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Novel Microalgal Fuel Cell System for Sustainable Dairy Wastewater Treatment, Bio-electricity Generation, and Nutrient Recovery

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Generation of renewable power and treatment of wastewater in order to ensure zero liquid discharge remain pivotal for human survival. The treatment of wastewater, in particular, requires significant removal of biological oxygen demand (BOD), chemical oxygen demand (COD), and re-utilization of vital nutrients like nitrogen and phosphorus. To address these challenges, this study explores microalgal fuel cells (MAFC) as the multi-faceted approaches to treat wastewater, recover nutrients, and simultaneously generate electricity. These *Spirulina platensis* based fuel cells utilize the oxygen present in the atmosphere, similar to realistic scenarios. For further advancement, coal fly ash ceramic membrane is used to substitute the fluorinated polymer membranes improving sustainability and bio-fouling resistance. The system showed complete removal of nitrogen, phosphorus, and ammonium ions within 9 days of operation along with the potential output of over 220 mV. Furthermore, electrical impedance analysis established the growth curve of biofilm on the membrane while showcasing the least effect for the coal fly ash membrane, compared to PTFE and Nafion - 117. This system showcases the practical possibility of zero total waste (i.e., a circular system for the industry), ensuring the generation of bio-electricity for storage and consumption, possibly using thermoelectrics generators; recovery and re-utilization of nitrogen and phosphorus for fertilisers, along with the zero-liquid discharge. Moreover, energy costs are estimated to be reduced by 50% initially, ideally negating any expenditure and making it an economically viable and environmentally sustainable model.

Keywords: Zero-Liquid Discharge, Microalgal Fuel Cells, Spirulina Plantesis, Coal Fly Ash Ceramic Membrane

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