Piezocatalysis with Optimized Turbulent Flow in Hydro Turbine for Eutrophication Remediation

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Eutrophication affects 65% of coastal and 53% of freshwater regions in the US but no scalable cyanobacterial degradation methods exist. Piezocatalysis harnesses mechanical energy to produce reactive oxygen species (ROS) in water, which degrade organic pollutants by oxidation without generating toxic residues. This study designed a novel hydro-turbine using bluff bodies that maximize kinetic flow energy available for aquatic remediation via piezocatalysis. MoS2-doped films exhibited first-order ROS chain reaction production when agitated in Anabaena (20 µg/L), and has potential to inhibit cyanobacterial positive feedback growth by converting nitric products into reactive nitrogen species. The inverted piezo-active flag model was computationally optimized to enhance polarization with turbulent energy and ensure rapid charge dispersion with flow-induced vibrations. The 90° upstream triangle yielded maximum coefficients by effective flow separation (12.6 drag, 18.6 lift) and a flag length ratio of 0.75 was optimal while avoiding canceling zones. The optimized piezocatalytic hydro-turbine design yielded 78% remediation under 800gph for 60s (p=0.032). A minimum flow speed was identified by energy/order to be 0.5m/s, with 0.7W/(1g MoS2). Application depth of 0.3m-2m was identified with cyanobacterial concentration, turbulence needed for crossflow effectiveness, and speed; conditions are within industrial scalability standards. Chain reactions allow the remediation of still-water and high-volume downstream regions through tributaries. In the future, the device can be studied in environments with varying meander speeds and upstream ROS exposure times. The device presents a potential industrial eutrophication treatment applicable in ~93% of fluvial environments.