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Use Of Landfill Leachate to Generate Electricity in Microbial Fuel Cell.

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Abstract

Bioenergy is a renewable energy that plays a vital role in today's increasing energy demand**.** Microbial fuel cell (MFC) concurrently treats the wastewater and produce the energy. Microbial fuel cells, in which microorganisms catalyze the transfer of electrons released from the oxidation of organic compounds onto an electrode, are a promising biotechnological approach for harvesting energy in the form of electricity from certain wastes.

The Problem

Untreated leachate causes serious hazardous impacts to the surrounding environment, and thus requires prompt and efficient action with suitable treatments. At present, Electro-Fenton Process, Sequencing Batch Reactor, Internal Circulation anaerobic reactor and Up flow Anaerobic Sludge Blanket are commonly used to treat landfill leachate. Due to the complex composition of landfill leachate, these treatments alone are not able to achieve complete removal of the diverse organics from leachate, causing secondary pollution and further affecting the environment and human health.

Purpose Of Study

The purpose of this study was to determine if landfill leachate is a productive source of substrate and microbes for generating electricity in microbial fuel cells. Research methods included filling the anodic chambers of multiple fuel cells with landfill leachate. Landfill leachate contains a wide range of organics, inorganics, heavy metals and salts. It is generally characterized with a high concentration of ammonia and a low biodegradable organic matter content. Hence, it is necessary to develop new technologies for the effective removal.

1. Introduction

Microbial fuel cells (MFCs) are a new method of generating electrical energy through microbially catalyzed organic oxidation. Prior studies have shown that MFCs are capable of removing pollutants from landfill leachate at low energy consumption. Compared with conventional leachate treatments, MFC can achieve the same or even higher removal performance, while generating energy and saving aeration costs summarized the effects of different feed modes, cell structures and leachate loading rates on the energy recovery efficiency of MFCs, and identified chemicals and leachate characteristics that could potentially improve bio electrochemical activity and energy production. These include high concentration of nitrogen and electrical conductivity, which could improve the electrical performance by reducing the internal resistance. By far, research has been focused on using MFCs to recover bioenergy and value-added products from leachate, but MFC has very limited effect on wastewater treatment. Developing a technology that can remove pollutants and generate energy and simultaneously extract clean water from liquid waste stream will be more competitive than existing wastewater treatment technologies. Forward osmosis (FO) can extract clean water from wastewater, but it only concentrates wastewater without degradation of organic pollutants. The combination of FO and MFCs can address their inherent problems and achieve synergetic benefits.

2. Materials and Method

2.1 Leachate Characterization

The leachate sample is collected from the primarily treated effluent of UASB and it is stored at 4°C. Based on standard methods in the physio-chemical characterization of primarily treated leachate such as pH, Total solids (suspended solids and dissolved solids), Total chemical oxygen demand (TCOD) and soluble chemical oxygen demand (SCOD) were analyzed. All the experiments were done in triplicate and results were the mean values of triplicates. Table 1 displays the characteristics of pretreated leachate.

Table 1. Characteristics of pre-treated leachate.

S. no	Parameters	Influent
1	pH	6
2	Total chemical oxygen demand (mg/L)	400±20
3	Soluble chemical oxygen demand (mg/L)	250±10
4	Total solids (mg/L)	460±20
5	Total suspended solids (mg/L)	250±20
6	Total dissolved solids (mg/L)	200±20

2.2 UMFC Reactor

In this experiment, UMFC reactor was in tubular shape with two chambers, anode and cathode which is made up of plexiglass. Each tubular chambers have the measurement of height - 11.3 cm and diameter – 7 cm. A proton exchange membrane (PEM) with the size of 10×10 cm which separates the chambers and having a working volume of 500 mL for each chamber. The PEM is placed in fiber gasket which connects both the chambers. Anode chamber is present in the bottom of UMFC reactor with two ports for sampling (influent and effluent) and a wire point for wire to connect with electrodes. In this UMFC, cathode chamber is present at the top of the reactor which consists of three ports in which two ports for sampling (influent and effluent) and one for aeration and a wire point as similar to anode chamber. Santoro et al. reported that activated carbon felt (ACFF) has the characteristics of high porosity and electrical conductivity, relatively it is low-cost material. The surface of the felt allow the microbes to develop the biofilm easily. In this study, ACFF is used as electrodes (anode and cathode) each with dimensions of 140 sq.cm were located at a distance of 5 cm away from each other.

