Textile dye decolorization & bioelectricity generation in a microbial fuel cell

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ABSTRACT - Microbial fuel cells (MFC) have been gained a considerable attention during past few decades due to its ability to treat wastewater effluents while generating bioelectricity. In this study anode to cathode area ratio was varied to maximize the output voltage simultaneously achieving the required color reduction. The highest voltage was observed as 515mV from anode to cathode area ratio of 3:1 on the 7th day from the beginning. At the latter stage, all arrangements show more than 85% color reduction at 200h. Therefore, it can be concluded that electrode area ratio has no significant effect for the fractional color reduction.

Keywords: Microbial fuel cell; dye decolorization; microorganism; bioelectricity generation

INTRODUCTION

Today, discharge of chemical industrial effluents in an eco-friendly way has become a controversial issue worldwide. Most existing wastewater purification technologies consume a lot of energy (Mustakeem, 2015). To address this inefficiency, Microbial Fuel Cells can be explored to treat wastewater in a more economical and sustainable way (Rahimnejad, 2015). This solution will also be effective as an alternative source in modern energy crisis.

In textile industry, synthetic dyes are widely used. During dyeing operation processes, about 10-15% of dyes ends up in wastewater. To address this circumstance, decolorization treatment of dye effluents has receiving a growing attention (Guo, 2014). As chemical treatment methods have their own disadvantages, alternatively biological treatment MFCs, which convert the chemical energy resident in organic materials in to electricity, may represent efficient way to remove dyes from wastewater.

The main components of the MFC are the anode, cathode, Proton Exchange Membrane (PEM), conductor, the substrate and the microorganisms (Juan, 2013). MFCs can produce electricity with the use of wastewater as a substrate. Bacteria inhabitants in the substrate colonize the anode, oxidize the organic content (glucose) in the wastewater and donate the electrons to the anode (Madhavan, 2016). Electrons are transferred to the cathodic chamber through an external electric circuit, while protons travel to the other side through PEM. Electrons and protons reacted in the cathode chamber along with parallel reduction of oxygen to water (Gude, 2016).

However, despite of all the advantages provided by MFC, its low performance in bioelectricity generation has become a cause for concern (Rahimnejad, 2015). Several measures have been taken nowadays in order to enhance the efficiency by changing parameters such as, cathode material, electrode surface, electrode spacing, configuration, buffer solution properties and concentration of substrate (Song, 2015).

METHODOLOGY

According to the previous research, it was found the capability of dye decolorization, the optimum dye concentration for the maximum color reduction and the electricity generation using the microbial fuel cell apparatus. In this research, it was decided to optimize the cell performance by varying the Anode: Cathode ratio.

- Selected species: *Proteas mirabilis*
- Source: Synthetic Dye Sample
- Selected Dye Sample: Yellow CXF

2.1 Preparation of LB broth

The ingredients for cultivating the initial inoculum were prepared by adding 1g Tryptone, 0.5g yeast extract and 1g NaCl to 100ml of distilled water.

2.2 Preparation of substrate for the MFC

The nutrients for microbes were prepared by adding 1g of glucose, 0.5g of NH_4Cl and 5g of Na_2HPO_4 to 1L of distilled water.

2.3 Preparation of Microbial Fuel Cell

A dual chamber MFC made of Perspex having natural rubber as the PEM was used. Carbon plates having dimensions 4x50x150 mm were used as electrodes. The whole apparatus was sterilized using 70% ethanol. The external circuit was prepared using a copper wire combined with a 1kΩ external resistor. As it was necessary to keep the anodic chamber in anaerobic conditions, it was sealed using the Perspex lid and silicone glue. 3L of water was filled to the cathodic chamber. An air pump was used to aerate the chamber.

2.4 Investigating the effect Anode to Cathode area ratio on microbial dye decolorization

All the steps mentioned earlier were carried out for three times using Anode to cathode ratios of 1:1, 2:1, and 3:1. Area alteration was taken place by varying the number of plates used. Voltage measurements were taken using the multimeter. Absorbance values for each dye samples were checked using the spectrophotometer to compare the color reduction. Prior to checking the absorbance, samples were centrifuged for 10 minutes at 10000rpm.

RESULTS AND DISCUSSION

The experiments were carried out according to three different anodes to cathode ratios as 1:1, 2:1, and 3:1. Results were obtained for the variation of voltage and fractional color reduction of dye during the period.

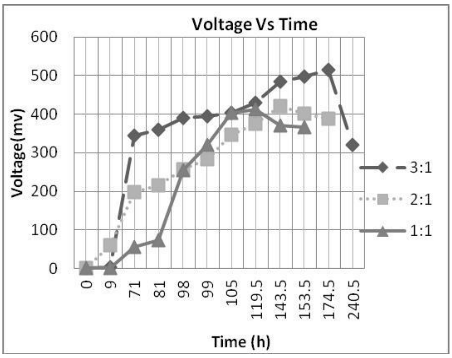

Figure 1 Voltage vs Time Graph

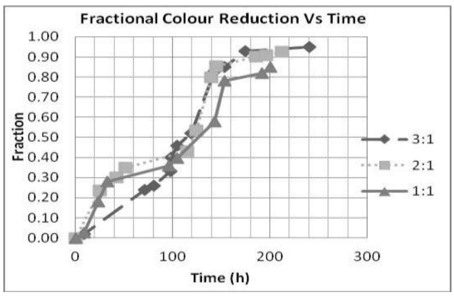

Figure 2 Fractional Color Reduction vs Time graph

According to the results, the anode to cathode ratio 3:1 has the highest performance in terms of voltage generation and all three configurations achieved above 85% color reduction at the end of 200h. During the first 100h, 1:1 and 2:1 configuration indicate a better performance in terms of color reduction than 3:1, but during the same period, they have less performance in voltage generation compared to 3:1 as well.

This also aligns with the MFC operating mechanism. Here the electrons are generated from the action of microorganism consuming the glucose supplied. The same amount of glucose and same amount of a microbial culture were introduced under the same conditions to each anode chamber. Once the glucose consumption begins, electron generation also begins. A portion of electrons is taken by the dye azo bond for the decolorization and the other portion is taken by the anodes to generate the voltage through the fuel cell. From the above results, it is evident that the attraction of electrons to anode is higher when the anode to cathode ratio is high which resulted in high voltage generation in 3:1 compared to others. Since this effect is less in 1:1 and 2:1, they utilized their generated electrons more towards decolorization. Therefore, they had better color reduction at the initial stage than 3:1.

CONCLUSION

This research was extended with the purpose of optimizing the performance of the microbial fuel cell in terms of electricity generation and simultaneous color reduction. Objective was to optimize the output voltage by varying anode to cathode area ratio through series of experiments. According to the results 3:1 is the most suitable anode to cathode area ratio for the maximum voltage output. Gives higher voltage output than the other two configurations throughout the time. Therefore, it can be concluded that output voltage is increased with the increase of anode to cathode area ratio. Regarding fractional color reduction anode to cathode ratio 1:1 and 2:1 has higher performance in dye decolorization while 3:1 has a less effect. However, there is no significant variation in color reduction with anode to cathode area ratio.

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