Electricity Generation Using Textile Wastewater by Single Chambered Microbial Fuel Cell

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Abstract-*Increased human activity and consumption of natural energy resources have led to decline in fossil fuel. The current methods of energy production are not compatible with the environment. Therefore, a new treatment approach of using Microbial fuel cell (MFC) has been developing recently. The technology of Microbial Fuel cells is the latest method for producing electricity from biomaterial by using microorganisms. In this study microbial source uses Textile wastewater as a substrate and is inoculated with cow dung for the production of electricity and used to remove the concentration of COD, BOD and Solids. This research explores the application of single chambered MFC in generating electricity. The maximum current, voltage and power produced were respectively 4.32mA, 3.12V and 0.812W/m^2 at 28th day and 1750 mg COD/L feed concentration. The maximum removal efficiency of COD, BOD$_5$, TS, and DS was respectively achieved at 79.6%, 74.7%, 66.7%, and 63.3%. The results showed that generating bioelectricity and treatment of Textile wastewater by single chambered MFC is a good alternative for producing energy and treating wastewater at the same time.*

Key words: Microbial Fuel cell (MFC), Textile wastewater, Electricity generation, Single chambered MFC.

1. INTRODUCTION

Energy calamity in India is rising each year, as there is constant activity in the price of fuels and also due to depletion of fossil fuels to a larger level. The demand for an alternating fuel has erupted extensive research in discovering a potential, economical and reusable source for energy manufacture. Rapid urbanization and industrialization in the developing countries like India pose severe problems in collection, treatment and disposal of effluents. This situation leads to serious public health problems. For constructing a sustainable world we require to minimize the expenditure of fossil fuels as well as the pollution generated. These two aims can be accomplished all together by treating the wastewater (From disposing waste to using it). Industrial waste, agricultural waste and household waste are ideal substrates for energy productions as they are rich in organic contents.

Many researches have shown that hydrogen and bioelectricity can have an important role as fuel in the future [2]. The technology of MFC is the latest method for producing electricity from biomaterial by using microorganisms. MFCs are electrochemical converters and convert the chemical energy stored in organic material to current energy by microorganisms which act as biocatalysts in anaerobic condition [3],[10]. Microorganisms in the anode chamber oxidize the substrate added to the system such as Textile wastewater and produce electrons and protons. Free electrons are transferred to the anode electrode and through the external circuit they reach the surface of the electrode cathode. The produced protons pass through the proton exchange membranes or salt bridges and reach the cathode surface and in the presence of oxygen and electrons from water molecule [4]. In this process along with the production of electric power, the wastewater in the anode chamber is used as a substrate for treatment. The function of microbial fuel cells is affected by several factors such as the amount of oxidation and electron transfer to the electrodes by microorganisms, loading rate, the nature of the used carbon source, the nature of the proton exchange membrane, proton transfer through the membrane to the cathode chamber, oxygen supply in the cathode, the nature and type of electrodes, circuit resistance, the electrolyte used, pH and sedentary time [6], [7], [10]. Industrial Textile wastewater is an important source of organic material for electricity production by using MFC. In this study we are showing the electricity production directly from Textile wastewater and its simultaneous treatment by using single chambered MFC technology.

Textile wastewater is still remained as one of the most complicated wastewaters to treat because of the complex pollutants that it is composed of. Textile wastewater contains very high concentration of color, COD, suspended solids and others pollutants. Being a complex kind, Textile wastewater requires most sophisticated and thus expensive treatment methods which are not affordable to Textile industries in developing worlds. [9].

The methods that are available to treat Textile wastewater include physical, chemical and biological methods. Some of them are effective in removing pollutants but some are not that efficient. Some of the methods such as reverse osmosis, nano-filtration and ultra-filtration, as we know, are very expensive and many developing countries cannot afford the cost of installation and operation. Therefore, a new kind of treatment technology, which would be effective in terms of pollutant removal and affordability, is inevitable for this ever growing industry [9].

2. MATERIALS AND METHODOLOGY

2.1 Treatment by Microbial Fuel Cell (MFC):

Single (MFC-1) Microbial fuel cells have been fabricated for the treatment of Textile industry wastewater.

