

# Critical Review on Generation of Electricity from Waste by Microbial Fuel Cell Technology

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**Abstract:** *Energy is the lifeblood of the society and to harness energy in a clean and green way, the scientist all over the world is exploring for the newest techniques and procedures. The energy production is extremely dependent on the fossil fuels, but these non – renewable sources are extremely limited in quantity and so the entire world is shifting from non renewable energy sources to renewable energy sources. The outgrowth of the non conventional sources of energy is not completely a matter of industrial interest, but also it is a matter of scientific inquiry. Regarding this aspect, this paper discusses the generation of electricity from waste. This paper focuses on generation of electricity from organic waste and, it also discusses the parameters affecting the efficiency of the microbial fuel cell which are the only converters of waste to electricity. The paper just enhances the concept of waste to wealth logic where electricity is the wealth we obtained from waste. Generation of electricity from waste is the need of the hour and if this technology gets popularized then surely the energy deficiency can be reduced to a greater extent.*

**Keywords:** Biocathodes, bioenergy, microbial fuel cell, extracellular.

## 1. Introduction:

The ever rising population of humans has played a major role in the increase in the demand for energy consumption throughout the world. The major energy providers present in the marketplace at the present scenario are the fossil fuels. But the limitation of the fossil fuels is their finiteness in quantity. And then the full world is shifting from non renewable energy sources to renewable energy sources. The outgrowth of the non conventional sources of energy is not completely a matter of industrial interest, but also it is a matter of scientific inquiry. Usage of available wastewater for the generation of hydrogen is attaining attention as an origin of alternative energy method for holding the cleaner fuel [1-11]. The total quantity generated waste in India is segregated as 55% of the waste is comprises of organic matter, 15% are the recyclable waste and 30% is the residual waste [13, 14]

The facts and figures clearly indicate that the main portion of the waste generated is organic in nature. According to the World Bank report, the Municipal Solid Waste [MSW] is about to double by the year 2025 and the pace of urbanization also affects the quantity of waste generated [15].



**Figure 1:** Composition of Waste in India Chart [13,14]

Immediately the question springs up what to do about the waste that is generated? And so the principle of 3R's that is Reduce, Reuse and Recycle comes into the picture, but this rule is also not applicable to all the categories of waste. The accumulated waste should be used in such a manner that neither the waste remains nor does; it leads to some other problem like environmental contamination. Waste Management is also practiced by burning the waste which leads

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emission of gaseous contaminants into the atmosphere or dumping the waste. In such processes we not only eliminate the waste, but also we contaminate our environment. So the best way to eliminate the waste and to conserve our environment is the use of microbial fuel cell. Use of microbial fuel cell enables us to obtain bioenergy from the waste [16, 17]. Microbial Fuel Cell [MFC] is a promising technology, which assures the conversion of the biomass into electricity. These biological batteries use the microbial metabolism for the generation of electricity from biomass [18-21]. As compared to other bioenergy conversion processes like gasification, fermentation, anaerobic digestion, etc., MFCs are advantageous as they involve less sludge formation, and a cost effective process as they can be operated at ambient physical conditions [22, 23]. MFC technology has created a fresh hope in scientific community for the genesis of the electricity from waste which helps in reaching two goals at a time, one of the energy generation and the other of waste elimination. MFC can be well used to get electricity from the waste water, oceanic sediments and biomass [24-26, 78]. The main principle involved in the MFC working is the usage of an innate bacterial respiratory process which involves the extracellular electron transfer [27-29, 76]. MFC can be utilized for the nitrate reduction from the water resources like waste water, dry land, water or synthetic waste water [30-34]. The basic diagram of the MFC is represented in the figure 2. In the figure a proton exchange membrane [PEM] is present, which divide the anodic and the cathodic compartments. There are lids numbered 1 which seals the anodic and the cathodic compartment. This report basically focuses on the parameters affecting the efficiency of the functioning of MFC.

## 2. Effect Of Anode On MFC:

Microorganisms play a significant part in the anode chamber. As noted earlier, the electric current is formed due to the extracellular electron transfer and this process, thus results in the organic waste removal [35, 75]. The bacteria available in the anode chamber function as the effective catalyst in increasing the activation energy required for the reaction to proceed in the forward direction [36-39].