2.3 UMFC Working and Power Measurements

In this UMFC, anode chamber act as anaerobic zone in which primarily treated leachate is introduced for treatment and inoculated with activated sludge. Fig. 1 shows the experimental setup of laboratory up flow microbial fuel cell. Since it has anaerobic setup, methanogenic activity would take place which obstruct the electricity production. A pinch of BES (Bromo ethane sulphonate) was added at the start of reaction to stopover the methanogenic activity. Phosphate buffer (Na2HPO4 – 4.58 g/L, NaH2PO4.H2O – 2.45 g/L, NH4Cl – 0.31 g/L and KCl – 0.13 g/L) was introduced into cathode chamber and maintained in aeration condition with pH 7. UMFC rector was run for one month continuously in open circuit for acclimatization phase. In this period, the reactor achieved maximum voltage of 376 mV in open circuit mode. After acclimatization phase, the circuit was closed with external resistance and the reactor runs in closed circuit mode. In closed circuit mode, the anode chamber of the reactor was run in continuous mode and therefore the sample was continuously introduced into the chamber with the different organic loading rate (OLR) such as 0.27, 0.32, 0.38, 0.48, 0.64, 0.96 and 1.37 gCOD/Ld by varying the flow rate from 14.29 to 71.43 mL/hr. In every OLR, organic removal, solids removal and current production was measured to assess the reactor working performance.

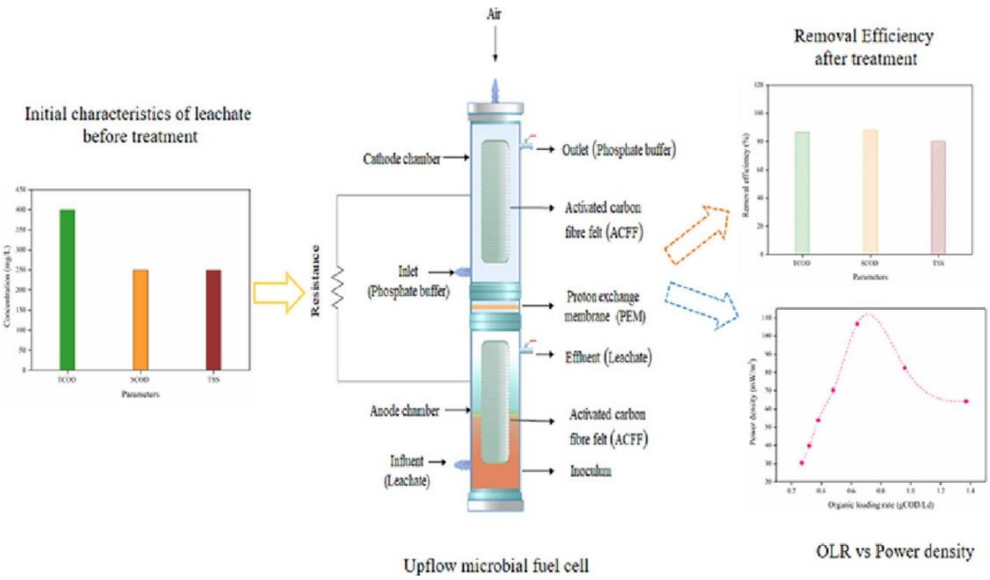

Figure 1: Graphical Abstract

3. Results and Discussions

3.1 Organic removal at different OLR

MFC is operated in continuous mode for 30 days in acclimatization phase at open circuit. For the 2nd day of acclimatization phase, voltage production in MFC was 45 mV. While in 20th day, voltage production increased and gets stabilized at 271 mV. After stabilization, at 28th day the open circuit voltage of 376 mV was achieved. During this phase, maximum COD removal efficiency of 65% was achieved. After acclimatization phase, UMFC was run in continuous mode at varied loading rate from 0.27 to 1.371 gCOD/Ld by adjusting the retention time from 35 to 7 h in closed circuit mode. The initial TCOD and SCOD concentration of anaerobically treated leachate was in the range of 400 ± 20 mg/L and 250 ± 10 mg/L Organic concentration of inlet and outlet COD concentration and organic removal efficiency at different loading rate. Organic matter easily attached on the surface of electrode and get develop into biofilm which leads to oxidation of organic matter, enhances the high organic removal.