2.1.1. Materials used for the fabrication of MFC:

Various materials used for the construction of MFCs were as follows:

- one Non-Reactive plastic box of ten liters capacity
- Agar agar bacto (for bacteriology), SDFCL
- Potassium chloride (1M), AR Grade, SDFCL
- Carbon rods of 4mm Diameter & 47mm length extracted from battery cells.
- PVC pipe 3.2cm diameter and length of 22cm
- Sealant: M-seal, pidilite industries ltd.
- Digital Multimeter (DT-830D)

Functions of the materials used for the fabrication of MFC

- **Plastic box:** used to prepare anode chamber. The anode chamber had 10 liters capacity with a working volume of 7.5 liters.
- **Agar agar Bacto:** It was used to prepare agar salt bridge i.e., proton exchange membrane for keeping the anode and cathode containing liquid separately. This membrane is permeable so that protons produced at anode can migrate to the cathode[1].
- **Carbon rods:** These were used as anode and cathode materials.
- **Copper wire:** was used to connect the electrodes to the multimeter which form external circuit.
- **PVC pipe:** holds the agar salt mixture, which is called as agar salt bridge.
- **Sealant:** PVC pipe was connected to the sides of the plastic box and sealed with epoxy or M-Seal to prevent the leakages.
- **Digital Multimeter:** was used to measure the current and voltage.

2.1.2. Construction of Microbial Fuel Cell

Step 1: Selection of Anode Chamber

Non-reactive, non-conductive and non-biodegradable plastic box is selected as anode chambers the dimensions of plastic box are shown in figure.1

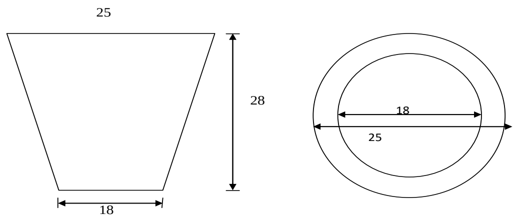

Fig-1: Plastic box. (All dimensions are in cm)

Step 2: Preparation of Agar Salt Bridge

The Agar salt bridge is constructed using common salt, agar and water. 650ml of water is boiled in a beaker, 65 grams of agar and 75 grams of salt are added to the boiling water, and the mixture is further boiled for 3-5minutes. Later on the mixture is filled in PVC pipe and allowed to solidify and is kept in the refrigerator for 24hours. The agar salt bridge is shown in figure 2.

Fig-2: Agar salt bridge

Step 3: Assembling of Electrodes

27 numbers of carbon rods extracted from battery cells as shown in figure 3 and are inserted in the flexible plastic pipe for the construction of Anode. The arrangement of Anode (electrode) is done on a flexible

plastic pipe in such a way that it looks like a carbon brush as shown in figure 4.

Fig-3: Extracted carbon rod from battery cell for preparing carbon brush

Fig-4: Arrangement of electrodes

In single chambered MFC there is no cathode chamber. Instead, the carbon rods extracted from Battery cell have been placed on one end of the agar salt bridge which is exposed to the air and the copper wire is wound on it. This acted as cathode for MFC. The oxygen from air would help in accepting the electrons from anode chamber.

Step 4: Assembling Of Microbial Fuel Cell

The assembled electrodes is placed into the Anode chamber, a circular hole is made on the side of the working volume of the center of the plastic box for fitting the PVC pipe containing agar salt, then the pipe is sealed and made air tight as shown in figure 5 and figure 6.The reactor is checked for water leakage. [8]

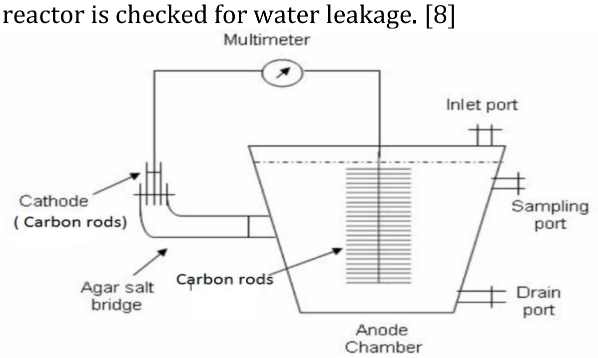

Fig-5: Schematic diagram showing single chambered MFC

Fig-6: Experimental set-up of Single Chamber Air Cathode MFC

2.2. MFC Operation

The $^{1}/_{4}$ Th (1.9 L) volume of the reactor is filled with a mixture of cow dung slurry prepared with septic tank waste as inoculums. The $^{3}/_{4}$ Th (7.5 L) working volume of reactor is filled with Textile wastewater. In the beginning the Anode chamber of MFC is loaded with 250 mg/L of COD and the electricity generated is measured for 4 days. On the 4^{th} day the current and voltage dropped down which shows the stabilization of the reactor for this loading. Similarly the same process is carried out for other 7 sets of readings till the final loading of 1850 mg/L of COD with an increment of 250 mg/L of COD for each loading.

