Granular Activated Carbon Single-Chamber Biocathode Microbial Fuel Cell (GAC-SCBMFC) for Simultaneous Decolorization of Dye Wastewater and Electricity Generation

Shafeer Kalathil, Jintae Lee, and Moo Hwan Cho*
School of Display and Chemical Engineering, Gyeongsan, Korea
(mhcho@ynu.ac.kr*)

Introduction

Azo dyes present in effluent from dye-manufacturing industries and textile industries make severe environmental problems such as obstruction of light and oxygen transfer into water bodies which in turn fatal to aquatic life (Pant et al., 2008). Besides, several of these dyes are toxic in nature. Recently some studies on decolorization of azo dyes have been reported using pure azo dyes such as active brilliant red X-3B (ABRX3), a model azo dye in a MFC (Sun et al., 2009). However, there was no attempt to treat real dye wastewater. The dye wastewater contains many numbers of azo dyes and large amount of organic and inorganic substrates. As a result, these make the dye wastewater highly complex and complicated for treatment. Here we treated the dye wastewater collected from dye wastewater treatment plant without further modifications using a single chamber microbial fuel cell with granular activated carbon (GAC) bioanode and biocathode. To our best knowledge, it is the first time using a GAC bioanode and biocathode for the treatment of the dye wastewater.

Materials and methods

The MFC consisted of two bottles (250ml) with granular activated carbon (GAC) electrodes packed in cylindrical stainless steel cages (volume: 34 cm^3).The bottles are joined by a glass bridge containing a glass wool separator instead of Nafion membrane held by a clamp between two flattened ends of glass tubes (inner diameter=1.3cm). GAC packed in a cylindrical stainless cage used as anode and similar electrode was used as cathode. A graphite rod (diameter: 1cm) was inserted in both anode and cathode and connected to an external resistance 800 ohm unless stated otherwise.

The anode and cathode were inoculated using only the bacteria present in the dye wastewater collected from the dye wastewater plant and it was operated in batch mode. Initially 10 ml of aerobic sludge collected from dye wastewater plant was inoculated in the cathode in addition to dye wastewater to enhance biocathode formation. The cathode was continuously sparged with air using an aquarium pump. The reactor solutions were replaced every two days. After six transfers, a stable voltage was reached and on further transfer power out was repeatable indicating the stable performance of the biofilm on the anode and cathode.Dye wastewater was continuously added to both anode and cathode without any modifications. All measurements were taken after the reactor had been operated for various retention times. All experiments were conducted at 30^0 C temperatures.

Analysis

The voltage (v) across an external resistance was monitored at 30 minutes intervals using a digital multimetre (Agilent 34405A) connected to a computer. Power density was calculated by varying external resistance from 100 to 3000 ohm using a variable resistance box. Decolorization was measured using Platinum-Cobalt Standard Method using Hach DR/2500. COD was measured using Reactor Digestion Method using Hach DR/2500.

Results and Discussion

Electricity production

Initially the voltage production was less and gradually it began to increase. After 12 days of operation, the MFC gave a stable voltage of 0.214 V (1.683 W/m^3) at 800 ohm external resistance (Fig 1). The open circuit voltage (OCV) was 0.451

Decolorization performance of GAC-SCBMFC

Decolorization of real dye wastewater in the single chamber biocathode MFC at an external resistance of 800 ohm was investigated at 12 hours intervals. As shown in Fig 2 accelerated decolorization was occurred in the initial 12 hours .52% of color removal was observed after 12 hours and 78% of color was removed after 48 hours. These increased color removals may be attributed to high performance of biofilm formed on GAC anode and GAC biocathode. In anode, organic and inorganic substrates present in the dye wastewater were oxidized by the anaerobic biofilm formed on anode producing a large number of electrons and protons. Some of the electrons and protons reacted with azo dyes present in the wastewater and cleaved the azo bonds which were responsible for color. Moreover, bacteria can utilize some of the dyes as substrates. Meanwhile dye wastewater present in cathode can accept electrons and protons coming via external circuit and glass wool respectively which would turn the breaking of azo bonds. These simultaneous breakings of azo bonds in anode and cathode making this MFC system an efficient tool for the removal of color from the real dye wastewater.

Effect of external resistance on decolorization of dye wastewater

The single chamber biocathode MFC was operated with different external resistance in order to investigate the effect of external resistance on decolorization of the dye wastewater. The MFC operated under open circuit was used as the control (Fig 3). When external resistance of 50 ohm was used, 70% of color removal was observed within 24 hours whereas same process took 36 hours at 800 ohm which is close to result reported by J. Sun et al 2009 using ABRX3 as dye. At an external resistance 5000 ohm, 55% of color removal was occurred within 24 hours whereas same process took place within 12 hours at 800 ohm external resistance. But at open circuit voltage only 47% of color removal was observed within 24 hours which was lower than all other experiments conducted at different external resistance. It was reported that 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 (Gil et al.,2003) and as a result more electrons are provided for the reduction of the –N=N- bonds in the dyes present in the dye wastewater ,and thus, a faster decolorzation rate was observed in anode and meanwhile more electrons reached in the cathode through the lower resistance making cathode decolorization rapid. These two combined effects made decolorization rate faster at lower resistance.

COD removal efficiency

The MFC operated at influent COD concentration 1752mg/L. After 12 hours of operation, 56.6% COD removal was observed and after 48 hours of operation around 79% COD removal was observed (Fig 4).

