INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Thesis Title: Studies on power generation in Water lettuce (*Pistia stratiotes*) assisted sediment microbial fuel cell

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Thesis Submitted to the Academic Division	:	School of Energy Science and Engineering
Date of completion of Thesis Viva-Voce Exam	:	28/08/2025
Key words for description of Thesis Work	:	Cathode potential, Dissolved oxygen, Ionic conductivity, pH, Self-sustainable, Water lettuce, Biofilm, Sediment microbial fuel cell, voltage reversal, power management system,

SHORT ABSTRACT

Sediment microbial fuel cells (SMFCs) are emerging as a promising green energy technology with enormous application potential for wastewater treatment and linked electrical energy production. However, the practical application of these devices is challenged by their low-performance factors pertaining to the imbalanced electrolyte and oxygen levels and weak cathodic functions in open environment conditions. This study explored to address the poor performance of the SMFC by coupling it with a free-floating aquatic plant, Water lettuce. Growth of the plant balanced the catholyte pH in the range of 7.2–7.6, increased the ionic conductivity by 60%, stabilized the sub-surface water oxygen level, and boosted the cathodic potential by ~ 102 mV and ~ 49 mV in open and close circuit operations mode, respectively. The cumulative effect of these inputs led to producing a power density of 22.45 mW/m2 and a current density of 136.84 mA/m2 at 2 kΩ and 50 Ω loads, respectively. The enhanced cathodic performance was also attributed to the colonization of Water lettuce root bacteria as biofilm on the cathode that supported catalytic oxygen reduction on the graphite electrode. Metagenomic analysis indicated the biofilm is created mostly by aerobic microbes such as *Ferrovibrio terrae, Comamonas aquatic, Achromobacter xylosoxidans, Hydrogenophaga taeniospiralis* etc. bearing catalase enzyme, *Pannonibacter phragmitetus, Streptococcus pyogenes, Streptococcus mutans* etc. bearing heme enzyme and these microbes synergistically catalysed cathodic reduction reactions. This study demonstrated the positive role of Water lettuce in boosting the power performance of SMFC mainly by activating the cathodic functions of the setup. The progress of this innovative green energy technology destined for open environment applications is also mired by their inherent low voltage generation. A solution to improve the voltage level is to stack several unit cells through series or parallel connections. Paradoxically, such stacks frequently encounter voltage reversal (VR), which grossly affects their performance. Thus this study also presents strategy to mitigate VR in stacked water lettuce-assisted SMFCs (WL-SMFCs) by tuning the anodic surface area. A theoretical framework was first developed to relate electrical parameters to anodic surface area, predicting that increasing the anodic surface area of the terminal unit would enhance the overall stack voltage. This prediction was experimentally validated using a laboratory-scale stack of series-connected WL-SMFC units. When the anodic surface area of the terminal unit was increased to match the total anodic surface area of all other units combined, VR was significantly reduced. In two-, three-, and four-unit stacks, VR decreased by 70%, 57%, and 54%, respectively. Electrochemical impedance spectroscopic analysis confirms the corresponding increase in anodic storage charge (C) to 318.25±12.35 (670±26), 453.08±12.12 (964±26), and 422.92±9.39 (872±19) from the unit value of 240.58±25.65 (523±55) with respective capacitance (pF) values shown in brackets. This anodic surface area tuning approach offers a technically simple, self-sustaining, and cost-effective solution for alleviating VR, thereby enhancing the feasibility of SMFCs for open-environment applications. Herein, another effort has been made to increase the power output of plant- assisted sediment MFCs, using a power management system (PMS). Water lettuce-assisted sediment MFCs with a reactor volume of 500 ml were constructed, and four stacks were made, each with two cell units connected in series. When each of the stacks was connected to a charge pump, the voltage increased to double with an efficiency of 97.15±0.01%. The output of the four charge pumps was cascaded for charging a pair of 3300 μF capacitors, which were then discharged in series through a 0.5 F supercapacitor. With the input from the capacitors, the time for charging the supercapacitor was 35 hours that generated 3.5 V, which is ~61.5% of its maximum voltage limit (5.69 V). At the maximum operating point for the stacks (10 kΩ load), the PMS delivers ~0.92 mW, which is 7.13 times the total power delivered by the stacks. The maximum power conversion efficiency of the PMS was 81.76%. This study demonstrated powering a 1 W LED using the fabricated PMS. The power efficiency for the PMS can be further increased by allowing additional charging time for the supercapacitor and increasing the supercapacitor's value. These results would be informative for designing a self-powered PMS topology to boost power in MFC stacks for their practical applications.