3. RESULTS AND DISCUSSION

3.1. General

Textile industrial wastewater was collected from Sholapur city and kept in a refrigerator at 4^{0}C before use. Wastewater is classified as nontoxic due to low hazardous chemicals and high amounts of biodegradable organics in comparison to other industrial wastewater. Some of the characteristics of both the wastewater are shown in Table 1.In order to evaluate the efficiency of wastewater treatment through the MFC system, the effluent from the anode chamber is examined with regard to COD, BOD_5, Total solids, Dissolved solids and pH according to the standard methods in the textbook of standard methods for water and wastewater examination. Similarly Current, Voltage and power is also measured.

3.2 Characteristics of Textile wastewater

The characteristics of textile wastewater are presented in Table.1

Table-1: Characteristics of textile wastewater

Sl.No.	Characteristics	Unit	Textile Wastewater
1.	pH	-	7.17
2.	Color	-	Dark greenish blue
3.	Total solids	mg/L	5720
4.	Dissolved solids	mg/L	4580
5.	Suspended solids	mg/L	1140
6.	COD	mg/L	1850
7.	BOD_5@20^{0}C	mg/L	994
8.	Chlorides	mg/L	2121.84

3.3 COD Removal Efficiency of Textile wastewater for Various Feed concentrations in MFC

Textile wastewater showed its potential for COD removal indicating the functions of microbes present in wastewater in metabolizing the carbon source as electron donor. It is evident from experimental data that current generation and COD removal showed relative compatibility. Continuous COD removal is observed in MFC. In MFC, the COD removal efficiency from day 1 to day 28th increased from 39.2% to 79.6% as the feed concentration increased from 250 mg COD/L to 1750 mg COD/L respectively as shown in chart 1. In MFC-1 the highest COD removal efficiency is 79.6% on 28th day. After 28th day onwards the COD removal efficiency decreased as the feed concentration increased from 1750 mg COD/L to 1850 mg COD/L from 79.6% to 74.5% in MFC. The microorganisms started to become inactive or rather they went into decline phase after 1750mg COD/L concentration, because of higher organic loading in MFC.

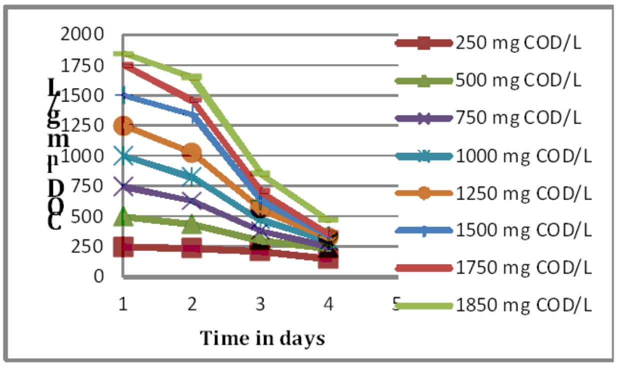

Chart 1: COD Reduction of Textile wastewater at various feed concentrations

3.4 BOD Removal Efficiency of Textile wastewater for Various Feed concentrations in MFC

The BOD removal efficiency of Textile wastewater is observed in MFC. The BOD removal efficiency from day 1 to day 28th increased from 38.4% to 74.7% as the feed concentration increased from 250 mg COD/L to 1750 mg COD/L respectively as shown in Chart 2. In MFC the highest BOD removal efficiency is 74.7% on 28th day. After 28th day onwards the BOD removal efficiency decreased as the feed
Concentration increased from 1750 mg COD/L to 1850 mg COD/L as 74.7% to 72.3% .The BOD removal efficiency improved with the increase in feed concentration up to 1750 mg COD/L, and slowly the BOD reduction started to decline with the further increment of feed concentration and the condition deteriorated at 1850 mg COD/L loading. The microorganisms started to become inactive or rather they went into decline phase after 1750 mg COD/L concentration, because of higher organic loading.

