International Journal of Engineering and Technology, *1 (2) (2012) 115-123*

www.sciencepubco.com/index.php/IJET

Performance of the Salt Bridge Based Microbial Fuel Cell

Maksudur R. Khan, Ripon Bhattacharjee, M. S. A. Amin*

Shahjalal University of Science and Technology
E-mail: mrkhancep@yahoo.com; saikat_cep@yahoo.com

Abstract

Electricity generation from readily biodegradable organic substrates accompanied by decolorization of azo dye was investigated using a Microbial fuel cell (MFC). Biodegradation was the dominant mechanism of the dye removal, and glucose was the optimal substrate for Red Cibacron-2G (RC) decolorization. Batch experiments were conducted to evaluate the performance of the MFC. As compared to traditional anaerobic technology higher decolorization efficiency was achieved by MFC. Effect of initial dye concentration and external resistance on power generation were studied. Polarization experiments were also directed to find the maximum power density. Maximum Power density of 100mW/m^2 (1.04A/m^2) was recorded at optimum operating conditions.

Keywords: *Decolorization; Microbial Fuel Cell; Polarization; Salt Bridge*

1 Introduction

Sustainable energy production and wastewater treatments are a top priority in the developing global community. Many industrially developed or developing countries had a lot of problems to treat some of the industrial waste materials, which cause pollution to the environment. Azo dyes which constitute the largest chemical class of synthetic dyes are extensively contained in effluent discharged from dye-manufacturing industries and dye-consuming industries. The intense color of dye-containing wastewater leads to severe aesthetic problems and obstructs light penetration and oxygen transfer into water bodies, thus affecting aquatic life.

In most cases wastewater from different industries disposed to the water basins without treatment brings disaster to people, plants, rivers and the eco-system. Treatment of dye-containing wastewater still presents a technical challenge. Most physicochemical methods can remove dye efficiently but are not feasible due to their expensive cost, limited versatility and sensitivity to other wastewater constituents. Alternatively, biological treatment may present a relatively inexpensive way to remove dyes from wastewater [1]. All the conventional wastewater treatment is usually the most energy-intensive unit

process and required a mass amount of energy. Some of this energy can be recovered by using Microbial Fuel Cell (MFC) as a source of sustainable energy using either of low or negative economic value such as wastewater. Recently, it has been reported that microorganisms can convert organic matter into electricity using MFCs while simultaneously accomplishing wastewater treatment [2-3]. Decolorization of azo dyes is usually achieved under anaerobic (methanogenic) or anoxic conditions. In the past few years several bacterial strains that can aerobically decolorize azo dyes have been isolated [4].

In MFCs, the bacteria in the anode must be grown in an anaerobic environment in order to produce a higher power output. MFCs offer a new technique in practical applications for enhanced decolorization of azo dye while at the same time recovering electricity from a readily degradable organic carbon source in practical applications.

In this present paper, MFC has been constructed by locally available material for simultaneous power generation and decolorization of azo dye. A series of experiments was conducted to investigate the performance of the MFC with respect to decolorization of dye and electricity generation from organic carbon sources.

2 Materials & Methods

2.1. Dye

Red Cibacron-2G was supplied from a local textile industry. The **IUPAC Name** tetra sodium
(3E)-5-benzamido-3-[[5-[[4-fluoro-6-[(1-sulfonatonaphthalen-2-yl)amino]-1,3,5-triazin-2-yl]amino]-2-sulfonatophenyl]hydrazinylidene]-4-oxonaphthalene-2,7-disulfonate.

2.2 MFC Construction & Operation

The dual chambered MFC was designed and fabricated in the laboratory using perplex material. Volume of the anode and cathode compartment was the same (0.5 L) and each chamber was provided with sample port, wire point inputs (top), inlet and outlet ports. A straight salt bridge was used to connect the two chambers. 9.5 cm long and 0.75cm diameter plastic tube was used for salt bridge shown in figure 1.

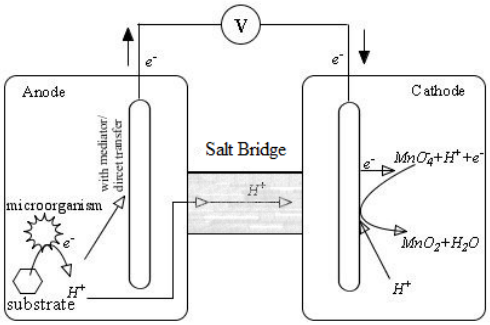

Figure 1: Schematic diagram of microbial fuel cell with schematic details

For salt bridge preparation, agar was dissolved into boiling water (at concentration of 100g/L) and 0.5gm of each KCl, NaCl, and KNO_3 salts were added to the agar/water