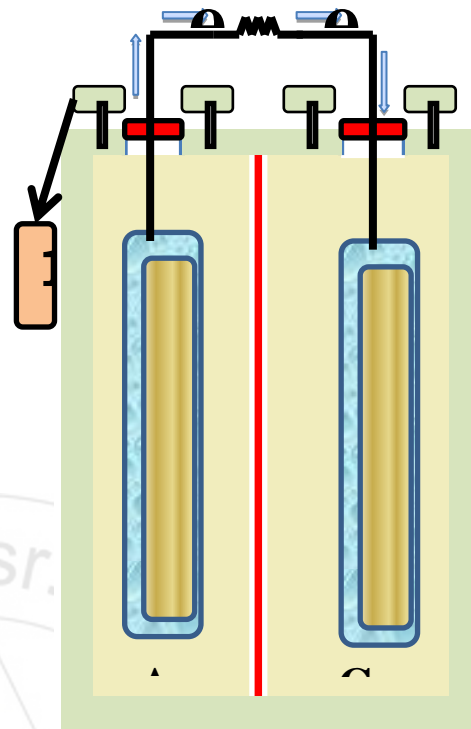


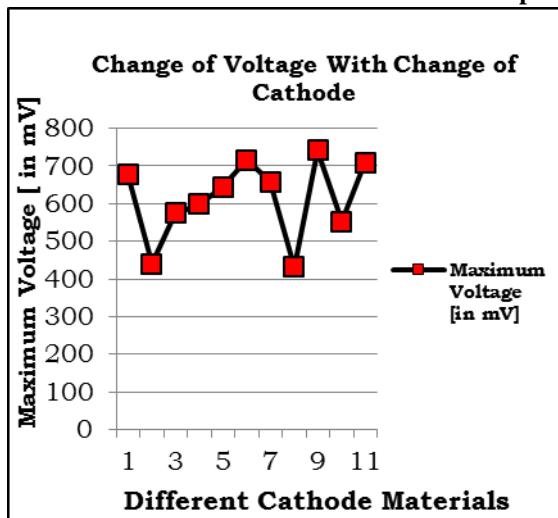
Figure 2 Schematic Illustration of MFC [75]

The principle job involved is the amplification of the anodic microbial electron transfer with the utilization of electron mediators or optimizing the system design and the electrode design [40-42]. The growth in the surface region of the electrode eventually improves the force generation capacity and in this aspect carbon nanotubes are believed to expand or increase the electron transfer feasibility [43]. Chemically stable polymers like PTFE are proven to boost the bioenergy production when the *Escherichia coli* were used as the active biocatalyst in the reaction and the power density obtained is  $760 \text{ mW/m}^2$  [44].

## 3. Effect Of Cathode On MFC:

The result of the different cathode on the generation of voltage can be presented in the accompanying graph.

Oxygen is the final electron acceptor at the cathode. But the activity at the cathode can be increased with the aid of a Biocathode. A Biocathode is one in which a flimsy film of microbes is present at the cathode which increase the electrical productivity of the MFC and thus increases the efficiency of the entire MFC system [51-54].



**Figure 3** Graph of Change in Voltage v/s Different Cathode Materials[45-49]

**Table 1:** Names of Cathode Material [45 -49]

Sr. No.	Cathode
1	Activated carbon fiber felt (ACFF) [45]
2	Air-cathode with graphite [46]
3	Carbon felt [45]
4	Plain carbon [45]
5	Pt-coated carbon paper [45]
6	Tubular ACFF [45]
7	ACFF granules (1 cm) [45]
8	Biocathode [47]
9	Graphite felt [48]
10	Parallel sheets of carbon paper secured by carbon fiber coated with Pt [49]

The utilization of Biocathode also helps in the handling of waste water by the microbes present in the cathodic area. Biocathodes not only does reduce the cost of the Cathodic material, but also aids in the efficient removal of the byproducts formed in the reaction by the cognitive operation of microbial metabolism [55]. The usage of oxidizing agent in MFC has the opportunities to increase the electrical power which is brought forth by the MFC [56].