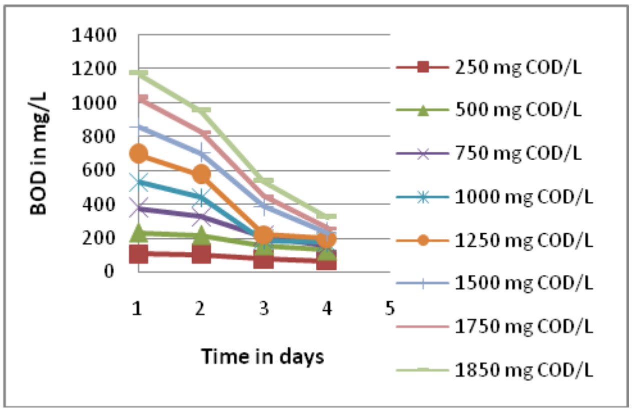

Chart 2: BOD Reduction of Textile wastewater at various feed concentrations in MFC

3.5 TS Removal Efficiency of Textile wastewater for Various Feed concentrations in MFC

Total Solids removal of Textile wastewater is observed in MFC and shows that microorganisms use it and the wastewater is being treated. One probable reason is the degradation of colloidal and complex organic material due to the biological catalysis process[10]. The TS removal efficiency from day 1 to day 28th increased from 30.2% to 66.7% as the feed concentration increased from 250 mg COD/L to 1750 mg

COD/L respectively as shown in chart 3. In MFC the highest TS removal efficiency is 66.7% on 28th day. After 28th day onwards the TS removal efficiency decreased as the feed concentration increased from 1750 mg COD/L to 1850 mg COD/L as 66.7% to 63.5% in MFC. The TS removal efficiency improved with the increase in feed concentration up to 1750 mg COD/L, and slowly the TS reduction started to decline with the further increment of feed concentrations.

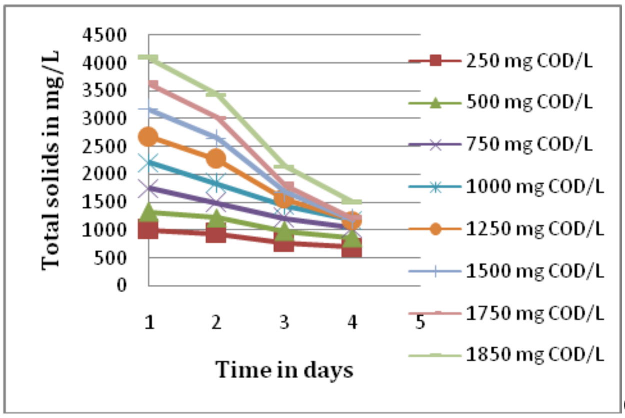

Chart 3: TS Reduction of Textile wastewater at various feed concentrations in MFC

3.6 DS Removal Efficiency of Textile wastewater for Various Feed concentration in MFC

During the operation considerable reduction in dissolved solids concentration of Textile wastewater is observed in MFC and shows that microorganisms use it and the wastewater is being treated. One probable reason is the degradation of colloidal and complex organic material due to the biological catalysis process[10]. The DS removal efficiency from day 1 to day 28th increased from 31.7% to 63.3% as the feed concentration increased from 250 mg COD/L to 1750 mg COD/L respectively as shown in chart 4. In MFC the highest DS removal efficiency is 63.3% on 28th day. After 28th day onwards the DS removal efficiency decreased as the feed concentration increased from 1750 mg COD/L to 1850 mg COD/L as 63.3% to 61.7% in MFC. The DS removal efficiency improved with the increase in feed concentration up to 1750 mg COD/L, and slowly the DS reduction started to decline with the further increment of feed concentration in MFC and the condition deteriorated at 1850 mg COD/L loading.

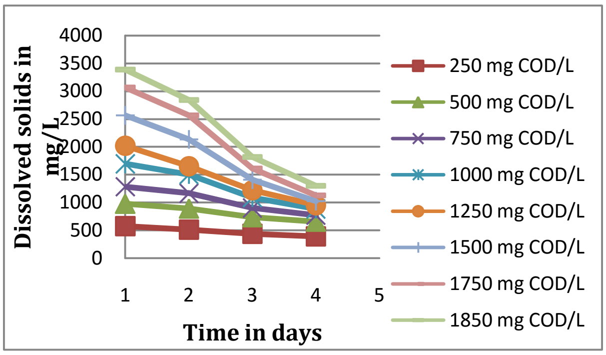

Chart 4: DS Reduction of Textile wastewater at various feed concentrations in MFC

