Project Purify: A Hybrid Electro-Photocatalytic System for Targeted Degradation of Microplastics

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Microplastic (MP) contamination is a persistent environmental and public health threat, with polyethylene terephthalate (PET) MPs detected in drinking water, human blood, and placental tissue. Existing mitigation strategies rely almost exclusively on physical filtration, which concentrates (rather than neutralizes) plastic pollution and generates secondary waste streams. Project Purify combines physical capture, electrophoretic concentration, and photocatalytic degradation of PET MPs in a single automated reactor. I developed a 3 phase system, which was optimized with over 400 quantitative measurements and triplicate aliquots per condition. Phase I evaluated MP capture using loofah, agar hydrogel, and a novel loofah - agar composite. The composite demonstrated the highest retention efficiency due to mechanical entrapment and hydrogel adhesion. Phase II tested electrophoretic concentration using carbon felt, graphite, and stainless steel mesh cathodes. Stainless steel mesh (4.5 V at 2 cm electrode spacing) yielded the highest particle interception. Phase III targeted PET degradation via immobilized TiO_2 photocatalysis. This approach achieved significantly greater apparent mass loss than slurry systems while preventing catalyst leaching. UV-on and UV-off controls confirmed degradation was photocatalytic, rather than mechanical. These components were integrated into a vortex reactor designed for autonomous operation. The final prototype achieved a 96% reduction in recoverable PET MPs, comparable to sequential testing (98%), and maintained high efficacy when tested with commercial bottled water. By neutralizing rather than relocating plastic waste, Project Purify establishes a realistic pathway toward mitigating one of the most pervasive pollutants of the modern era.

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