Conclusion

An efficient decolorization of real dye wastewater and bioelectricity generation can be successfully achieved using a single chamber microbial fuel cell with GAC bioanode and biocathode. Simultaneous decolorizations of dye wastewater at anode and cathode make this system more efficient and rapid. Due to high surface area of GAC particles, more biofilm can form on the surface of GAC which will enhance the performance of the MFC system. There are many advantages of the proposed MFC system. There is no need of expensive materials like Nafion membrane and platinum catalyst which will undergo biofouling in long term operations.

Acknowledgment

Shafeer Kalathil was supported by the Brain Korea 21 Project from the Ministry of Education and Human Resources, Korea.

References

1. B. E. Logan, C. Murano, K. Scott, N. D. Gray and I.M. Head, Water Research, 39,942,(2005)
2. D. Pant, A. Adholeya, Y. Satyawali and R. K. Gupta, J. Eniviron. Biol, 29, 79 (2008)
3. G. C. Gil, I.S. Chang, B.H. Kim, M. Kim, J. K. Jang, H. S. Park and H. J. Kim, Biosensor Bioelectron, 18, 327 (2003)
4. J. Sun, Y.Y.Hu, Z. Bi and Y. Q. Cao, Bioresource Technology, 100, 3185 (2009)
5. Z .Li, X. Zhang, J. Lin, S. Han and L. Lei, Bioresource Technology, 101, 4440(2010)

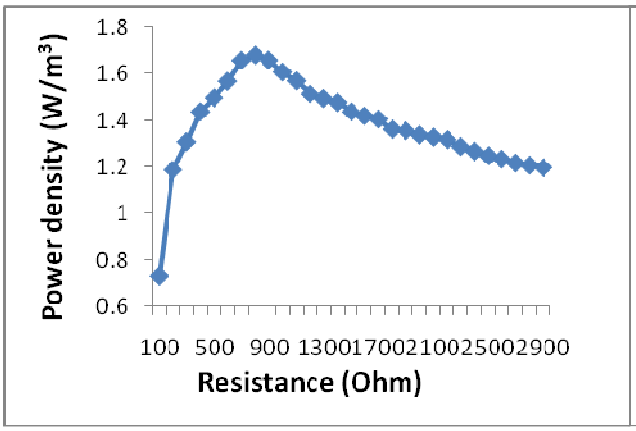

Fig 1: Power generation as a function of external resistance

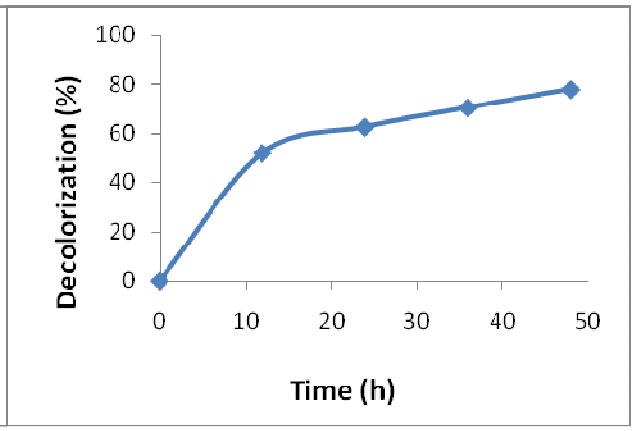

Fig 2: Decolorization performance of GAC-SCBMFC with different retention time

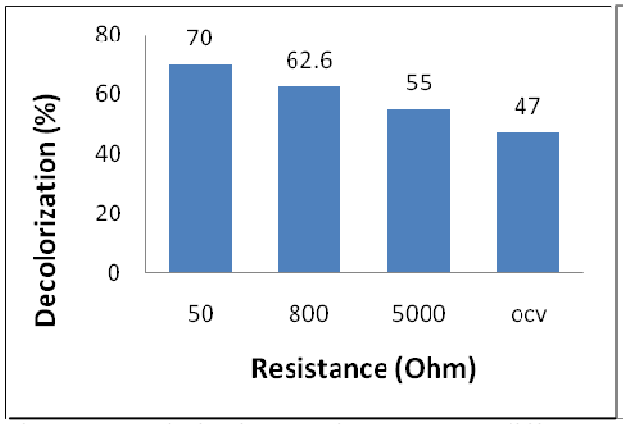

Fig 3: Decolorization performance at different external resistance after 24 h MFC operation.

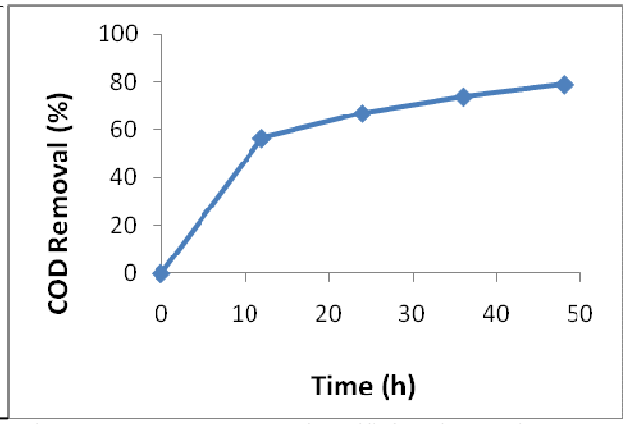

Fig 4: COD removal efficiencies of GAC-SCBMFC.

.