#### 4. Use Of Ceramics In MFC:

Ceramics extend its applications to the treatment of the residual water as they tend to convert the

contaminants to non toxic materials and thus the residual water gets treated [57]. The cathode made up of the ceramic material is proven to increase the performance of the MFC and also there was a sharp increase in the power curve observed [58, 59]. It is also reported the membrane made up of ceramic material is proven to enhance the efficiency the cell. The use PEM in the cell led to an increase in the cost of the cell and thus the ceramic provide a cheap alternative for such costly membrane [60-65].

#### 5. Limitations And Solutions:

Though microbial fuel cell has the ability to generate the electricity from the waste, but there is no commercial touch which given to these cells. The major hurdle which inhibits the intensification of the fuel cell on a large scale includes the price of the materials and the other difficulties which are present in the large scale models [66]. In the current MFC models the electrodes are made up of expensive materials like platinum, silver. Platinum is used as the cathode material to enhance the oxidation of the oxygen at the cathode [67-69]. Another major drawback associated with the MFC their low power generation as compared to other available renewable sources of energy [70]. It is likewise noted that the bearing of the protozoa decreases the current production rate of the MFC [77]. The problems associated with MFC scale up can be dealt with the principle of lowering the size of each MFC and then connecting these smaller units to form a pile of such cells. The major benefit achieved by the miniaturization of the MFC is the lowering of the electrode distance, an increase in surface area to volume ratio and also enhancement in the generation of the electricity [71-73].

#### 6. Conclusion:

The diminishing nature of the fossil fuel resources has led to a hunt of any renewable source of energy which has the propensity to resolve the energy crisis scenario. In this aspect, MFC is an attractive option for the energy production, though it has some drawbacks. Drawbacks or limitations are connected with every system, but optimization of the system is must to achieve the desired result or outcome. In the same way MFC provides the best clean and green alternative for the treatment of the waste and also to produce the electric power from it. It is the best example of the waste to wealth logic as it helps us to achieve two aims in one process that is treatment of the waste and power generation. Though MFC has the low power production till date but they are a newer technology and therefore the scientific inquiry is extended out across the globe to make the MFC system an efficient one.

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#### References:

- [1] A. Rollinson, J. Jones, V. Dupont, M. Twigg, "Urea as a Hydrogen Carrier: A perspective on its potential for safe, sustainable and long term energy supply", *Energy and Environmental Science*, Volume 4, 2011, Pg- 1216.
- [2] K. Christopher, R. Dimitrios, "A review on energy comparison of hydrogen production methods from renewable energy sources", *Energy and Environmental Science*, Volume 5, 2012, Pg - 6640.
- [3] Mr. Rohitkumar Singh, Mr. Akshay Prabhu, Mr. Navneet Sharma, Mr. Vishal Singh, "Hydrogen : A promising alternative energy source", *International Journal of Mechanical Engineering & Robotics*, Volume 4, 2016, Pg- 106.
- [4] W. Simka, J. Piotrowski, A. Robak, G. Nawrat, "Electrochemical treatment of aqueous solution containing urea", *Journal of Applied Electrochemistry*, Volume 39, 2009, Pg – 1137 .
- [5] R. Lan, S. Tao, J. Irvine, "A direct urea fuel cell – power from fertilizer and waste", *Energy and Environmental Science*, Volume 3, 2010, Pg – 438.
- [6] J. Kim, W. J. Choi, M. Hoffmann, H. Park, "Electrolysis of urea and urine for solar hydrogen", *Catalyst Today*, Volume 199, 2013, Pg – 2 .
- [7] I. Ieropoulos, J. Greenmann, C. Melhuish, "Urine utilization by microbial fuel cell; energy fuel for the future, *Phys. Chem. Chem. Phys.*, Volume 14, 2012, Pg – 94.
- [8] J. Kim, D Monllor – Satoca, W. Choi, " Simultaneous production of hydrogen with the degradation of organic pollutants using TiO<sub>2</sub> photocatalyst modified with dual surface components", *Energy and Environmental Science*, Volume 5, 2012, Pg – 7647.
- [9] Bryan Boggs, Rebecca King and Gerardine Botte, "Urea Electrolysis: Direct Hydrogen Production from Urine", *Chemistry Communication*, Royal Society of Chemistry, Volume 5, 2009, Pg – 4859.
- [10] G. Botte, U.S. Patent Application No. 0095636 A1 (2009).
- [11] L. Zhou, Y. Cheng, *International Journal of Hydrogen Energy*, Volume 33, 2008, Pg- 5897.
- [12] R. King, MSc. Thesis, 2010.
- [13] Sunil Pandey, Jai Kishan Malik, "Industrial and Urban Waste Management in India", *The Energy and Research Institute*, 2015.
- [14] Zhu, D. Asnani, P. Zurbrugg, C. Anapolsku, S. Mani, "Improving Municipal Solid Waste Management in India", *The World Bank*, 2008.
- [15] *Urban Development Series- Knowledge Papers*, World Bank.
- [16] T. Huggins, H. Wang, J. Kearns, P. Jenkins, Z. Ren, "Biochar as a sustainable electrode material for electricity production in microbial fuel cells", *Bioresources Technology*, Volume 157, 2014, Pg - 114.
- [17] Y. Yuan, T. Yuan, D. Wang, J. Tang, S. Zhou, "Sewage sludge biochar as an efficient catalyst for oxygen reduction reaction in a microbial fuel cell", *Bioresources Technology*, Volume 144, 2013, Pg- 115.
- [18] Chaudhuri K., and Lovley R., "Electricity Generation by Direct Oxidation of Glucose in Mediator less Microbial Fuel Cells", *Nature Biotechnology*, Volume 21, 2003, Pg- 101.
- [19] Du Z., Li H., and Gu T., "A State of the Art Review on Microbial Fuel Cells: a Promising Technology for Wastewater Treatment and Bioenergy", *Biotechnology Advances*, Volume 25 2007, Pg - 464.
- [20] Feng L., Chen Y., and Chen L., "Easy-to-Operate and Low-Temperature Synthesis of Gram-Scale Nitrogen-Doped Graphene and its Application as Cathode Catalyst in Microbial Fuel Cells", *American Chemical Society*, Volume 5, 2011, Pg- 9611.
- [21] I. Ieropoulos, J. Greenman, C. Melhuish, "Urine utilization by microbial fuel cells; energy fuel for the future", *Physical Chemistry*, Volume 14, 2012, Pg- 94.
- [22] H. Ren, H. Lee, J. Chae, "Miniaturizing microbial fuel cells for potential portable power sources: promises and challenges", *Microfluid. Nanofluidics*. Volume 13 2012, Pg- 353.
- [23] K. Rabaey, W. Verstraete, "Microbial fuel cells: novel biotechnology for energy generation, *Trends Biotechnology*", Volume 23, 2005, Pg- 291.
- [24] Zhang Y., Mo G., Li X., Zhang W., Zhang J., Ye J., Huang X., and Yu C., "A Graphene Modified Anode to Improve the Performance of Microbial Fuel Cells", *Journal of Power Sources*, Volume 196, 2011, Pg – 5402 .
- [25] Han Y., Yu C., and Liu H., "A Microbial Fuel Cell as Power Supply for Implantable Medical Devices", *Biosensors and Bioelectronics*, Volume 25, 2010, Pg - 2156.
- [26] Dai C., and Choi S., "Technology and Applications of Microbial Biosensor", *Open Journal of Applied Biosensor*, Volume 2, (2013), Pg – 83.
- [27] Busalmen, P., Esteve-Núñez, A., Berná, A., Feliu, J.M., "C-type cytochromes wire electricity-producing bacteria to electrodes", *Angew. Chem*, Volume 120, 2008.
- [28] Gorby, Y.A., Yanina, S., McLean, J.S., Rosso, K.M., Moyles, D., Dohnalkova, A., Beveridge, T.J., Chang, I.S., Kim, B.H., Kim, K.S., "Electrically conductive Bacterial nanowires

- produced by *Shewanella oneidensis* strain MR-1 and other Microorganisms”, Proc. Natl. Acad. Sci. U.S.A., Volume 103, 2006, Pg- 11358.
- [29] Logan, B.E., “Exoelectrogenic bacteria that power microbial fuel cells”, Nat. Rev. Microbiol., Volume 7, 2009, Pg- 375.
- [30] Tong Y., and Zhen H., “Nitrate Removal from Groundwater Driven by Electricity Generation and Heterotrophic Denitrification in a Bioelectrochemical System”, Journal of Hazardous Materials, Volume 262, 2013, Pg- 614.
- [31] Zhang Y., and Angelidaki I., “Bioelectrode-Based Approach for Enhancing Nitrate and Nitrite Removal and Electricity Generation from Eutrophic Lakes”, Water Research, Volume 46, 2012, Pg- 6445.
- [32] Li W., Zhang S., Chen G., and Hua Y., “Simultaneous Electricity Generation and Pollutant Removal in Microbial Fuel Cell with Denitrifying Biocathode over Nitrite”, Applied Energy, Volume 126, 2014, Pg- 136.
- [33] Morris J.M., Fallgren P.H., and Jin S., “Enhanced Denitrification through Microbial and Steel Fuel-Cell Generated Electron Transport”, Chemical Engineering Journal, Volume 153, 2009, Pg- 37.
- [34] Seveda S., Benetton D., Vanbroekhoven K., Sreerishnan R., and Pant D., “Characterization and Comparison of the Performance of two Different Separator Types in Air-Cathode Microbial Fuel Cell Treating Synthetic Wastewater”, Chemical Engineering Journal, Volume 228, 2013, Pg- 1.
- [35] I. Park, M. Christy, P. Kim, K. Nahma, “Enhanced electrical contact of microbes using Fe<sub>3</sub>O<sub>4</sub>/CNT nanocomposites anode in mediator-less microbial fuel cell”, Biosens Bioelectron., Volume 58, 2014, Pg- 75.
- [36] B. Virdis, S. Freguia, R.A. Rozendal, K. Rabaey, Z. Yuan, J. Keller, “Microbial Fuel Cells”, Elsevier Science publisher, Amsterdam, 2011.
- [37] M. Rahimnejad, M. Ghasemi, G. Najafpour, A. Ghoreyshi, G. Bakeri, K. Hassaninejad, F. Talebnia, “Acetone removal and bioelectricity generation in dual chamber Microbial Fuel Cell”, American Journal of Biochemistry and Biotechnology, Volume 8, 2012, Pg- 304.
- [38] M. Rahimnejad, G. Najafpour, A. Ghoreyshi, “Effect of mass transfer on performance of microbial fuel cell”, Mass Trans. Chem. Eng. Proc., Volume 5, 2011, Pg- 233.
- [39] S. Hassan, S. El-Rab, M. Rahimnejad, M. Ghasemi, J. Joo, Y. Ok, I. Kim, S. Oh, “Electricity generation from rice straw using a microbial fuel cell”, International Journal of Hydrogen Energy, Volume 39, 2014, Pg- 9490.
- [40] U. Schroder, “Anodic electron transfer mechanisms in microbial fuel cells and their energy efficiency”, Phys. Chem. Chem. Phys., Volume 9 2007, Pg- 2619.
- [41] H.Kim, S.Hong, H.Kim, S. Yang, S.Chung, “A study on quenching meshes as a possible controlling tool of hydrogen explosion in nuclear power plants”, In: 10th International Conference on Nuclear Engineering, American Society of Mechanical Engineers, Volume 2, 2002, Pg- 145.
- [42] P. Aelterman, K. Rabaey, H. Pham, N. Boon, W. Verstraete, “Continuous electricity generation at high voltages and currents using stacked microbial fuel cells”, Environ. Sci. Technol., Volume 40, 2006, Pg- 3388.
- [43] Y. Qiao, C. Li, S. Bao, Q. Bao, “Carbon nanotubes / polyaniline composite as anode material for microbial fuel cells”, Journal of Power Sources, Volume 170, 2007, Pg- 79.
- [44] T. Zhang, Y. Zeng, S. Chen, X. Ai, H. Yang, “Improved performances of E. coli-catalyzed microbial fuel cells with composite graphite/PTFE anodes”, Electrochem. Commun., Volume 9, 2007, Pg- 349.
- [45] Q. Deng, X. Li, J. Zuo, A. Ling, B. Logan, “Power generation using an activated carbon fiber felt cathode in an upflow microbial fuel cell”, Journal of Power Sources, Volume 195, 2009, Pg- 1130.
- [46] M. Rahimnejad, A. Ghoreyshi, G. Najafpour, “Power generation from organic substrate in batch and continuous flow microbial fuel cell operations”, Appl. Energy, Volume 88, 2011, Pg- 3999.
- [47] G. Chen, S. Choi, T. Lee, G. Lee, J. Cha, C. Kim, “Application of biocathode in microbial fuel cells: cell performance and microbial community”, Appl. Microbiol. Biot., Volume 79, 2008, Pg- 379.
- [48] A. Heijne, H. Hamelers, V. Wilde, R. Rozendal, C. Buisman, “A bipolar membrane combined with ferric iron reduction as an efficient cathode system in microbial fuel cell”, Environ. Sci. Technol., Volume 40, 2006, Pg- 5200.
- [49] J. Fornero, M. Rosenbaum, M. Cotta, L. Angenent, “Microbial fuel cell performance with a pressurized cathode chamber”, Environ. Sci. Technol., Volume 42, 2008, Pg- 8578.
- [50] S. You, Q. Zhao, J. Zhang, H. Liu, J. Jiang, S. Zhao, “Increased sustainable electricity generation in up-flow air-cathode microbial fuel cells”, Biosens. Bioelectron., Volume 23, 2008, Pg- 1157.
- [51] K. Watanabe, “Recent developments in microbial fuel cell technologies for sustainable bioenergy”, J. Biosci. Bioeng., Volume 106, 2008, Pg- 528.
- [52] L. Huang, J. Regan, X. Quan, “Electron transfer mechanisms, new applications, and performance of biocathode microbial fuel cells”, Bioresource. Technol., Volume 102, 2011, Pg- 316.
- [53] M. Rahimnejad, G. Najafpour, A. Ghoreyshi, F. Talebnia, G. Premie, G. Bakeri, J. Kim, S. Oh, “Thionine increases electricity generation from microbial fuel cell using *Saccharomyces cerevisiae*

- and exoelectrogenic mixed culture”, *J. Microbio.*, Volume 50, 2012, Pg- 575.
- [54] M. Zhou, J. Yang, H. Wang, T. Jin, D. Hassett, T. Gu, “Bioelectrochemistry of microbial fuel cells and their potential applications in bioenergy”, *Bioenergy Research: Adv. Appl.*, 2013, Pg- 131.
- [55] Z. He, L. Angenent, “Application of bacterial biocathodes in microbial fuel cells”, *Electroanalysis*, Volume 18, 2006, Pg- 2009.
- [56] G. Najafpour, M. Rahimnejad, A. Ghoreshi, “The enhancement of a microbial fuel cell for electrical output using mediators and oxidizing agents”, *Energy Sourc.* Volume 33, 2011, Pg- 2239.
- [57] Jonathan Winfield, Iwona Gajda, John Greenman, Ioannis Ieropoulos, “A review into the use of ceramics in microbial fuel cells”, *Bioresource Technology*, Volume 215, 2016, Pg- 296.
- [58] Thorne, R., Hu, H., Schneider, K., Bombelli, P., Fisher, A., Peter, L.M., Dent, A., Cameron, P.J., “Porous ceramic anode materials for photo-microbial fuel cells”, *J. Mat. Chem.*, Volume 21, 2001, Pg- 18055.
- [59] Winfield, J., Ieropoulos, I., Greenman, J., Dennis, “The overshoot phenomenon as a function of internal resistance in microbial fuel cells”, *Bioelectrochemistry*, Volume 81, 2011, Pg- 22.
- [60] Ghadge N., Ghangrekar M., “Performance of low cost scalable air cathode microbial fuel cell made from clayware separator using multiple electrodes”. *Bioresour. Technol.*, Volume 182, 2015, Pg- 373.
- [61] Park .H., Zeikus G., “Improved fuel cell and electrode designs for producing electricity from microbial degradation”, *Biotechnol. Bioeng.*, Volume 81, 2003, Pg- 348.
- [62] Seo N., Lee J., Hwang S., Park H., “Electricity generation coupled with wastewater treatment using a microbial fuel cell composed of a modified cathode with a ceramic membrane and cellulose acetate film”. *J. Microbiol. Biotechnol.*, Volume 19, 2009, Pg- 1019.
- [63] Behera, M., Jana .S., More T., Ghangrekar M., “Rice mill wastewater treatment in microbial fuel cells fabricated using proton exchange membrane and earthen pot at different pH”, *Bioelectrochemistry*, Volume 79, 2010, Pg- 228.
- [64] Ieropoulos .A., Ledezma, P., Stinchcombe, A., Papaharalabos, G., Melhuish, C., Greenman, J., “Waste to real energy: the first MFC powered mobile phone”, *Phys. Chem. Chem. Phys.*, Volume 15, 2013, Pg- 15312.
- [65] Pasternak G., Greenman J., Ieropoulos I., “Comprehensive study on ceramic membranes for low-cost microbial fuel cells”, *Chemosuschem*, Volume 9, 2016, Pg- 88.
- [66] S. Choi, “Microscale microbial fuel cells: Advances and challenges”, *Biosens. Bioelectron.*, Volume 69, 2015, Pg- 8.
- [67] B. Logan, J. Regan, “Microbial challenges and applications”, *Environ. Sci. Technol.*, Volume 40 2006, Pg- 5172.
- [68] L. Deng, M. Zhou, C. Liu, L. Liu, C. Liu, S. Dong, “Development of high performance of Co/Fe/N/CNT nanocatalyst for oxygen reduction in microbial fuel cells”, *Talanta*, Volume 81, 2010, Pg- 444.
- [69] L. Zhang, C. Liu, L. Zhuang, W. Li, S. Zhou, J. Zhang, “Manganese dioxide as an alternative cathodic catalyst to platinum in microbial fuel cells”, *Biosens. Bioelectron.*, Volume 24, 2009, Pg- 2825.
- [70] L. Woodward, M. Perrier, B. Srinivasan, C. Hc, B. Tartakovsky, “Maximizing Power Production in a Stack of Microbial Fuel Cells Using Multiunit Optimization Method”, *Biotechnol. Prog.*, Volume 25, 2009, Pg- 676.
- [71] I. Ieropoulos, J. Greenman, C. Melhuish, “Miniature microbial fuel cells and stacks for urine utilization”, *Int. J. Hydrogen Energy.*, Volume 38, 2013, Pg- 492.
- [72] F. Qian, D. Morse, “Miniaturizing microbial fuel cells”, *Trends Biotechnol.*, Volume 29, 2011, Pg- 62.
- [73] F. Qian, Z. He, M.P. Thelen, Y. Li, “A microfluidic microbial fuel cell fabricated by soft lithography”, *Bioresour. Technol.*, Volume 102 2011, Pg- 5836.
- [74] Jon Chouler, George A. Padgett, Petra J. Cameron, Kathrin Preuss, Maria-Magdalena Titirici, Ioannis Ieropoulos, Mirella Di Lorenzo, “Towards effective small scale microbial fuel cells for energy generation from urine”, *Electrochimica Acta*, Volume 192, 2016, Pg- 89.
- [75] Mostafa Rahimnejad, Arash Adhami, Soheil Darvari, Alireza Zirepour, Sang-Eun Oh, “Microbial fuel cell as new technology for bioelectricity generation: A review”, *Alexandria Engineering Journal*, Volume 54, 2015, Pg- 745.
- [76] Jeremiah Houghton, Carlo Santoro, Francesca Soavi, Alexey Serov, Ioannis Ieropoulos, Catia Arbizzani, Plamen Atanassov, “Supercapacitive microbial fuel cell: Characterization and analysis for improved charge storage/delivery performance”, *Bioresource Technology*, Volume 218, 2016, Pg- 552.
- [77] Dawn Holmes, Kelly Nevin, Oona Snoeyenbos-West, Trevor Woodard, Justin Strickland, Derek Lovley, “Protozoan grazing reduces the current output of microbial fuel cells”, *Bioresource Technology*, Volume 193, 2015, Pg – 8.
- [78] Ana Cucu, Athanasios Tiliakos, Iulian Tanase, Cristina Elena Serban, Ioan Stamatina, Adrian Ciocanea, Cornelia Nichita, “Microbial Fuel Cell

for Nitrate Reduction”, Energy Procedia, Volume 85, 2016, Pg- 156.

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