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BOARD # 299: REU SITE: Interdisciplinary Research to Address Microplastics in the Gulf Coast Region

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REU Site: Interdisciplinary Research to Address Microplastics in Gulf Coast Region

Abstract
This poster highlights the establishment of a Research Experiences for Undergraduates (REU) site at the University of South Alabama, which is aimed at tackling the growing issue of microplastics in the Gulf Coast region. The primary objective of this REU site is to cultivate a positive and proactive mindset among undergraduate students regarding the detection, measurement, and remediation of microplastics, while simultaneously instilling sustainable engineering practices. The program aims to recruit 30 undergraduate students for a 10-week experience at the University of South Alabama, where they will engage in collaborative research and experiential learning focused on microplastics. The intellectual framework of the program encompasses five key thrusts: (1) Understanding the degradation of plastics into microplastics and their impact on ecosystems, (2) Developing novel detection and measurement techniques for microplastics in various environmental contexts, (3) Designing and testing filters to mitigate microplastics in waterways, (4) Establishing systems to monitor microplastic pollution over time, and (5) Repurposing collected microplastics for alternative applications. Through this comprehensive approach, students will gain both fundamental research skills and practical experience, while working in teams to address real-world environmental challenges. In addition to research activities, the program emphasizes the development of essential skills such as ethics and responsible conduct in research, data collection and analysis, critical thinking, technical writing, and teamwork. Mentorship from faculty and peers will be central to the students' growth, fostering frequent interactions that encourage creativity and innovation. The ultimate goal is to transform undergraduate students from passive learners into independent, collaborative researchers equipped to tackle complex environmental problems, with a focus on sustainable solutions for the future.
Keywords: Microplastic issue, interdisciplinary approach, undergraduate research experience, Gulf coast region

1. Introduction

Waste plastic pollution is one of the most pressing environmental issues due to the dire needs of plastic products in our daily life. As the plastic production increases annually and ineffective waste plastic management, it is evidently overwhelming challenge we are facing in today's society [1, 2]. The plastic recycling is in progress, and in most cases, waste plastics are inappropriately discarded in the environment, which results in a massive deposit of plastic products in rivers, lakes and oceans. Those waste plastics break down into small pieces, which is so-called microplastics. They are persistent and have the potential to cause health issues and ecotoxicological damage, as evidenced by a lot of medical records and studies. [3]. The Gulf of Mexico has been found to have concentration of microplastics. This is where most of the plastic manufacturers are located [4]. Microplastics in the Gulf of Mexico are mainly found in sediments, water and marine biota. A rough estimate of the abundance ranges from 31.7 to 1392 items per square meter and 60 to1940 items per kilogram in the sediment, 12 to 381 particles per liter in the water, and 1.31 to 4.7 particles per fish in the biological community [5]. A study by Wessel et al. [6] sampled a total of 84 quadrats on seven different shorelines in Mobile Bay, Alabama, and they found the microplastics can reach up to 117 per square meter. All of the plastics are secondary plastics, which are derived from the breakdown of larger plastics. The background outlined above highlights the challenges posed by microplastic pollution in the Gulf Coast region. To address these issues and engage undergraduate students, an NSF REU site has been established at the University of South Alabama. This project integrates expertise from five distinct fields to detect, quantify, and characterize microplastics along the Gulf Coast, as well as to explore their recycling and reuse.

2. Objectives

The REU site plans to recruit a cohort of 10 outstanding undergraduate students each year. Under the guidance of five professors from diverse fields including civil engineering, environmental engineering, mechanical engineering, electrical and computer engineering, and marine science, students will engage in the following activities:

(1) Microplastic Identification and Measurement: Students will learn to use a microplastic sampler developed for capturing microplastics from water bodies. They will extract, collect, and analyze samples using Fourier-transform infrared spectroscopy (FTIR) to determine microplastic concentrations and characterize their composition.

(2) Data Visualization: Leveraging the collected data, students will develop skills to create detailed maps of microplastic density. These visualizations will illustrate the types and concentrations of microplastics in various regions along the Gulf Coast, providing a clearer understanding of pollution patterns.