mixture while the mixture was still hot. Agar/salt mixture was poured into the plastic pipe while it was still warm and before it begins to thicken. The agar/salt mixture was allowed to cool and solidify. Both anode and cathode electrodes were made of graphite Rod (6 cm; 0.8 cm diameter) and were positioned at a distance of 4 cm on either side of the salt bridge. The electrodes had a surface area of 6.031 sq. cm (anode and cathode). Prior to use, the electrodes were soaked in de-ionized water for a period of 24 h. Contact between electrodes and copper wires was sealed with epoxy material. Red Cibacron-2G (RC) was used as mediator in the anodic chamber of the MFC. The mixture of dye and sludge was stored in a jar with air bubbling. 1 g/L of glucose was used in that mixture as a nutrient for microorganism. This mixture was used as the original anodic inoculums. The sludge was collected from the Shahjalal University of Science and Technology's waste water drainage system. Before inoculation, the sludge was filtered through a 0.25 mm pore size sieve to remove the impurities. During operation, the anode chamber was maintained at pH condition by using 0.1M NaOH or HCl. The MFCs were all operated in a batch-fed mode at a fixed load (130.6Ω unless stated otherwise). All experiments were conducted at least in duplicate, in a constant temperature room (30 ± 2 ^{0}C), and the average value was reported for all data.

2.4 Analysis and calculations

2.4.1 Decolorization Calculation:

Decolorization of RC was determined by monitoring the decrease in absorbance at the maximum wavelength of 513.5 nm. UV-visible spectrophotometer (Shimadzu, Model - 1650) was used for this purpose. For the 48-hr decolorization experiment, test samples (5ml) where withdrawn from the reactor at 0, 2, 4, 6, 8, 10,12, 24, 30, 36 and 48 hr. samples where centrifuged at 5,000 rpm for 5 min to remove suspended biomass from the liquid media and absorbance was measured. Decolorization activity was calculated as the following:
Decolorization rate (%) = *(A-B)/A x 100*
A is the initial absorbance; B is the observed absorbance.

2.4.2 COD calculation:

COD of a sample can be calculated by the following equation
COD of the sample = *2133.33 (A - B) ppm*
If, A = ml of Mohr's solution required for the sample, B = ml of Mohr's solution required for distilled water.

2.4.3 Current density:

By the ammeter current was recorded every 5 min with a fixed resistance. Then the current density (A/m^2) calculated by the following equation
Current Density,

$$J = I/A$$

Here, I= current and A= Projected cross sectional area of anode

2.4.4 Power Density:

The voltage difference between the anode & cathode (V) was recorded every 5 min using a precise multi-meter. Power density (mW/m^2) was calculated according to the following equation

Power Density,

$$P = IV/A$$

Where I is the current, V is the voltage and A is projected cross-sectional area of the anode.

3 Results and Discussion

3.1 Comparative study with MFC

The MFC was compared with the traditional anaerobic batch reactors (without electrodes) for evaluation of the decolorization performance of the MFC using a mixture of 400 ppm RC and glucose as the substrate. In Figure 2, decolorization of RC was observed in the MFC as compared to a traditional anaerobic rector at any given time during the 72 hr decolorization experiment. The color was removed almost Reductive cleavage of the –N=N– bond [5-6], which leads to azo dye decolorization under anaerobic conditions refers to the direct electron which leads to azo dye decolorization under anaerobic conditions refers to the direct electron transfer to azo dys as terminal electron acceptors via enzymes during bacterial catabolism, a process connected to energy conservation [7]. Decolorization of azo dye by bacteria could be due to adsorption by microbial cells or to biodegradation was reported by Sani & Banerjee et al. In adsorption, cells may become deeply colored because of adsorbing dyes, where as those retaining their original color are accompanied by the occurrence of the biodegradation [8]

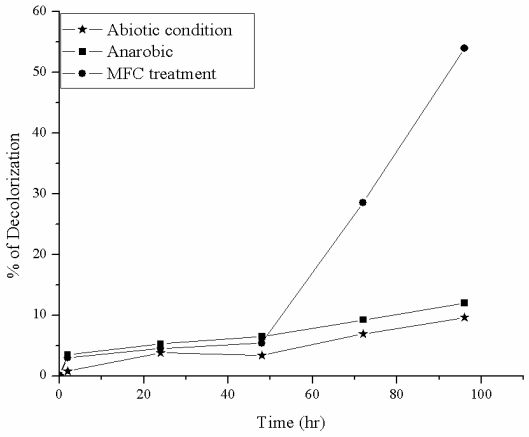

Figure 2: Performance of RC (370 ppm) in MFC treatment, anaerobic and abiotic

Accelerated decolorization of RC in the MFC as compared to traditional anaerobic treatment in this study might be attributed to the presence of the anode, which increases the metabolic rate of anaerobic bacteria with sufficient anaerobic terminal electron acceptors [9]. This could results in faster conversion of the co-substrate (glucose) to

produce more electrons for azo dye reduction, realizing an indirect accelerated decolorization of RC.

