SIMULTANEOUS ELECTRICITY GENERATION AND WASTEWATER TREATMENT USING MICROBIAL FUEL CELLS

By

Safwat Mahmoud Safwat Abd ElAzim Ahmed

A Thesis submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfillment of the
Requirements for the Degree of
DOCTOR OF PHILOSOPHY
in
CIVIL ENGINEERING - PUBLIC WORKS

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
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ABSTRACT

This study shows the effects of various conditions on performance of microbial fuel cells (MFCs) used to treat wastewater. The conditions included the following: three different configurations (dual chamber MFC with proton exchange membrane (PEM), single chamber MFC with PEM, and single chamber MFC without PEM); bacterial adhesion; and increasing the anode surface area by using activated alumina, extruded activated carbon and granular activated carbon. The maximum voltage production, power density, and COD removal values were 28mV, 0.46 mW/m^2, and 68.8% respectively in case of dual chamber MFC with PEM; 3 mV, 0.0053 mW/m^2, and 54.5% respectively in case of single chamber MFC with PEM; and 78 mV, 10.77 mW/m^2, and 83%, respectively in case of single chamber MFC without PEM. The voltage generation, power density, and COD removal increased to 351 mV, 218 mW/m^2, and 98.7 %, respectively, when using an anode electrode that was immersed in the microbial solution for one week beforehand in the single chamber MFC without PEM. The voltage generation and power density improved to 420 mV, and 312 mW/m^2, respectively, after increasing the anode area through with 170 gm activated alumina, but no improvement was observed when using extruded activated carbon or granular activated carbon under the same conditions. Then the performance of single chamber membrane less microbial fuel cells used to treat three different carbohydrate synthetic wastewaters was investigated. The three synthetic wastewaters contained glucose, sucrose, and soluble starch respectively. Two different inocula were used: microbial solution containing different species of microorganisms, and anaerobic sludge. Results showed that the highest values of voltage, power densities and COD removal efficiencies were obtained in case of microbial fuel cells fed with glucose-based synthetic wastewater, and were found to be 351 mV, 218 mW/m^2, and 98.8 % respectively in case of microbial solution, and were found to be 508 mV, 456.8 mW/m^2, and 94.3 % respectively in case of anaerobic sludge. In all experiments, the values of voltage and power densities obtained in case of anaerobic sludge were higher than those obtained in case of microbial solution, while the values of COD removal efficiencies obtained in case of anaerobic sludge were less than those obtained in case of microbial solution. The study proved that the voltage generation, power densities, and COD removal efficiencies were inversely proportional to the complexity of carbohydrate used in single chamber microbial fuel cells. After that, the performance of a single-chamber microbial fuel cell (MFC) with various substrates was investigated. These substrates were primary settled domestic wastewater at pH = 6, primary settled domestic wastewater at pH = 7.2, primary settled domestic wastewater at pH = 8, phenol-based wastewater, and benzene-based wastewater. Electricity was successfully generated when these substrates were used as fuel in single-chamber MFCs inoculated with anaerobic sludge. The maximum voltages and power densities were 74 mV and 9.7 mW/m^2 for primary settled domestic wastewater at pH = 6, respectively; 135 mV and 32.3 mW/m^2 for primary settled domestic wastewater at pH = 7.2, respectively; 150 mV and 39.8 mW/m^2 for primary settled domestic wastewater at pH = 8, respectively; 58 mV and 5.95 mW/m^2 for phenol-based wastewater, respectively; and 106 mV and 19.9 mW/m^2 for benzene-based wastewater, respectively. The removal efficiencies for chemical oxygen demand (COD) and coulombic efficiencies were 78.2

% and 35.3 % for primary settled domestic wastewater at pH = 6, respectively; 85.1 % and 55.4 % for primary settled domestic wastewater at pH = 7.2, respectively; 80.8% and 72.9 % for primary settled domestic wastewater at pH = 8, respectively; 58.9 % and 15.1 % for phenol-based wastewater, respectively; and 73 % and 25.7 %for benzene-based wastewater, respectively. The highest voltage production, power density and COD removal were obtained using primary settled domestic wastewater, whereas the lowest values were obtained using phenol-based wastewater. The performance of the MFC was enhanced by increasing the influent pH of the primary settled domestic wastewater. The lowest coulombic efficiencies were obtained from phenol-based wastewater and benzene-based wastewater, which indicated that electrogenic bacteria were not the primary microorganisms responsible for the biodegradation of phenol and benzene.

Key words: Microbial Fuel Cells; Configurations; Bacterial Adhesion; Anaerobic Sludge; Carbohydrates; Benzene; Domestic Wastewater; Phenol