3.7 PH Variation of Textile wastewater for Various Feed concentrations in MFC

Textile wastewater showed its potential for increments of pH. Continuous increment is observed in MFC, the pH increased from 6.9 to 7.79 as the feed concentration increased from 250 mg COD/L to 1750 mg COD/L respectively as shown in chart 5. pH was neutralized for every 24hours and pH varied from neutral to slightly alkaline during the oxidation process. The result of this research and other studies done by other researchers showed that microbial activity is slower in pH less than the optimum pH in comparison to optimum pH. Low pH in the anode chamber deactivates microorganisms and decreases the MFC efficiency. The low current intensity around the optimum pH of the anode chamber may be due to weak transfer of protons to the other side of the membrane. Changes in pH were seen more in the initial steps of MFC operation, and this is due to the slower transfer of protons through the proton exchange membrane in comparison to its production rate in the anode chamber and its consumption rate in the cathode chamber [5],[10]. One more reason may be Oxygen reduction reaction (ORR) occurred in the cathode regions causing the alkaline under closed-circuit way and variations in pH change large related to the aperture of membrane. The pH of the cathode started to increase when current generation was initiated, and it increases over time.

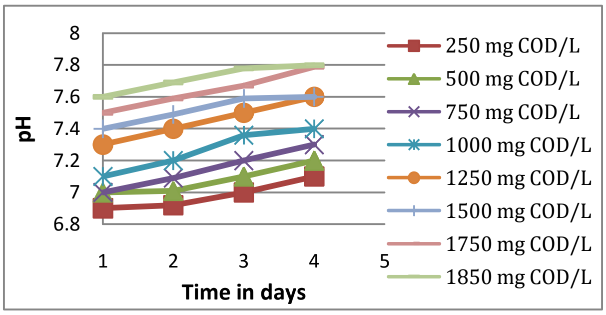

Chart 5: pH variations of Textile wastewater at various feed concentrations in MFC

3.8 Current and voltage Generation of Textile wastewater for various feed concentrations in MFC

The average value of current and voltage for each feed concentration in MFC is given in the chart 6 and 7. The current and voltage showed a gradual increase with respect to increase in feed concentration. The highest average values of current and voltage obtained as 4.32 mA in MFC with a feed concentration of 250 mg COD/L to 1750 mg COD/L respectively as shown in chart 6.Similarly the voltage value is obtained as 3.12 V in MFC as shown in chart 7. The power produced for $1m^2$ area is 0.812 W for single chambered MFC.

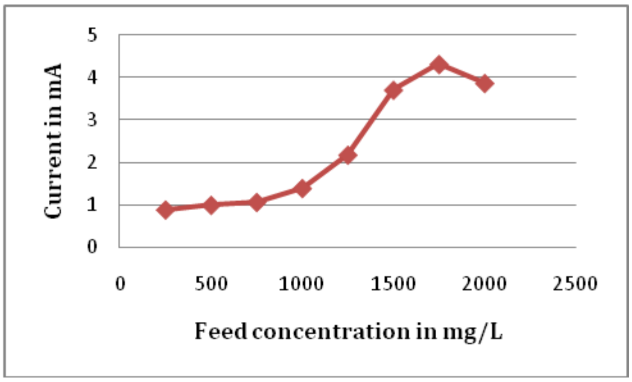

Chart 6: Current generation of Textile wastewater at various feed concentrations in MFC

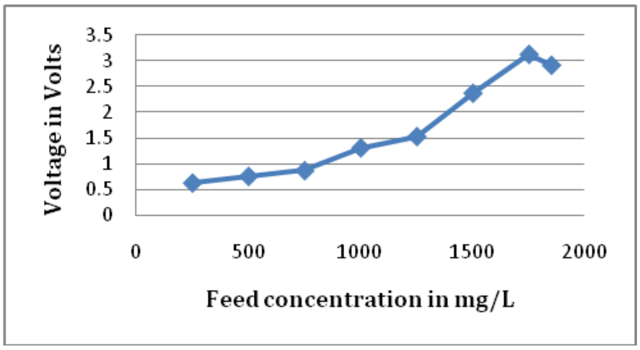

Chart 7: Voltage generation of Textile wastewater at various feed concentrations in MFC

3.9 Overall Treatment Efficiency of Textile wastewater in MFC

The percentage removal of COD, TS, DS and BOD are represented, and the overall treatment efficiencies in single chambered MFC is given in Chart 8. The COD, BOD, TS & DS percentage reduction is highest at 1750mg COD/L. The chart 8 clearly depicts that the optimal feed concentration for MFC is 1750 mg COD/L. The optimal COD, BOD, TS &DS removal efficiencies are 79.6%, 74.7%, 66.7% & 63.3% respectively..