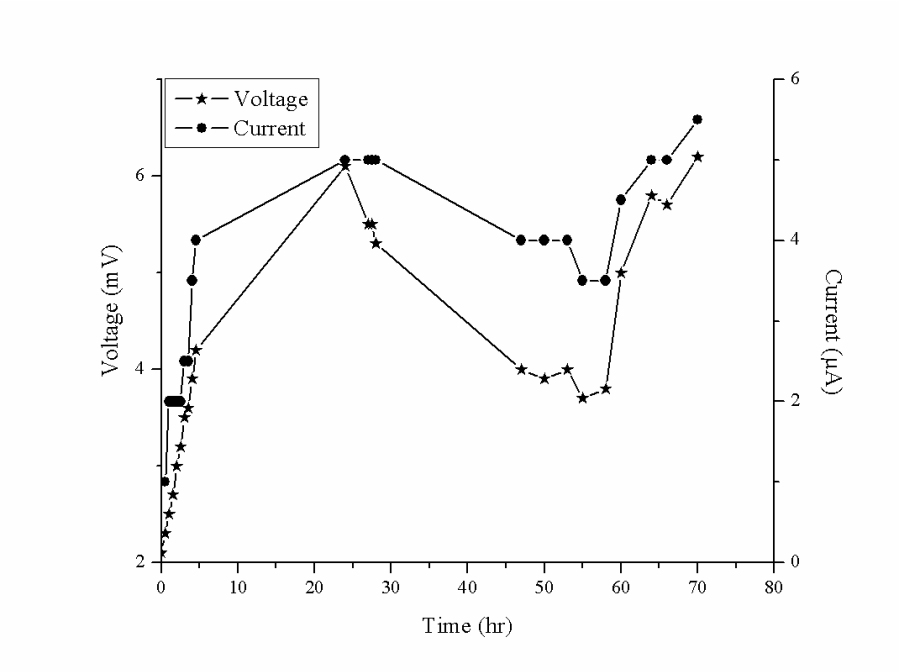

Figure 4: Overall performance of the MFC

In MFC, initial current and voltage were very low which was observed in figure 4. But with respect of time, it increased. After 24 hr both of current and voltage gain a highest value as 5.2mV and 5 μA, and it decreased as time increasing.

3.2 Effect of dye concentration in MFC

Decolorization of RC in MFC was examined at different initial dye concentrations (200–750 ppm). The percent decolorization decreased with an increase of RC concentration during 50 hr of experiment (figure 5).

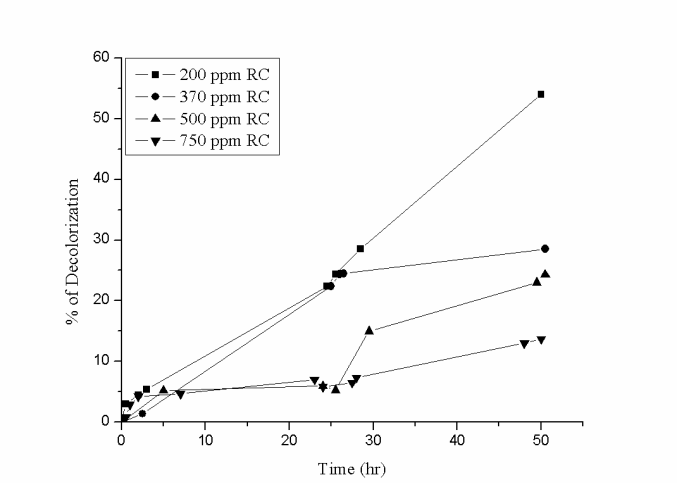

Figure 5: Effect of the initial dye concentration (ppm) on the decolorization efficiency of RC

Maximum 55% of the RC was removed from the solution within 50 hr at an initial dye concentration of 200 ppm. Further increasing the dye concentrations to 370-750 ppm the decolorization rate decreased. These results indicate that, although an increase of dye concentration decreased the decolorization activity, the toxic tolerance of dye for the microbial consortium present in MFCs was excellent.