(3) Microplastic Removal Techniques: Students will work on developing effective methods to remove microplastics from the Gulf Coast ecosystem, contributing to practical solutions for environmental cleanup.

(4) Real-Time Tracking Systems: Participants will contribute to the design and implementation of systems for monitoring microplastics in real time, advancing the capability for ongoing observation and management.

(5) Recycling and Repurposing Microplastics: The program will explore innovative strategies to recycle microplastics, repurposing them for infrastructure applications and reducing their environmental footprint.

3. Work Plan of Interdisciplinary Research Experience for Undergraduates

This REU site provides undergraduate students with comprehensive training to address environmental challenges through a collaborative, interdisciplinary approach. By cultivating technical and analytical skills, raising awareness of environmental protection, and promoting STEM education, research, and outreach, the program aims to foster a new generation of informed, proactive stewards of the Gulf Coast environment. We anticipate that this initiative will significantly contribute to talent development in the region and inspire students to pursue impactful careers in sustainability and environmental science.

Each student will be paired with a faculty mentor and a graduate student to foster close guidance and support. To ensure mentors are well-prepared, we have developed a comprehensive mentor training program that includes the following components: (1) Mentor Orientation: A structured onboarding session to familiarize mentors with the program's goals, expectations, and effective mentoring practices. (2) Ongoing Support: Mentors will receive continuous support from the

REU leadership team through regular check-ins. These sessions will address challenges, provide guidance on mentoring strategies, and ensure alignment with program objectives. (3) Peer Learning: Mentors will participate in peer learning opportunities, sharing experiences and strategies to enhance mentoring effectiveness. This collaborative approach promotes a supportive environment and continuous improvement. With this framework in place, the following research activities will be carried out, as described in Section 3.1 to 3.5.

3.1. Understanding the Impacts and Degradation of Plastics into Microplastics

The sources of microplastics in the environment are complex and can be divided into primary and secondary microplastics. The sources of primary microplastics mainly include industrial raw materials of plastic/resin particles, industrialized products containing microplastic particles or cleaning microbeads, such as pharmaceuticals, polishing materials, personal care products (cosmetics, facial cleansers, toothpaste and shower gel). After entering the water body, plastics break up, decompose or reduce in size through physical (wear and tear, water disturbance, wave attack, wind), chemical (ultraviolet radiation, freeze-thaw cycles) and biological processes (degradation), forming tiny plastic fragments called secondary microplastics. This task will equip students with an in-depth understanding of the creation and fate of microplastics through literature reviews, hands-on modeling and experiments, data collection, and synthesis. Students will acquire this knowledge through a variety of engaging activities designed to enhance their comprehension and skills.

3.2. Collect and Analyze Microplastics Using Instrumental Analysis

The standard analytical workflow for the separation, counting and identification of microplastics using spectroscopic techniques requires five main steps: sampling, sample preparation or sample pre-treatment, filtration, detection/data acquisition, and analysis/reporting. Currently, the main methods for sampling microplastics are direct selection, large sample size, and concentrated samples. Direct selection involves using tools such as forceps and the human eye to directly select samples from the environment, which is difficult and may not result in a complete selection of microplastic samples. The large sample size method involves retaining all collected samples and bringing them back to the laboratory for analysis, which minimizes experimental error. The concentrated sample method involves increasing the abundance of the substance to be measured in the environment through concentration. Since the abundance of microplastics at the influent of the wastewater treatment plant is very high, a large amount of microplastic samples can be obtained without concentration, so the large sample method is selected. However, the concentration of microplastics at the effluent of the wastewater treatment plant is relatively low, so the concentration method. The common method for treating microplastics in laboratories at present is the Fenton reagent method. Microplastics are identified both qualitatively and quantitatively. Students will learn to use a microplastic sampler to sample sewage treatment plants along the coast of Mexico, and then bring it to the laboratory for separation and collection. This enhances students' practical skills, teaches them standardized laboratory procedures, and strengthens their understanding and use of chemical instruments.