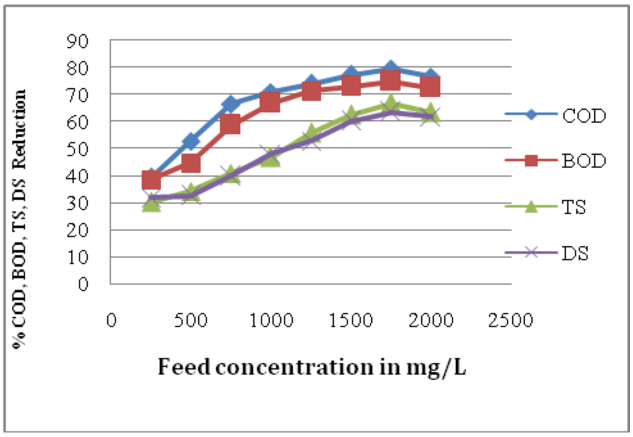

Chart 8: Overall treatment efficiency of Textile wastewater at various feed concentration

4. CONCLUSION

The study demonstrated the removal efficiency of Textile wastewater of different feed concentrations from 250 mg COD/L to 1750 mg COD/L increased and it is observed that the removal efficiency decreased by increasing the feed concentration from 1750 mg COD/L to 1850 mg COD/L and simultaneously it is noticed that the electricity production decreased. On analyzing the results based on the laboratory experiments conducted, the following conclusions are drawn.

- For the maximum feed concentration of 1750 mg/L the corresponding removal efficiency of COD, BOD, TS and DS are 79.6%, 74.7%, 66.7% and 63.3% respectively.
- At the maximum feed concentration of 1750 mg COD/L the current, voltage and power generation in the reactor are 4.32 mA, 3.12 V and 0.812 W/m^2 respectively.

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REFERENCE

[1] Bruce. E. Logan, “Microbial Fuel Cells”, John Wiley & Sons Inc., New Jersey, 2008

[2] L.T. Angenent, K. Karim, M.H. Al-Dahhan, B.A. Wrenn, R. Domı´guez-Espinosa, Production of bioenergy and biochemicals from industrial and agricultural wastewater, Trends Biotechnol. 22, (2004), 477–485.

[3] M. Behera, M.M. Ghangrekar, Performance of microbial fuel cell in response to change in sludge loading rate at different anodic feed pH, Bioresour. Technol. 100, (2009), 5114–5121.

[4] K.Y. Cheng, R. Cord-Ruwisch, G. Ho, A new approach for in situ cyclic voltammetry of a microbial fuel cell biofilm without using a potentiostat, Bioelectrochemistry 74,(2009), 227–231.

[5] G.S. Jadhav, M.M. Ghangrekar, Performance of microbial fuel cell subjected to variation in pH, temperature, external load and substrate concentration, Bioresour. Technol. 100 ,(2009) ,717– 723.

[6] S. Ginkel, S. Oh, B. Logan, Biohydrogen gas production from food processing and domestic wastewaters, Int. J. Hydrogen Energy 30, (2005),1535–1542.

[7] I. Ieropoulos, J. Greenman, C. Melhuish, J. Hart, Energy accumulation and improved performance in microbial fuel cells, J. Power Sources 145, (2005), 253–256.

[8] Cheng S, Xing D and Logan B.E,“ Electricity Generation of Single Chambered Microbial Fuel Cells at Lower Temperatures”, Biosensors and Bioelectronics, 26, (2010), 1913-1917.

[9] Sarker.S. K,“Textile wastewater treatment and electricity generation by Microbial Fuel Cell with freezing technology as pretreatment”, Dept. of Land and Water Resources Engineering, Royal Institute of Technology, (2012) ,1-10.

[10] H.J Mansoorian, A.H. Mahvi, A.J.Jafari, N.Khanjani, “Evaluation of dairy wastewater treatment and simultaneous bioelectricity generation in a catalyst-less Membrane microbial fuel cell”, Journal of Saudi Chemical Society, 20, (2014), 88-100.