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Efficiency of single chamber microbial fuel cell (MFC) in wastewater treatment

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ABSTRACT

This paper describes the efficiency of the microbial fuel cells in wastewater treatment and power generation. Throughout the experiment, the single chamber – MFCs (SC-MFCs) can treat the wastewater up to 60%. With using the municipal or domestic wastewater as a substrate, the optimum power generation produce is 0.031V. To further improve the efficiency of the wastewater treatment using the MFCs, a better understanding in wastewater and MFCs itself is crucial. For example, understand and examine the microorganisms in the wastewater. Besides that, the setup of the MFCs also needs understanding and knowledge. The results indicated that MFCs is efficient in treat the wastewater and produce power generation. From the research, it is concluded that further improvements on MFCs is required for further development of the MFCs.

1. Introduction

When wastewater is adversely affected in quality by anthropogenic influence, it is normally defined as "wastewater" (Sulieman et al., 2010). In other words, all consumed water will turn into wastewater. Wastewaters are generated from a variety of sources. Everything that we flush down your toilet, or rinse down the drain is wastewater as well as rainwater runoff along with various pollutants and also from agricultural and industrial sources. Different source of generation will produce different qualities of wastewater. For example, wastewater from domestic area will produce wastewater with high organic material and yet relatively easy to treat compared to industrial wastewater. To develop a proper wastewater treatment is a challenge. Without appropriate management, wastewater can lead to serious impact to human health and living organisms. Most of this wastewater is sent to centralized facilities and treatment. Conventional wastewater treatment processes consume large amounts of energy; and the demand for energy by these systems is expected to increase as much as 20% over the next 15 years (Logan, 2005). At the present time, the primary technologies for treating municipal, agricultural, and industrial wastewater are based on energy intensive aerobic biological processes that were developed more than a century ago and related to this aeration interpretations for as much as 70% of the energy used in wastewater treatment plants. The high energy constraint of conventional treatment systems are demanding for the alternative treatment technology which will necessitate less energy for its effective operation and recuperate useful energy to make this operation sustainable (Rati et al., 2013). Microbial fuel cells (MFCs) are being investigated as an alternative to activated sludge as they produce energy from wastewater and they generate much less sludge. MFCs are devices that use microorganisms to directly produce electrical current from biodegradable organic and inorganic compounds where the chemical energy store in waste organic being converted into electricity (Logan, 2005). Basically, the overall process that happens in the fuel cell is reverse of water electrolysis where in electrolysis; an electric current applied to water produces hydrogen and oxygen whereas by reversing the process, hydrogen and oxygen are combined to produce electricity and water (and heat). MFC usually consists of two electrodes (anode and cathode) and external circuit to utilize the energy and the wastewater. Anode compartment is typically maintained under anaerobic conditions as oxygen inhibits electricity generation whereas the

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cathode is exposed to oxygen (Rahimnejad et al., 2009). It is believed that MFCs will able recover the output energy in wastewater by limiting the energy input and could be a smart alternative to reduce the cost of treatment yet generate electricity in the future. MFCs used bacteria as mediator to oxidize the organic and inorganic matters and generate current. The MFCs has several benefits with comparison to the current wastewater treatment, including the clean, safe, quiet performances, low emissions, high efficiency and direct electricity recovery. In conclusion, MFC offer cleaner energy to the environment together with effective treatment of wastewater. Kuching is the capital city of the Sarawak State in Malaysia with Kuching population itself is 600 000. For the past few years, the existing sewerage infrastructure of Kuching depends almost on individual septic tank. Commercial complexes, major institutions and high-rise buildings are provided with Imhoff tanks or small package plants. Grey water, oil and grease are not collected or treated. Kuching is now moving toward to the implementation of centralized wastewater treatment plant. Currently, Phase 1 had successfully operated in which it needs to treat approximately 1.9 million liters of gray water per day and with annual cost of over million dollars. However, when all 6 phases are fully operated in the future, imagine over million liters of wastewater will need to be treated each day of annual cost of 80% - 90% than current practice. This high cost is due to large amount of energy consumption from treatment facilities.

Besides that, the conventional method produces excessive sludge production and this sludge need a proper handling storage and disposal. This is the reason of Microbial Fuel Cell (MFC) is recommended. Thus this study aim to investigate the ability of wastewater in Single Chamber Microbial Fuel Cell (SCMFC) to accomplish biological wastewater treatment and at the same time generates electricity. In order to achieve the aims, the following objective is set up:

- To evaluate the effectiveness of the MFC device to treat wastewater with the comparison to the conventional method.
- To study the electricity production potential from the MFC single chamber.