3.3 Effect of external resistance on MFC

The MFCs were operated with different external resistance across the anode and cathode using glucose as a substrate to explore the effect of external resistance on decolorization of RC (400 ppm). It was observed that the lower the resistance was, the faster the decolorization rate. After 24 hr, with an external resistance of 130Ω, over 25% of color was removed; whereas in this same time 1 kΩ, 2.68 kΩ, and 3.26 kΩ displayed 18%, 15% and 8% respectively.

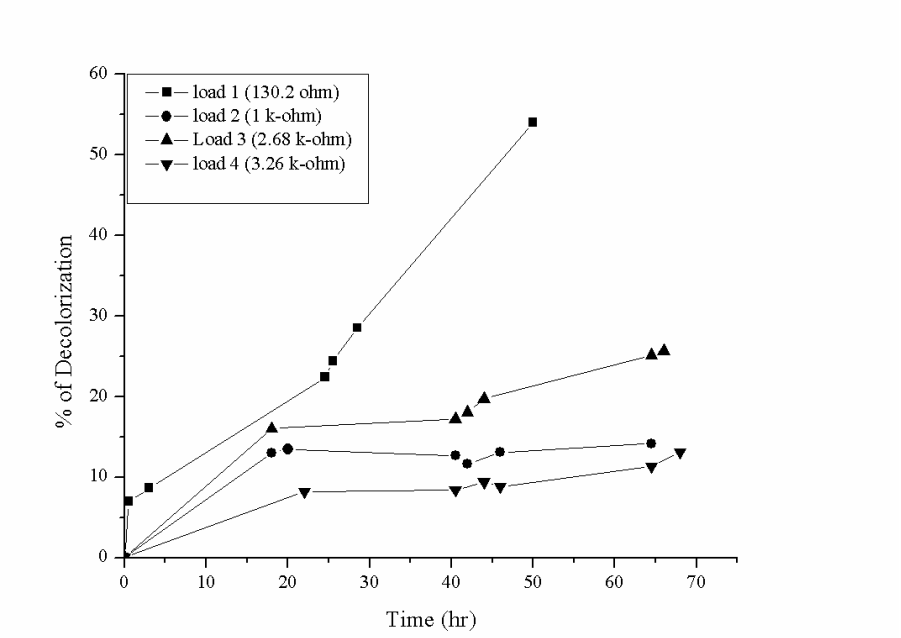

Figure 6: Decolorization of RC (400 ppm) in MFC system at different external resistances

The lower the resistance was, the higher the Coulombs recovered from substrates, this was due to an increased substrate conversion rate as compared to a higher resistance during MFC operation [2]. As a result, more electrons were provided for the reduction of the –N=N– bond in RC, and thus, a faster decolorization rate was achieved.

3.4 Polarization curve

Polarization curve as a function of current density and power density measured at variable resistances (46.8Ω-12.28KΩ). Current generation in different resistors was observed once the maximum voltage was attained. From the fig-9 maximum power density of 100.2 mW/sq. m obtain from 500ppm RC at resistances (10.72KΩ). For 370 ppm and 200 ppm of RC, the maximum Power density 51.2 mW/sq. m and 21 mW/sq. m. studied respectively. For the resistance range 46.8 to 99.7Ω show increasing of power density with increased current density. Then the power density begins to fall down with increasing current density. Current generation showed decreasing trend with increase in resistance and is consistent with the reported literature [10], which indicated a typical fuel cell behavior. At higher resistance used (12.28 KΩ), relatively less power density of 26.04 mW/sq. m was observed. Relatively less voltage drop was observed at lower resistance indicating less potential drop. Voltage stabilization was comparatively rapid at higher resistances studied. Effective electron discharge observed at lower resistances might be the probable reason for further potential drop and slow stabilization of the voltage at lower resistances.

