineering designs. Other examples of his research include the dynamics of fluid interfaces that is directly applicable to the current project, how animals drink, and how different organisms (such as fish and birds) interact with their surrounding flows.

Dr. Daisuke Takagi is an assistant professor of Mathematics at University of Hawai'i at Manoa who obtained his PhD in Applied Mathematics at University of Cambridge. He combines rigorous mathematical modeling and hands-on experiments to model fluid mechanical phenomena in nature, especially in flows around living organisms (such as bacteria and zooplankton) and bio-inspired robotics. His research is currently funded by National Science Foundation and Army Research Office.

ORGANIZATION DESCRIPTION

This project will be conducted at the University of Minnesota (UMN) at Twin Cities, the state's leading land-grant university. The proposed research naturally aligns with one of UMN's focused research areas (known as the Grand Challenges), namely, "Assuring Clean Water and Sustainable Ecosystems." The project will be carried out primarily in the UMN Department of Mechanical Engineering that boasts state-of-the-art facilities and machine shop to enable the proposed research.