2. Methodology

2.1. Microbial fuel cell (MFC)

MFC for single chamber were experimentally setup as shown in Fig. 1 where each batch of MFC setup consists of a 1L beaker, 2 graphite electrodes (represent anode and cathode) which were connected to voltmeter and resistor via copper wire and wastewater sample as substrate. In this study, MFC experiment was run for five batches which will take on the average or mean value. Each set was filled with 1 litre of substrate; anode electrode was submerged in the wastewater while cathode electrode was partially submerged in wastewater. This is to provide aeration to biochemical process occurred in the cathode compartment. Once the MFC-single chamber is properly set up, the voltage reading is observed and recorded at one hour time interval. Continuous observation was carried out for the 8 hours straight of experiment.

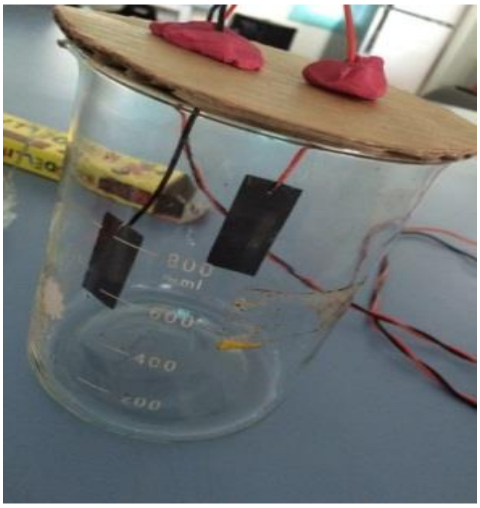

Fig. 1: MFC-Single chamber

2.2. Parameter test

In this study, wastewater was collected from Kuching Centralized Sewage Treatment Plant. Wastewater samples consist of two different collections, one set of sample were collected at the inlet pumping station where the wastewater are not being treated yet and labeled as RAW whereas the other set of sample were collected at the outlet point where the wastewater had undergone primary treatment, biological treatment (activated sludge), secondary clarifier and wetland and labeled as TREATED sample respectively. The sample is being preserved by storing them at 4°C temperature to avoid bacterial degradation. The RAW and TREATED sample is then being tested in the laboratory to obtain their quality by looking at the following parameter (biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), total phosphorus and ammonia).

The procedure of testing method is according to the Standard Method for BOD, COD and TSS. Then, raw wastewater sample were treated using MFC single chamber. After 8 hours of running experiment, the treated sample from MFC single chamber were tested for BOD, COD, TSS and ammonia. The results obtained from the MFC single chamber treatment were being compared to the treated effluent obtained from wastewater treatment plant in order to determine the effectiveness of the treatment which is the main objective of this study. During the experiment stage, electrical measure is observed and recorded continuously. It is vital to indicate a functional MFC.

3. Results and discussions

3.1. Removal rate of single chamber MFC

As shown in Table 1, the maximum removal of COD, BOD, TSS, Total Phosphorus and Ammonia Determination was respectively 63.64%, 59.48%, 60.64%, 30.71% and 51.2%. As the bacteria begin the process of breaking down this waste, dissolved oxygen is consumed by aerobic bacteria as the need oxygen to live. As mentioned earlier, BOD is a measure of the oxygen used by microorganisms to decompose this waste. If there is a large quantity of organic compounds in the water supply, there will also be a lot of bacteria present working to decompose this waste. In this case, the demand for oxygen will be high (due to all the bacteria) so the BOD level will be high. As the organic compound is consumed through the water, BOD levels will begin to decline. In other words, BOD reading is directly proportional to COD reading. Decrease number in COD and BOD indicates that the wastewater is being treated via bacterial metabolism.

In refer to result recorded, TSS reading shown depletion in reading from 281 mg/l to 110.6 mg/l significantly showing 60.64% removal rate. The decrease of the suspended solids in sample may be due to availability of biodegradable substrate in wastewater sample leading to competitive inhibition in microorganisms. Total Phosphorus concentration in the substrate (raw wastewater sample) was 28 mg/l and recorded removal rate at 30.71% leaving final concentration reading of Total Phosphorus at 19.4 mg/l only. This result indicated that phosphorus in the wastewater was dissolved in the liquid phase during operation. Finally, the Ammonia Determination recorded removal rate at 51.2% most due to ammonium ions diffusing into the cathode to enforce charge balance. Another reason is due to stripping of ammonia (Kjeang et al., 2009). In all the fuel cells, the ammonia stripping increased with electricity generation due to the pH shift around the cathode.

