INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Thesis Title: Domestic Wastewater Treatment with Integrated Constructed Wetland – Microbial Fuel Cell Emphasizing Organics and Coliform Remediation with Bioelectricity Generation

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SHORT ABSTRACT

India as a nation is facing a serious concern due to the lack of domestic wastewater treatment capacity in the urban and rural sectors. Traditional wastewater treatment technologies are primarily designed for the reduction of organic loading in domestic wastewater and are less focused on reducing fecal contamination. The integrated constructed wetland microbial fuel cell (CW-MFC) technology serves the purpose of eco-friendly wastewater treatment with the potential of reducing the areal footprint of constructed wetlands along with high-rate organic removal, low maintenance, and the scope of bioenergy harvesting. Therefore this research was conducted for the treatment of domestic wastewater using an integrated CW-MFC reactor for organics and coliform removal with bioelectricity generation and for understanding the inherent bioelectrochemical mechanisms. The probable economic benefits of the CW-MFC system were also assessed using a cost-benefit analysis study.

The removal of organics and fecal coliforms from domestic wastewater was evaluated using three identical reactors. One vertical planted constructed wetland (R1), one planted CW-MFC (R2), and one unplanted CW-MFC (R3). In terms of COD removal, R2 achieved 93.13±4.83% efficiency, and R1 and R3 achieved 87.21±4.56% and 86.31±4.37% efficiencies, respectively. BOD_5 removal efficiency in R1, R2, and R3 reactors was found to be similar from 91.79±3.58% to 92.7±3.3%. The fecal coliform removal in R2 was much higher (log 3.51) compared to R1 (log 2.94). The maximum open-circuit voltage in R2 was 886 mV and in R3 was 487 mV during the complete study.

Spatial analysis of treated effluents showed a considerable amount of organics and fecal coliform removal at the vicinity of the anode in R2. Assessment of the microbial population inside all the reactors revealed that electroactive bacteria (EAB) (*Firmicutes, Bacteroidetes, and Actinobacteria*) were more abundant in R2 compared to R1 and R3. Simultaneous bioelectricity monitoring inferred that voltage generation can be correlated to faster fecal coliform inactivation, which was probably due to EABs outcompeting other exogenous microbes in a preferable anaerobic environment with the presence of an anode.

Periodic reduction of hydraulic retention time (HRT) resulted in deteriorated organics and fecal coliform removal by the reactors. R2 showed higher pollutant removal and voltage generation throughout as compared to R1 and R3. R2 exerted 93%, 87%, and 57% COD removal during the HRT of 36 h (Phase 1), 24 h (Phase 2), and 18 h (Phase 3); with maximum voltage generated as 865 mV, 695 mV, and 429 mV respectively. Multiple batch studies revealed the main role of reactor media and plant roots was to support the attached microbial growth for biodegradation of the organics.

A comparative cost-benefit analysis of three reactors: R1, R2, and R3 was conducted with 36 h and 24 h HRT, and the respective cost-benefit ratio was determined. Results revealed that R2 was the most sustainable option with maximum economic benefits during Phase 1 and Phase 2 without effluent disinfection. With effluent disinfection in place, R1 emerged with the best cost-benefit ratio due to less investment cost and low revenue from electricity production in R2 and R3. Sensitivity analysis with net investment cost, power density, electrode area, effective reactor volume, and HRT; showed power density was the most influential parameter affecting the cost-benefit ratio.

Multi-anode CW-MFC reactors (both planted and unplanted and equipped with three anodes: A1, A2, and A3) were employed to compare the organics and fecal coliform removal performance and bioelectricity enhancement with that of single-anode CW-MFCs (planted and unplanted). The multi-anode reactors were named R'1 (planted) and R'2 (unplanted), and the single-anode reactors were named R1 (planted) and R2 (unplanted). In the case of multi-anode reactors the planted R'1 rendered better COD removal, fecal coliform inactivation, and operating voltage as compared to unplanted R'2. The operating voltage and the power density were enhanced significantly in the multi-anode reactors as compared to single-anode reactors. For R'1 and R'2, different anodes rendered different operating voltages depending on the COD availability and the respective distance from the cathode. Anode A2 which was placed at an intermediate position in between anodes A1 and A3, showed the maximum operating voltage (791 mV) and power density (7.47 mW/m2). The fecal coliform removal efficiencies of all reactors were reduced during open circuit mode operation as compared to closed-circuit operation.