Moreover, the decrement in removal due to the toxic content in microbial activity by gathering of intermediary products released during the organic degradation. In increased OLR, the availability of solids is high but the limited growth of microbes' leads to decrease of solids removal. The deposition of fermentable organics suppresses the activity of androphiles. Thereby reducing the biomass from the reactor, increases the suspended solids (SS) concentration in outlet. In optimal OLR of 0.64 gCOD/Ld, the presence of TSS was least in outflow which concludes that no possibility of biomass loss in peak TSS removal.

3.2 Power Generation

Polarization curve is used to characterize current as a function of voltage and which shows that how well the MFC maintains a voltage as a function of the current production. Electrical measurements in MFC such as voltage, power and current densities were depicted as polarization curve. In acclimatization phase, maximum voltage of 376 mV was achieved in open circuit mode. The OLR and the formation of biofilm in the electrode influence the power generation in MFC. In this experiment, polarization curves were plotted by connecting external resistance in range of 100 Ω - 10,000 Ω. In the starting OLR of 0.27 gCOD/Ld, the maximum internal resistance of 380 Ω and the least resistance of 120 Ω were recorded. This decrement in internal resistance is happens because of the endophilic microbes' catalytic activities. A fuel cell characteristic shows that slow stabilization happens in low resistance, whereas quick stabilization takes place in maximum resistance. Voltage was declined initially this is because of the redox reaction which slowly takes place in anode. This decrement also related with increasing current density as a result of ohmic losses. At 0.27 gCOD/Ld and 0.48 gCOD/Ld OLR, power density of 30.3 mW/m2 and 70.1 mW/m2 were recorded respectively. It was observed that there was an increase in power density up to the optimum OLR of 0.64 gCOD/Ld and this is because of gradual increase in organic matter degradation in wastewater from the OLR of 0.27 gCOD/Ld to 0.64 gCOD/Ld leads to better electricity production. The power density of 106.6 mW/m2 with the achieved current density of about 151.9 mA/m2 in the voltage of 702 mV (external resistance of 400 Ω) at 0.64 gCOD/Ld. When the OLR was further increased to 0.96 gCOD/L d, a remarkable decrement in power density of 82.5 mW/m2 was noted. In power generation, internal resistance present in MFC played a major role. In MFC, reducing internal resistance is mandatory to achieve maximum power generation. Some factors such as reactor structure, materials used as cathode and anode, space between the electrodes, OLR of wastewater and formation of biofilm in the electrode influence the internal resistance during power generation in MFC. This increased power production with varying OLR might happens due to the effective consumption of the organic matter by the microbes in inoculum and anode surface. Bose et al reported that power production in MFC might depend on the microbial density on the electrode surface. Consequently, above the OLR of 0.64 gCOD/Ld, there was a decrement in power density this is because at peak loading rate, retention time for the biomass in the reactor is low. Therefore the contact period between the microbes and organic matter is minimum for the substrate degradation Thus it reduces the current generation. The substrate presence is more when OLR increases which might be beyond exaelectrons oxidizing capacity and thus affects COD consumption and power generation. Kim et al. reported that in tubular MFCs, the low power recovery by electrogenesis might happens due to the ratio of non-electrogenic to electrogenic COD degradation. Behera and Ghangrekar, also reported that methanogenesis may affect the electrochemical process when wastewater is feed into MFC. Hence in optimum OLR of 0.64 gCOD/Ld organic matter removal and maximum power production was obtained.

4. Conclusion

In this study, continuous UMFC was operated using primary treated wastewater for the period of 130 days in continuous mode under various OLR condition. The operating issues can be controlled to lessen the polarizations so that enhance the UMFC performance. The maximum power generation of 106.6 mW/m^2 was obtained at the optimum OLR of 0.64 gCOD/Ld with coulombic efficiency of 35.5%. TCOD, SCOD and TSS removal efficiency of 84.6%, 88%, and 80% respectively were accomplished in this study. The bacterial community results with presence of proteobacteria (58.9%), firmicutes (40.3%), Bacteroidetes (3.8%) and absence of methanogens at OLR of 0.64 gCOD/Ld authenticated the potential leachate treatment with power production in UMFC. Thus, the present study clearly recommends the use of continuous UMFC for potential treatment of primarily treated leachate coupled with energy production.

5. Author’s Biography

Vrushali Rajendra Borkar is a TGT science teacher at School of Scholars, Yavatmal. She has completed her B.Sc in Biology, M.Sc in Communications and Bachelors in Education. She has cleared both Paper 1 and 2 of CTET and is also a two time best teacher award recipient in MGS group.

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