Ferro-Filter: A Ferrofluid-Based Microplastic Filtration Module for Urban Water Systems in Continuous-Flow Applications

Bhaskaran, Yuhaendan (School: American High School)
Jog, Shaunak (School: American High School)
Polavajram, Abhay (School: American High School)

Microplastics (MPs), defined as plastic particles smaller than 5 mm, are pervasive environmental pollutants linked to cardiovascular, neurological, and carcinogenic health risks. Although ferrofluid-based filtration has demonstrated high efficiency in laboratory settings, its application in continuous-flow environments remains largely unexplored, limiting real-world implementation. This project introduces Ferro-Filter, a continuous-flow filtration system designed for integration into urban water infrastructure including storm drains, wastewater treatment systems, and industrial discharge pipelines, aiming to remove MPs at the source of contamination. This system combines three mechanisms: a helical static mixer to enhance ferrofluid-MP interaction, a vibration motor to promote MP-ferrofluid agitation, and magnetic separation using a Halbach array and electromagnet to recover ferrofluid-bound MPs. Prototype performance was evaluated across varying flow velocities, with MP removal and ferrofluid recovery efficiencies quantified using “colorimetric segmentation,” a custom OpenCV-based data-collection method to analyze post-filtered samples. Iterative prototyping demonstrated performance improvements across versions, resulting in greater than 86.6% MP removal efficiency under continuous-flow conditions. The system maintained high efficiency across variable flow regimes (70-280 mL/sec), demonstrating robustness to realistic hydraulic conditions. Overall system power draw was measured to be ~16.2 W/hr and cost of prototype was ~$222, demonstrating the cost-effectiveness and efficiency of Ferro-Filter. These results validate Ferro-Filter as a scalable, energy-efficient, and infrastructure-compatible solution for mitigating microplastic pollution before environmental release.

Awards Won: