IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 13, Issue 6 Ver. II (Nov. - Dec. 2016), PP 80-86
www.iosrjournals.org

Utilization of Multistage Microbial Fuel Cell for Septic Wastewater Treatment

Leton, T.G., Yusuf, M. & Akatah, B.M.
Department of Civil and Environmental Engineering University of Port Harcourt

Abstract: *The use of multistage microbial fuel cell (MFC) for septic waste water remediation was carried out for 18 days retention period. In the study, the multistage microbial fuel cells were designed, electrical voltage, current, power output were measured and calculated. Septic wastewater qualities such as Biochemical Oxygen Demand (BOD), nitrate, TSS, and pH of both the raw and treated wastewater were determined in the laboratory on three days basis for the MFC loaded with external resistors ranging from 50 -1000Ω. The result revealed that a single fuel cell loaded with a 1000 ohms resistor can can effectively remove 99.8% TSS, 86.4% BOD and 82.8% nitrate in 18 days. The fuel cell can be used to effectively treat septic waste water in our homes.*

I. Introduction

Wastewater can be described as water that the quality has been severely affected by human impact or activities. It is a by product of water used for operations in homes, industries, etc. Wastewater may be municipal or industrial. Most municipal wastewater contains sewage sludge. In homes, the wastewater generated are collected and channel into septic tanks that are air tight chamber used for anaerobic treatment of sludge in order to reduce the volume and cost of wastewater disposal (Kargi, 2009). This wastewater may be used for biogas production. Despite the huge potential with biogas as source of energy, several factors limit the success of this technology (Ge et al, 2013). For instance, electric generators used to convert and produce biogas are expensive and also biogas may need some form of pre-treatment (Appels et al, 2008).

Treatment of waste water from homes, industries and commercial centres is a serious problem. This is because treatment of wastewater uses a significant amount of energy in the world. It is a fact that waste water influent has higher energy value in the form of organics (He et al, 2013). Many methods have been used for wastewater treatment in both developed and developing nations some of these methods are expensive and constitute nuisance and environmental issues. In many developing nations such as Nigeria and other African countries, septic tank system is used for wastewater treatment while some developed countries like the USA uses activated sludge system. The use of the above systems occupies large space, consume reasonable amount of energy and contributes to high cost of wastewater treatment. The environmental issues, high cost of treating wastewater, use of large area of land for construction of treatment systems and consumption of considerable amount of energy has led researchers to look for alternative means of wastewater treatment. One of the methods that have been investigated and used for remediating wastewater is the use of Microbial Fuel Cells (Wang, 2008). MFCs have been utilized by many researchers for the treatment of wastewater, raw sludge, primary effluent, etc. He et al (2013) used MFCs to treat raw sludge and primary effluent. Also, Yazdi et al (2007) and Huggins et al, (2016) utilized pluggable Microbial Fuel Cell stacks to remediate septic wastewater and produce electricity. Hence, utilization of MFCs is not a new method or system for wastewater treatment but is an emerging technology in the world presently.

Microbial fuel cells are device that uses micro-organisms to produce electricity from biochemical energy generated during the oxidation of substrates. Electrons produced by the microbes from the substrates are carried to the anode and move to the cathode connected by a conductive material having a resistor load (Bruce et al, 2006; He et al, 2013; Barua and Deka, 2010; Deval et al, 2014). The use of fuel cells for wastewater remediation and electricity production is an interesting area for the simultaneous remediation of wastewater and direct electric energy production. The production of electricity from a MFCs and subsequent treatment of wastewater is only possible if electron acceptors are placed outside the cells since microbes utilized substrates as their energy sources which result in the release of electrons that are moved to electron acceptors. When the electron acceptors are placed outside the cells, microbes transport electron onto anode surface resulting in the production of electricity while the crushed filter media (graphite) will help in the filtration of septic wastewater and trapping of microbes from the septic wastewater.

Raw sludge, domestic wastewater and septic wastewater have been treated using single chamber and pluggable MFCs. Raw sludge (He et al, 2013), septic wastewater (Yazdi et al, 2015) treated by pluggable MFC stacks and wastewater from water treatment treated by single chamber MFC (Zielke, 2006).

In this work, a multiple stage MFC filled with crushed graphite will be used to treat septic wastewater and subsequently generate electricity.

II. Methodology

Materials

1. Recycled graphite water plastic bottle
2. 200 ohms resistor
3. Multimeter
4. Connecting wire
5. 20 liter plastic bucket
6. flexible pipes with tap
7. Plaster of Paris (POP) material
8. Septic wastewater

MFC Design and Construction

Crushed some of the recycled graphite and sieve it using a set of sieves ranging from 750 microns to 3.0mm. Arrange the crushed graphite in perforated cone side of the empty eva water plastic bottle based on the different sizes of crushed graphite with the least size or diameter placed below as shown in the set up. Connect the different perforated cones contain of crushed graphite together using graphite rods. This forms the anode. Construct the cathode using a single perforated plastic cone. Separate the cathode from the anode using POP material which serves as a membrane or bridge. Then provide an inlet and an outlet at the anode side. After this, connect the anode to the cathode using connecting wire, connected from the anode terminals to the multimeter, then to the resistor and finally the cathode terminal.

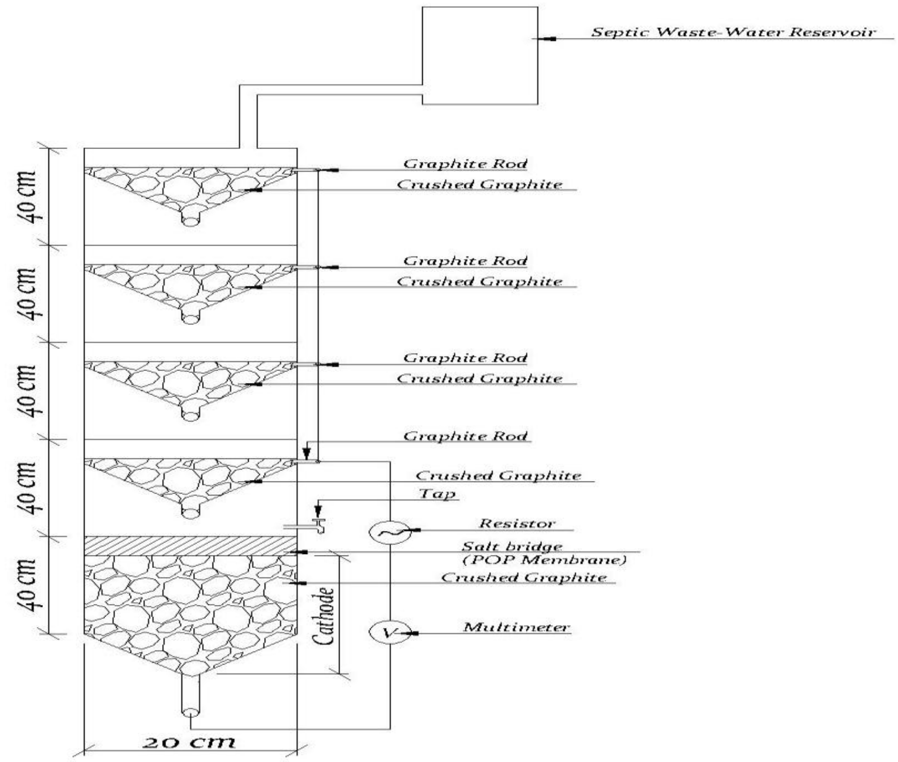

Fig 1: Multistage Microbial Fuel Cell

III. Results And Discussions

Characterization of septic waste water

The septic waste water used in this research was determined to possess the following physiochemical properties presented in Table 1 before the remediation process and electricity production.

Table 1: Characteristics of septic waste water used in the study

Parameter	Result
pH	7.5
TSS (mg/l)	1146
BOD (mg/l)	275
Nitrate (mg/l)	8.7

Studying the Effect of Varying Resistor Loads on Septic Waste Water Treatment and Power Output
The effect of varying resistor loads consisting of 50, 100, 150, 560 and 1000Ω respectively was studied in order to understand the treatment or removal efficiency of BOD, TSS, nitrate and pH. The results obtained from the study are presented below.

Septic waste water remediation and power generation at 50 resistor load
The effect of applying a 50Ω resistor across the single set-up of the MFC is presented in Table 4.2 for a retention time of 18 days.

Table 2: Septic wastewater characteristics with retention time in MFC using 50 ohms resistor

Parameter	**Retention Time (day)**							**% removal**
	0	3	6	9	12	15	18	
pH	7.5	8.0	8.0	8.1	8.1	8.1	8.1	
TSS (mg/l)	1146	26.4	18.5	12.4	9.4	5.2	2.8	99.76
BOD(mg/l)	275	255.2	241.1	162.5	104.6	94.3	83.7	69.56
Nitrate(mg/l)	8.7	8.5	5.9	4.7	3.6	3.1	2.7	68.97

From Table 2, it was observed that the MFC with 50Ω resistor load removed about 99.76% TSS, 69.56% BOD and 68.97% nitrate. The BOD removal rate is shown in figure 2 below.

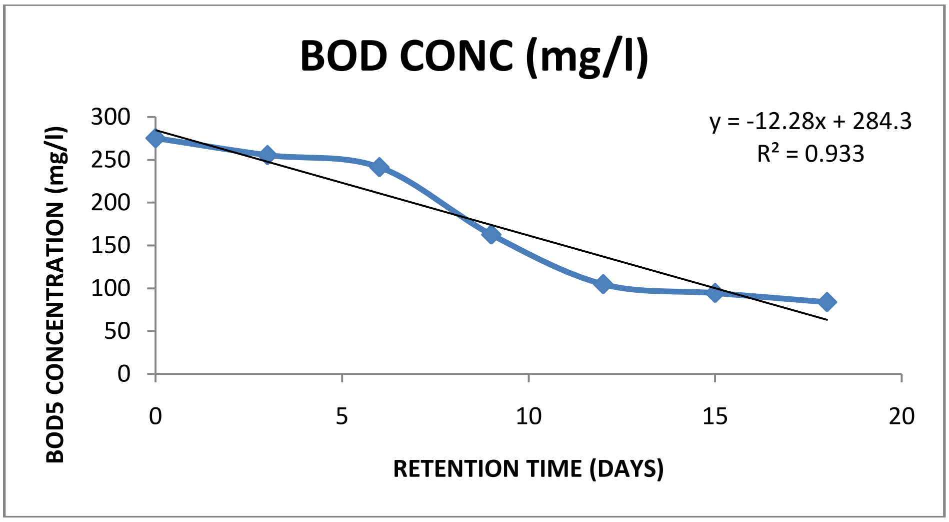

Fig 2: BOD_5 concentration with time in MFC with a 50Ω resistor load

From figure 2 above, the relationship between the BOD_5 concentration and retention time is given by $BOD_5 = -12.28t + 284.3$.

Septic waste water remediation and power generation at 100 resistor load
The effect of applying a 100Ω resistor across the single set-up of the MFC is presented in Table 4.3 for a retention time of 18 days.

Table 3: Septic wastewater characteristics with retention time in MFC using 100 ohms resistor

Parameter	**Retention Time (day)**							**% removal**
	0	3	6	9	12	15	18	
pH	7.5	8.0	8.0	8.1	8.1	8.0	8.0	
TSS (mg/l)	1146	26.4	18.2	12.5	9.2	5.0	2.8	99.76
BOD(mg/l)	275	255.3	240.7	162.4	103.6	93.8	76.2	72.29
Nitrate(mg/l)	8.7	8.4	5.9	4.6	3.3	2.9	2.4	72.41

From Table 3, it was observed that the MFC with 100Ω resistor load removed about 99.76% TSS, 72.29% BOD and 72.41% nitrate. The BOD removal rate is shown in fig 3 below.

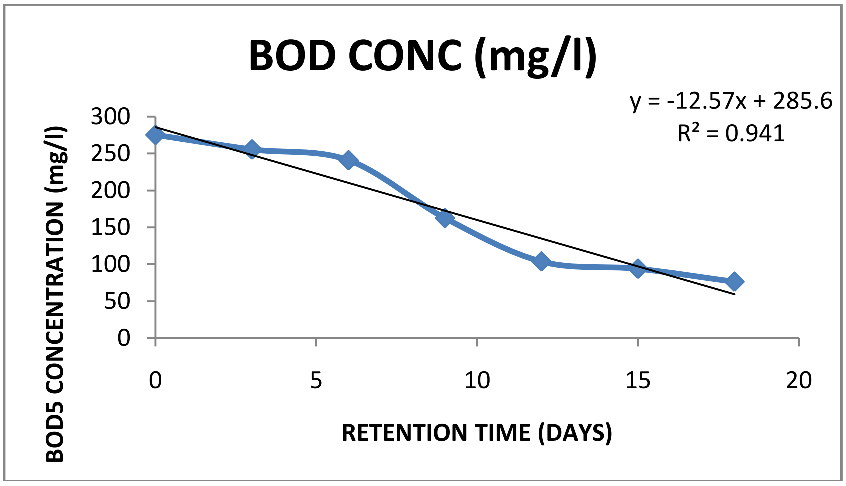

Fig 3: BOD_5 concentration with time in MFC with a 100Ω resistor load

From figure 3 above, the relationship between the BOD_5 concentration and retention time is given by $BOD_5 = -12.25t + 285.6$.

Septic waste water remediation and power generation at 150 resistor load

The effect of applying a 150Ω resistor across the single set-up of the MFC is presented in Table 4for a retention time of 18 days.

Table 4: Septic wastewater characteristics with retention time in MFC using 150 ohms resistor

Parameter	**Retention Time (day)**							**% removal**
	0	3	6	9	12	15	18	
pH	7.5	8.0	8.0	8.1	8.0	8.1	8.0	
TSS (mg/l)	1146	26.4	17.8	11.1	7.5	3.1	2.4	99.76
BOD(mg/l)	275	255.1	236.5	163.5	103.7	89.4	68.1	75.2
Nitrate(mg/l)	8.7	8.3	5.9	4.5	3.4	2.9	2.3	73.6

From Table 4, it was observed that the MFC with 150Ω resistor load removed about 99.76% TSS, 75.2% BOD and 73.6% nitrate. The BOD removal rate is shown in fig 4 below.

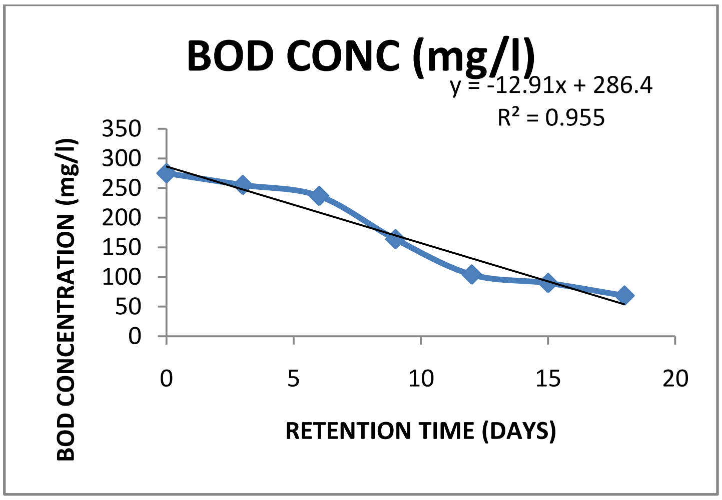

Fig 4: BOD_5 concentration with time in MFC with a 150Ω resistor load

From figure 4 above, the relationship between the BOD_5 concentration and retention time is given by $BOD_5 = -12.91t + 286.4$.

Septic waste water remediation and power generation at 560 resistor load

The effect of applying a 560Ω resistor across the single set-up of the MFC is presented in Table 5 for a retention time of 18 days.

Table 5: Septic wastewater characteristics with retention time in MFC using 560 ohms resistor

Parameter	**Retention Time (day)**							**% removal**
	0	3	6	9	12	15	18	
pH	7.5	8.0	8.0	8.1	8.0	8.0	8.1	
TSS (mg/l)	1146	26.1	20.5	10.4	6.5	3.1	2.6	99.77
BOD(mg/l)	275	254.0	234.2	160.1	103.2	80.4	62.5	77.3
Nitrate(mg/l)	8.7	8.3	5.9	4.2	3.5	2.8	1.9	78.2

From Table 5, it was observed that the MFC with 560Ω resistor load removed about 99.8% TSS, 77.3% BOD and 78.2% nitrate. The BOD removal rate is shown in fig 5 below.

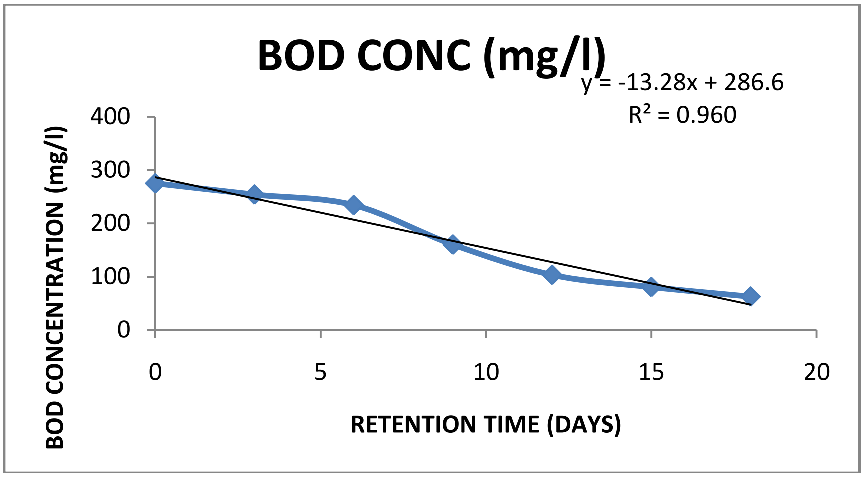

Fig 5: BOD_5 concentration with time in MFC with a 560Ω resistor load

From figure 4.10 above, the relationship between the BOD_5 concentration and retention time is given by $BOD_5 = -12.91t + 286.4$.

Septic waste water remediation and power generation at 1000 resistor load

The effect of applying a 1000Ω resistor across the single set-up of the MFC is presented in Table 4.6 for a retention time of 18 days.

Table 6: Septic wastewater characteristics with retention time in MFC having 1000 ohms resistor

Parameter	**Retention Time (day)**							**% removal**
	0	3	6	9	12	15	18	
pH	7.5	8.0	8.1	8.1	8.0	8.1	8.1	
TSS (mg/l)	1146	26.2	18.0	10.5	7.1	3.2	2.3	99.8
BOD(mg/l)	275	251.6	220.1	150.3	91.5	60.2	37.4	86.4
Nitrate(mg/l)	8.7	8.2	6.0	3.9	3.4	2.1	1.5	82.8

From Table 6, it was observed that the MFC with 1000Ω resistor load removed about 99.8% TSS, 86.4% BOD and 82.8% nitrate. The BOD removal rate is shown in fig 6 below.

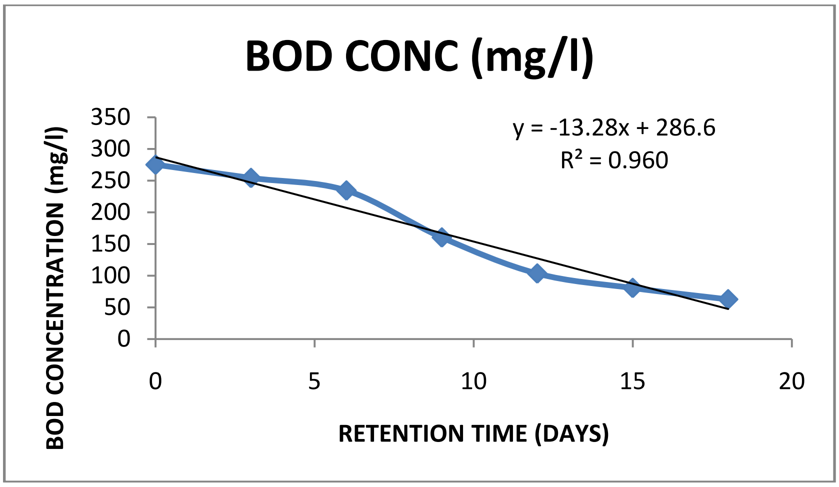

Fig 6: BOD_5 concentration with time in MFC with a 1000Ω resistor load

From figure 4.13 above, the relationship between the BOD_5 concentration and retention time is given by BOD_5 = -13.28t + 286.6.

IV. Conclusion

The multistage microbial fuel cell design provides a solution for simultaneous septic wastewater treatment and electricity (power) generation for our waste water treatment systems in homes. The MFC with 50Ω resistor load removed about 99.76% TSS, 69.56% BOD and 68.97% nitrate, that with 100Ω resistor load removed about 99.76% TSS, 72.29% BOD and 72.41% nitrate, MFC with 150Ω resistor load removed about 99.76% TSS, 75.2% BOD and 73.6% nitrate, MFC with 560Ω resistor load removed about 99.8% TSS, 77.3% BOD and 78.2% nitrate and the MFC with 1000Ω resistor load removed about 99.8% TSS, 86.4% BOD and 82.8% nitrate.

References

[1]. Aiba, S., Humphrey, A.E., Millis, N.F., (1965). Biochemical Engineering. New York: Academic Press.
[2]. Allen, R. M and Bennetto, H. P., (1993). "Microbial fuel cells: Electricity Production from Carbohydrate". Appl. Biochem. Biotechnol. Vol. 39, P. 27 – 40.
[3]. APHA, AWWA, WPCF (1998). Standard methods for Examination of water and Waste water, 21st Edition. Washington Dc: American Public Health Association.
[4]. Appels, L., Baeyens. .1., Degreve, J. and Dewil, R. (2008). ''Principles and Potential of the Anaerobic Digestion of Waste—activated Sludge''. Progress in Energy and Combustion Science, Vol. 34, No. 6, P,755 – 781.
[5]. Bahan, S., Mikrob, A., Air, M. and kultur, S. (2011). ''Microbial Fuel cells using Mixed Cultures of Wastewater for Electricity Generation''. Sains Malaysiana, Vol.40, No.9. P.993 -997.
[6]. Bard, A. J., Parsons, R. and Jordan J. (1985). Standard Potentials in Aqueous Solution. New York: Marcel Dekker.
[7]. Barua, P.K and Deka, D. (2010). "Electricity Generation from Biowaste based microbial fuel cells". Intl. Journal of Energy, Information and Communications, vol. 1, Issue I, P.77 – 82.
[8]. Bennetto H.P. and Allen, R.M. (1993). "Microbial Fuel Cells: Electricity Production from carbohydrates". Appl. Biochem. Biotechnol. Vol. 39/40 P. 27-40.
[9]. Bernetto, H.P (1990). "Electricity Generation by Microorganisms". Biotechnology Education, vol. 1, No. 4 P. 163 – 168.
[10]. Bond D.R. and Lovely, D.R. (2003). "Electricity Production by Geobacter sulfurreducens Attached to electrodes".
[11]. Bruce. E.L. Harnelers, B., Rozendal, R, Schroder, U., Keller, J., Freguia, S., Aelterman, P. Verstraete, W Rabaey, K. (2006). Microbial Fuel Cells: Methodology and Technology. American Chemical Society, Vol. 40, No. 17 P.5181- 5792.
[12]. Chang, I. S., Jang, J. K., Gil, G. C., Kim, M., Kim, H.J., Cho, B. W. and Kim, B. H. (2004). "Continous determination of biochemical oxygen demand using microbial fuel cell type biosensor". Biosens bioelectron, vol. 19, P. 607 – 613.
[13]. Chang, I. S., Moon, H., Jang, J. K., and Kim B. H. (20050. "Improvement of a microbial fuel cell performance as a BOD sensor using respiratory inhibitors".
[14]. Biosens Bioelectron. Vol. 20, P. 1856 – 1859.
[15]. Das, S. and Mangwani, N,(2010). ''Recent Developments in Microbial Fuel Cells: A Review''. Journal of Sc. and Industrial Research, Vol. 69, P. 727 -73 1.
[16]. Davis, F. and Higson, S. P. J. (2007). "Biofuel cells-Recent advances and applications". Biosens. Bioelectron. Vol. 22, P. 1224 – 1235.
[17]. Deval, A., Bhagwat, A.M. and Dikshit, A.K. (2014). Importance of Mixed Culture in Generation of Electricity from Anaerobically Digested Distillery Waste Water through Microbial Fuel Cell. Adv. Biores., Vol. 5, No. 2, P. 74-80.
[18]. Franks, A. E. and Nevin, K. P. (2010). Microbial fuel cells, A current review. Department of microbiology, University of Massachusetts, Amherst, USA.
[19]. Ge, Z., Ping, Q., He, Z., (2013). "Hollow-fiber Membrane Bioelectrochemical Reactor for Domestic Wastewater Treatment". Journal of chemical technology and biotechnology. DOI: 10.1002/jctb.4009.
[20]. Gregory, K. B., Bond, D.R. and Loveley, D. R. (20040. "Graphite Electordes as Electron Donors for Anaerobic Respiration". Environ Microbial. Vol. 6, P. 596 – 604.
[21]. He, Z. Zhang, F. and Ge, Z. (2013) .Using Microbial Fuel Cells to Treat Raw Sludge and Primary Effluent for Bioelectricity Generation: Final Report. Department of Civil Engineering and Mechanics, University of Wisconsin- Milwaukee.
[22]. Ieropoulos, I.A., Greenman, J., Melhuish, C. and Hart, J. (2005). "Comparative study of three types of microbial fuel cell". Enzyme Microb. Tech., vol. 37, P. 238 – 245.
[23]. Karmakar, S., Kundu, K. and Kundu, S. (2014). "Design and development of microbial fuel cells". Department of Biochemical Engineering, Banaras Hindu University, Varanasi, India.
[24]. Kim, H. J., Park, H. S., Hyun, M.S., Chang, I.S., Kim, M. and Kim, B. H. (2002)."A mediatorless microbial fuel cell using metal reducing bacterium, Sheqannella Putrefaciens". Enzyme Microb. Tech. vol. 30, P. 145 – 152.
[25]. Kim, J., Kim., Ye, H., Lee, E., Shin, C., McCarty, P.L., Bac, J. (2011) "Anaerobic Fluidized bed membrane bioreactor for wastewater treatment". Environ Sci. Technol, Vol. 45, No. 2, P576 – 581.
[26]. Kumlaghan, A., Liu, J., Thararungkul, P., Kanatharana P. and Mattoasson B. (2007). "Microbial fuel cell-based biosensor for fast analysis of biodegradable organic matter". Biosensor bioelectron., vol. 22,P. 2939 – 2944.
[27]. Logan, B.E., Hamelers, B., Rozendal, R., Schroder, U., Keller, J., Freguia, S., Aelterman, P., Verstraete, W., and Rabacy K. (2006). "Microbial fuel cells: Methodoogy and Technology". Environ Sci. Technol. Vol. 40, P5181 – 5192.
[28]. Lovely, D. R. (19930. "Dissimlatory Metal Reduction". Annu. Rev. Microbial., vol. 47, P. 263 – 290.
[29]. Manohar K. A., Bretschger, O., Nealson, H.K. and Mansfeld F. (2008). Electrochemica Acta, Vol. 53, P. 3508 - 3573.
[30]. Min, B., Cheng S. and Logan, B. E. (2005). "Electricity Generation using Membrane and salt bridge Microbial fuel cells". Water Res, vol. 39 P. 1675 – 1686.
[31]. Muthu, R.V., Muthuvel A. Narayan, K. C.,and Priyanka, C.M. (2010). ''Analysis and Design of Automated Electric Power Generation Unit from Domestic Waste''. Intl Journ. Of Envtal Sc and Dew., Vol. 1, No.5, P. 383 -386.
[32]. Park, D.H and Zeikus, J.G. (2000). "Electricity Generation in Microbial Fuel Cells using Neutral Red as an Electronophore". Appl. Environ Microbial, vol. 66 No. 4., P. 1292 – 1297.

[33]. Raman M.V., Multhuvel AMR, Naiayan K.C. and Priyanka, K.M. (2010). "Analysis and Design of Automated Electric Power Generation unit from Domestic waste". Intl Journal of Environ. Sci. and Devt. Vol. 1, NO. 5, P.383 – 386.
[34]. Singh, D., Pratap, D., Baranwal, Y., Kurnar, B. and Chaudhary, R.K. (2010). Microbial Fuel Cells: A Green Technology for Power generation. Annals of Biological Research, Vol. l, No. 3, P. 128 -138.
[35]. Takuji, and Kenji, K (2003). "Violectrocatalyses-Based Application of Quinoproteins and Quinoprotein-containing bacterial cells in biosensors and biofuell cells". Biochemphys, Acta. Vol. 1647, P. 121 – 126.
[36]. Zhang G., Wang., K., Zhao, Q., Jiao, Y. and Lee, D.J., (2012). "Effect of cathode types on long-term performance and anode bacterial communities in microbial fuel cells". Bioresource technology, vol. 118, P.249 – 256.
[37]. Zhang, F., He, Z. (2012). Integrated Organic and nitrogen removal with electricity generation in a tubular dual cathode microbial fuel cell". Process biochemistry, vol. 47, P. 2146 – 2151.
[38]. Zielke, E. A. (2006). Application of Microbial Fuel Cell Technology for a Waste Water Treatment Alternative.