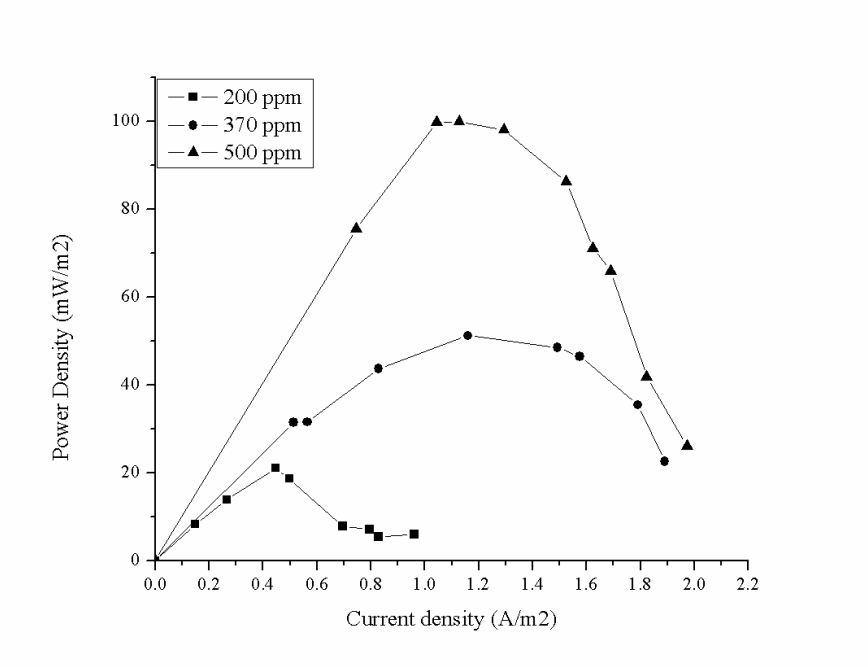

Figure 9: Power Density Vs current density polarization curve

Oxidation of substrates by microbes was observed to be more at lower resistance than at higher resistance, where microbes donated electrons to the anode as the electrons were discharged in a closed circuit [11]. Rozendal and co-workers reported power density of 563 mW/sq. m using MFC fabricated with platinum-coated titanium graphite felt anode and aerated cathode. Relatively lower power (100.2 mW/sq. m) observed in this study might be because of using graphite electrode without any coating [12].

4 Conclusion

- Microbial Fuel cell was fabricated and constructed with local materials.
- Decolorization performance in MFC treatment was higher than traditional anaerobic and abiotic condition.
- Effect of dye concentration and COD in MFC were studied and found that about 55% of dye and 48% of initial COD reduced. Dye concentration higher than
- Higher decolorization observed for low resistance which was studied in the effect of external resistance on MFC
- Effect of initial dye concentration on electricity generation has been investigated and no specific trend was found
- The polarization curve was plotted for particular MFC. Due to the ohmic resistances, sharp drop in the voltage was observed with the increase of the current density. This indicated, the external resistances in electrode, connecting weir, circuit etc were dominated in the MFC efficiency.

References

[1] DosSantos A.B., Cervantes F.J., Van-Lier J.B. Review paper on current technologies for decolourisation of textile wastewaters: perspectives for anaerobic biotechnology. Bioressour. Technol. (2007), 98, 2369-2385.

[2] Mohan S.V., Saravanan R., Veer S.R., Mohanakrishna G., Sarma P.N. Bioelectricity production from wastewater treatment in dual chambered microbial fuel cell (MFC) using selectively enriched mixed microflora: Effect of catholyte. Bioresour. Technol. (2006), 99(3), 596-600.

[3] Logan B. E., Regan J. M. Microbial fuel cells: Challenges and applications. Environ. Sci. Technol. (2006), 41, 5172-5180.

[4] Park D. H., Zeikus G. Improved fuel cell and electrode designs for the producing electricity from microbial degradation. Biotechnol. Bioeng. (2003), 81, 348-355.

[5] Jian S., Hu Y., Bi Z. Simultaneous decolorization of azo dye and bioelectricity generation using a microfiltration membrane air-cathode single-chamber microbial fuel cell. Bioresource Technology (2009), 100, 3185–3192.

[6] Liu H., Ramanarayanan R., Logan B. E. Production of electricity during wastewater treatment using a single chamber microbial fuel cell. Environ. Sci. Technol. 2004, 38, 2281-2285.

[7] Pandey, A., Singh P., Iyengar L. Bacterial decolorization and degradation of azo dyes. Int. Biodeterior. Biodegrad. (2007), 59, 73-84.

[8] Sani, R.K., Banerjee U.C. Decolorization of triphenylmethane dyes and textile and dye-stuff effluent by Kurthia sp. Enzyme Microb. Technol. (1999), 24, 433- 437.

[9] Morris J.M., Jin S., Crimid B., Prudend A. Microbial fuel cell in enhancing anaerobic biodegradation of diesel. Chem. Eng. J. (2009), 146, 161–167.

[10] Min B., Logan B. E. Continuous electricity generation from domestic wastewater and organic substrates in a flat plate microbial fuel cell. Environ. Sci. Technol. (2004), 38, 5809–5814.

[11] Liu H., Cheng S., Logan B. E. Production of electricity from acetate or butyrate using a single-chamber microbial fuel cell. Environ. Sci. Technol. (2005), 39, 658–662.

[12] Rozendal A.R., Hamelers M.V.H., Buisman N.C. Effects of membrane cation transport on pH and microbial fuel cell performance. Environ. Sci. Technol. (2006), 40, 5206-5211.