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Microbial Fuel Cell for Nitrate Reduction

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Abstract

Microbial electrochemical systems present a breakthrough for environmental technology, perhaps even a promising solution to the magnifying problem of waste management. Our current research focuses on simultaneous energy production and organic matter removal from wastewaters by Microbial Fuel Cells (MFCs). An MFC system was inoculated with microbial cultures obtained from the silt of a river basin that regularly accepts heavy loads of nitrates from the local agriculture; the organic load was collected from the Facai Wastewater Treatment Plant in Romania.
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1. Introduction

Wastewater biomass from agricultural, municipal, and industrial sources is rich in carbohydrates that store chemical energy; thus, it can be used as a substrate for the direct energy conversion of sugars to electrical power with the help of microorganisms. An alternative strategy for waste treatment can be traced to a new technology under development: Microbial Fuel Cells (MFCs), specialized fuel cells capable of generating electric energy from organic matter through microbial metabolism [1-3]. Direct conversion of microbial metabolic products into

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electricity offers the potential to recover energy from wastewaters, marine sediments, and biomass; with promising applications in wastewater treatment, biosensors, and even medical devices [4-6].

MFCs consist of an anode, where organic matter is oxidized by microorganisms, and a cathode that hosts the electron acceptor (oxidant); various oxidants have been employed as electron acceptors, the most sustainable being oxygen due to its capacity to give a high reduction potential and its accessibility through the atmosphere [3,7]. The latest approach in MFC research targets nitrate reduction, with nitrates obtainable from different water sources: ground waters [8,9], wastewaters [10,11], or synthetic wastewaters [12].

We have assembled an MFC experimental prototype that employed naturally occurring microorganisms from a Romanian river which regularly accepts heavy loads of organic fertilizers from local agricultural activities, and we have loaded it with wastewaters collected from the Facai Wastewater Treatment Facility in Oltenia, Romania. The system was characterized according to its capacity for simultaneous organic matter and nitrate removal, as well as current and power production.

2. Materials and Methods

2.1. Materials

The following materials were used in the assembly of the MFC:

Anolyte solution: the anolyte total volume of 300mL was comprised of 150mL wastewater and 150mL of sediment bearing microorganism cultures. Wastewater samples were collected from the Facai Wastewater Treatment Plant in Oltenia. The sediment used for MFC inoculation was collected from a depth of 10cm below the Burtea River silt basin; it housed a naturally occurring mixture of microorganisms: bacteria, microalgae, and protozoa. All anolyte ingredients were used as received.

Electrodes: both anode and cathode electrodes were fabricated from carbon felt (AM&T VDG) with a surface area of 56.54cm2, and activated as follows: a.) soaked in HCl (1M) for one hour, washed with distilled water (DW), then soaked for a full day in HCl (1M) and washed again with DW; b.) soaked for a day in NaOH (1M), washed with DW, then soaked for another day in HCl (1M) and rewashed with DW; and c.) soaked for a day in NaOH (1M), washed several times with DW until the pH was close to neutral, and kept in DW until use.

The mono-chamber MFC system was assembled from acrylic, having a single chamber of 6cm height by 9cm diameter (available volume of 382mL), containing the anode and the cathode at opposite sides of the chamber (activated carbon felt electrodes of 56.54cm2 surface area each), and the 300mL of anolyte. A cylindrical Plexiglas of 3cm height was used as a spacer between the electrodes, each one connected with titanium wire to a data acquisition unit (Picotech ADC 10/11) that monitored the electrical potential in real time.

2.2. Analytical techniques

The following techniques were used in our analysis:

Polarization and power density profiles: obtained using a variable resistor box to set the external loads ranging from 20MΩ to 5Ω in a periodical decreasing order. Current density was calculated according to:

$$I = E/R \cdot A \tag{1}$$

where E is the cell voltage [V], R is the external resistance [Ω], and A is the projected surface area of the anode (56.54cm2).

Power density was calculated according to:

$$P = \left(I \cdot E\right)/A \tag{2}$$

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