3.3. Research on Carbon-Based Materials as Adsorbents for Microplastics

Adsorption involves porous materials (e.g., activated carbon, biochar, or sponges) that capture microplastics. This method is highly efficient and simple but depends on the adsorbent's regeneration capability. Students will investigate the effectiveness of three filter media—sand, powdered activated carbon (PAC), and biochar—in removing microplastics through lab-scale continuous-flow column experiments. The experiments will use a 1-meter-tall acrylic column filled with 0.1 meters of coarse gravel and 0.75 meters of test media, with synthetic wastewater containing microplastics (<1 mm) such as polyethylene, polypropylene, and polyester fibers. Filtration rates will range from 5 to 20 m^3/hour, and filtration performance will be monitored until either 50 bed volumes are treated or microplastics are detected in the effluent. The media will be tested in both single and mixed configurations (e.g., Sand + PAC). Following filtration, the treated water will be analyzed for microplastics using FTIR, and the media will be evaluated for fouling, head loss, and reuse potential.

3.4. Establishing a Microplastics Monitoring System

The proposed IoT-enabled microplastics monitoring system consists of sensor nodes, an energy harvesting system, and a data collection and storage component (e.g., a data center or cloud). Sensor nodes will be deployed at critical locations to monitor microplastics in real time. The data collected will be transmitted via cellular networks from node to node and centralized in a data center or cloud for analysis and storage. The energy harvesting system, utilizing sources such as solar panels, wind turbines, or environmental electromagnetic radiation, provides continuous power to the sensor nodes, enabling immediate operation or energy storage for future use. The system's design, including power transmission and data communication, can be tailored to specific application requirements. Key advantages include real-time monitoring, low-cost sensor nodes constructed with affordable electronic components, and self-sustained operation without reliance on external power supplies. Students will develop a user-friendly app to display real-time microplastics and nanoplastics data, supported by a regularly updated website to serve as an early warning system for harmful microplastics accumulation.

3.5. Repurposing Collected Microplastics for Alternative Applications

Once captured by the designed filter systems, the microplastics can be repurposed for other applications, presenting an opportunity for students to explore innovative reuse strategies. For instance, roadways composed of surface courses, bases, subbases, and roadbeds require materials like asphalt, concrete, aggregate, and soil. These materials can serve as reservoirs for stabilizing recycled microplastics, offering significant potential for large-scale use in pavements and infrastructure. This approach can save substantial amounts of virgin materials, reduce environmental impacts, and lower energy consumption. Students will focus on characterizing the specific gravity of microplastics, determining optimal proportions for incorporating them into plastic-modified asphalt and concrete mixtures, and evaluating their strength, durability, and environmental impact through leachate testing. The results will demonstrate the feasibility and effectiveness of using recycled microplastics in civil infrastructure. Students will gain practical insights into sustainability and innovative, effective methods for reusing recycled microplastics. This will be achieved through hands-on experiments, feasibility studies, and modeling, all within the context of civil engineering project design. These activities will foster the development of systems thinking and critical thinking skills, equipping students to address complex environmental challenges.

4. Summary

This work-in-progress paper introduces the proposed REU site, which demonstrates significant intellectual merit through its comprehensive approach to detecting, monitoring, and removing microplastics from water bodies. The initiative addresses critical gaps in understanding microplastic concentrations in wastewater facilities and natural water systems along the Gulf Coast. The project tackles pressing societal, economic, and environmental challenges posed by microplastics while providing an invaluable research opportunity for undergraduate students, particularly those from socioeconomically disadvantaged backgrounds in the Gulf Coast region. By engaging in impactful research, students will develop environmental awareness and a commitment to sustainability, guided by the principles of "reduce, recycle, reuse, and rethink." This interdisciplinary initiative fosters diverse learning experiences, enhancing the caliber and inclusivity of the workforce while promoting sustainability education and community engagement. Open access to project outcomes ensures widespread knowledge dissemination, with anticipated long-term benefits including strengthened environmental education in the region. Partnerships among colleges, high schools, and communities aim to create a ripple effect of positive change, inspiring future generations to address environmental challenges collaboratively.

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