3.2. Comparison of parameter test

In order to evaluate the efficiency of wastewater treatment through MFC system, parameter test result of both MFC treated and conventionally treated were compared as shown in Table 2 and Fig. 2 generally. From the result it can be seen that MFC treatment had an equivalent performance as conventional treatment and better than conventional treatment for certain parameter such as COD, BOD and TSS. This shown that MFC treatment a great potential in treating an improving the quality of the wastewater.

Table 1: Summary of result

Parameter	MFC-Single Chamber Treated							Removal Rate
	Initial	MFC Batch E	MFC Batch D	MFC Batch C	MFC Batch B	MFC Batch A	Mean	
COD	725	266	262	259	261	270	263.6	63.64%
BOD	271	108	110	115	107	109	109.8	59.48%
TSS	281	113	110	109	111	110	110.6	60.64%
TOTAL PHOSPHORUS	28	20	19	17	20	21	19.4	30.71%
AMMONIA DETERMINATION	25	12	15	10	11	13	12.2	51.20%

3.3. Power generation

From the result below, a gradual incensement of power generation from the first hour until the fifth hour before it slump eventually. Along with the power generation, COD removal of 63.64% was observed at end of this experiment. This indicates, an anaerobic treatment is occurred. It happens when bacteria start to convert organic compounds (COD). Not only do the bacteria remove contaminating compounds from the wastewater, they also producing a series of electron which able to detected in the form of power (V) as recorded in the Table 3 and Fig. 3. As per mentioned previously, MFC leads other wastewater treatment system for generating energy from organic matter. This is shown by the power generation from the MFC system as the direct conversion of substrate into electricity permits high conversion of efficiencies. Bacteria in the MFC reacted as catalysts consume the organic compound and sludge and as a result, parameter reading of MFC is lower than the conventional wastewater treatment system. In other words, lower readings interpret cleaner treated wastewater. It is vital to ensure best quality of treats wastewater before it is discharged to the environment such sea or river.

Theoretically the operating time in high temperature was longer than low temperatures, but the voltage produced at high temperatures was more. As for the performance of microbial fuel cell subjected to variation in pH, temperature, and external load and substrate concentration whereas the effects of temperature and ferrous sulfate concentrations on the performance of microbial fuel cell (Wei et al., 2013). As temperature increases, the rate of bacterial growth and their rate of bacterial growth and their rate of biochemical reactions is also increase.

As the bacterial growth and biochemical rate increase, the metabolism rate of bacteria also increase thus result higher power generation reading. However, when high temperature is implied vital compounds in cells such as nucleic acid and other material are exposed to temperature and may get damaged which will lead to deterioration of cell function or cell death. This situation influenced the power generation to decrease dramatically.

Table 2: Comparison result based on parameter test

Parameter	MFC Treated (mg/l)	Conventional Treated (mg/l)
COD	263.6	325
BOD	109.8	258
TSS	110.6	202
TOTAL PHOSPHORUS	19.4	20
AMMONIA DETERMINATION	12.2	19

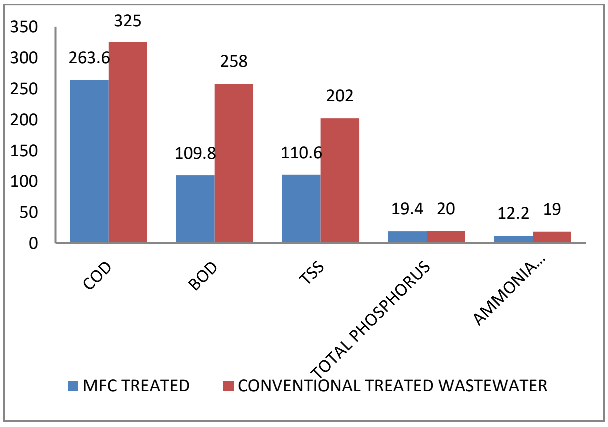

Fig. 2: Comparison graph between MFC treated and conventionally treated wastewater

Besides, the slow growth rate of bacteria due to low temperatures can leads to decrease in the population of bacteria in the anode chamber directly thus affect the power generation to deteriorate. In other words, each bacteria live in specific temperature where growth, reproduction rate and bacterial metabolism directly dependent to surrounding temperature which later on will affect the final product. This explained low power generation in this study (Kjeang et al., 2009).

3.4. Relationship between power generation and concentration

As resulted in this study, power generated reading did not exactly match maximum power generated by literature review and this may due to above problem stated. Besides that, it also may due to the existence of additional existing electron acceptors such as nitrate or sulfate in the wastewater (Ishii et al., 2008).

