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Conclusions and Future Prospective

This study successfully demonstrated the potential of using PMFCs to remediate the organics from saline wastewater with the advantage of generating bioelectricity and value-added products. Incorporating halophilic microalgae, *D. salina*, and halophilic bacteria into the PMFC system represents notable progress in sustainable wastewater management and bioenergy generation.

The initial study was performed at a laboratory scale that operates independently of the external electron donor substrate supply. Isolation of *D. salina* from Sambhar Salt Lake and its effective cultivation in saline conditions have shown that this microalga can thrive in environments that challenge traditional wastewater treatment methods. The alga's ability to grow in high salinity supports its use in PMFCs and indicates its potential for biomass production in saline environments. The PMFCs exhibited varying performance based on salt concentrations, with optimal power generation of 213.38 mW/m^2 observed at 0.5 M NaCl, highlighting the efficiency of this system in energy recovery. Additionally, producing valuable compounds such as glycerol and β-carotene indicates the dual benefits of waste treatment and resource recovery.

The PMFC was further scaled up to high volume, such as PMFC having 15 l cathodic and 2 l anodic volume, which successfully showed the capability of PMFCs to remove organic pollutants from saline wastewater at a practically relevant scale. The use of LEA as an electron donor facilitated significant organic matter degradation. The highest operating voltage of 615 ± 79 mV and energy recovery of 0.496 kWh/m^3 were observed at 0.5 M LEA fed-PMFC. The analysis of the anodic biofilm of the lowest and highest saline system with LEA as a substrate showed the presence of diverse electrogenic microorganisms, varying dominance based on salinity. Understanding these microbial interactions and their roles in the bio-electrochemical processes offers valuable insights into optimizing PMFC performance and enhancing pollutant degradation. The results obtained by the work are promising and show the efficacy of the operating PMFC in treating saline wastewater. However, there is much scope for the system to enhance the treatment process while generating high power output by exploring diverse microbial communities, advancing reactor designs, optimizing materials, and conducting real-world applications.

Future work will include collaborative work with optimization of the halophiles for power generation based on AI-based tools and utilizing that data for real experiments. Scaling up the technique from laboratory scale to field scale and using real wastewater from industries and agricultural practices to assess the long-term performance in dynamic environmental conditions and also use of seawater to assess the effect of salinity on the aquatic flora and fauna. Monitor the biofouling and its impact on the efficiency of the system over time. Explore hybrid systems that combine photomicrobial fuel cells with conventional wastewater treatment methods to enhance overall efficiency and energy recovery.