Chitoflux: TFF-Optimized Chitosan Media Filtration System for Biofilm and Microplastic Inhibition

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Biofilms are communities of microorganisms that aggregate and grow on microplastic (MP) surfaces. Bacterial proximity strengthens antibiotic-resistance through the dissemination of antibiotic-resistance genes (ARG) via horizontal gene transfer. With the CDC spending ~$680 million on ARG-induced microbial diseases, there is a crucial need for filtration tools to prevent biofilm-microplastic interactions. Chitosan, a polysaccharide derived from chitin, possesses strong antimicrobial properties and biomass filtration abilities with little harm to humans. Modern-day filtration systems remain lacking, with high biomass accumulation on filtration surfaces and biofilm formation on permeate matter. To address these limitations, four key innovations were made. First, a tangential waterflow (TFF) system was implemented to minimize biomass blockage by shearing away accumulation at the filter site. Next, using a photodiode-microcontroller system, water-flow rates were tailored to maximize filter efficiency. Chitosan coated high-silica sand was then packed into a column in the TFF system. Finally, an Ordinary Differential Equation (ODE) framework was developed to predict chitosan-inhibition on microbial growth. To quantify the efficacy of chitosan, lab trials tested E.coli K12 biofilm growth on regular and chitosan-coated microplastic, with a growth reduction of 93%. The system filtered 89% of large MP's, with the chitosan medium coating microplastics that passed through. A competitive-inhibition constant of 9999 mL/mg proved that 1.0 mg/mL chitosan-coated sand reduced microplastic attachment by a factor of 10^4. An R^2 value of 0.97 using set microplastic (MP) concentrations vs corresponding absorbance validated MP-concentration benchmarks for the microcontroller-photodiode system.

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