That extra electron acceptor causes an additional flow of electron from substrate to other acceptor. Extra electron acceptor consumes electrons and caused lower the power generated. Another factor that might influence the increase in power generation is the presence of electrochemically active microorganisms in the wastewater substrate.

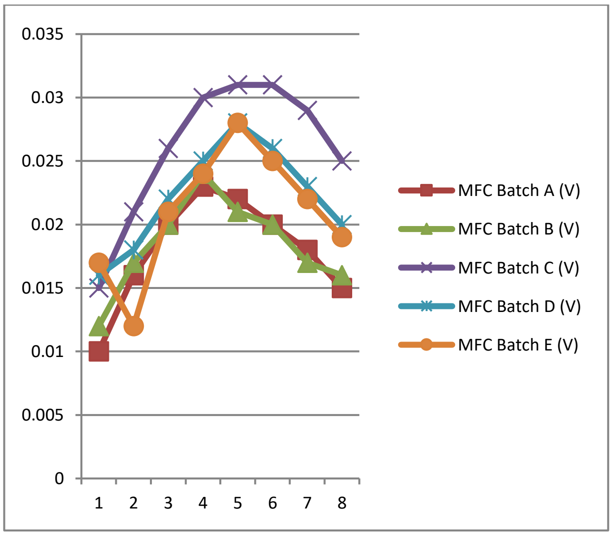

Fig. 3: Power generation throught eights hour experiment

Table 3: Power generation

Hour	MFC Batch A (V)	MFC Batch B (V)	MFC Batch C (V)	MFC Batch D (V)	MFC Batch E (V)
1	0.01	0.012	0.015	0.016	0.017
2	0.016	0.017	0.021	0.018	0.02
3	0.02	0.02	0.026	0.022	0.021
4	0.023	0.024	0.03	0.025	0.024
5	0.022	0.021	0.031	0.028	0.028
6	0.02	0.02	0.031	0.026	0.025
7	0.018	0.017	0.029	0.023	0.022
8	0.015	0.016	0.025	0.02	0.019

4. Conclusion

From the research, the objectives listed were achieved. Throughout the experiment, the efficiency of single chamber microbial fuel cell (MFC) has achieved total removal of COD, BOD, TSS, Total Phosphorus and Ammonia Determination was respectively 63.64%, 59.48%, 60.64%, 30.71% and 51.2%. The power generation that yield from the experiment conducted was 0.031V. Besides that, the result achieved has indicate us the MFC build in single chamber has great potential in utilizing wastewater as one of energy source in the future. However, a lot of study needs to be done in order to understand in details MFC advantageous and limitation. Power generated by the cell may not be enough to run a sensor or a transmitter continuously.

This is the principal problem with using microbial cells. It can be solved by increasing the surface area of the electrodes. Also the other solution is to use a suitable power management program. The data are transferred only when enough energy is stored and this occurs by using ultra capacitor. Finally, the other limitation of MFCs is that they cannot operate at extremely low temperatures due to the fact that microbial reactions are slow at low temperatures.

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References

Ishii SI, Hotta Y, and Watanabe K (2008). Methanogenesis versus electrogenesis: Morphological and phylogenetic comparisons of microbial communities. Bioscience, Biotechnology and Biochemistry, 72(2): 286-294.

Kjeang E, Djilali N, and Sinton D (2009). Microfluidic fuel cells: A review. Journal of Power Sources, 186(2): 353-369.

Logan B (2005). Generating electricity from wastewater treatment. Water Environment Research, 77(3): 211-211.

Rahimnejad M, Mokhtarian N, Najafpour G, Daud W, and Ghoreyshi A (2009). Low voltage power generation in a biofuel cell using anaerobic culture. World Applied Sciences, 6(11): 1585-1588.

Rati P, Sabat R, Swain MK, Jyoti J, and Sarangi MS (2013). Utilization of waste water and production of electricity using non mediated microbial fuel cell. IOSR Journal of Electronics Engineering, 4(2): 47-51.

Sulieman AMEH, Yousif AMW, and Mustafa AM (2010). Chemical, physicochemical and physical properties of wastewater from the Sudanese fermentation industry (SFI). In the Fourteenth International Water Technology Conference (IWTC'10), Cario, Egypt: 305–315.

Wei L, Han H, and Shen J (2013). Effects of temperature and ferrous sulfate concentrations on the performance of microbial fuel cell. International Journal of Hydrogen Energy, 38(25): 11110-11116.