MICROBIAL FUELCELL TECHNOLOGY: PROSPECTS FOR WASTEWATER TREATMENT AND TACKLING ELECTRICITY CHALLENGES IN NIGERIA

Fidelis NKESHITA[1*], Busola ORONTI[2], Adebola ADEKUNLE[3], Adedayo BADEJO[4]

[1*]Department of Civil Engineering, Federal University of Agriculture, Abeokuta

[2]Department of Mechatronics Engineering, University of Agriculture, Abeokuta
[3]Department of Civil Engineering, Federal University of Agriculture, Abeokuta
[4]Department of Civil Engineering, Federal University of Agriculture, Abeokuta
***Corresponding author: chufid@yahoo.com**

ABSTRACT

Treating wastewater is very critical for preserving the quality of surface and ground waters. It is estimated that there is about nine times more energy in the wastewater than was used to treat it. Nigeria's power supply has continued to linger with its electrification rate less than half of the population and many parts of the country enmeshed in pitch darkness. Microbial Fuel Cells are an emerging technology that uses bacteria to generate electricity from wastewater. With this power source, clean sustainable energy can be produced at lower cost and thus, help to improve Nigeria's current power supply challenges.

Keywords: microbial fuelcell, wastewater treatment, renewable energy

INTRODUCTION

The effective disposal of wastewater from domestic households and industries is very critical in preserving the quality of water bodies so that this vital natural resource can be used for drinking water, recreation, and fishing. Inadequate treatment of wastewater diminishes water quality and aquatic life by reducing dissolved oxygen (DO) concentrations in the receiving waters (Kelly, 2013). A report from The United Nations estimate the earth's population to be about seven billion inhabitants, with a projected population reaching nine and a half billion inhabitants by 2050 (UN news centre, 2013). Conventional methods of wastewater treatment can consume between 950 and 2850 kJ/m3 of wastewater treated (Chitkela*et al*, 2012). According to Shizas and Bagley (2004), a traditional wastewater treatment facility in Toronto, showed that there was about nine times more energy in the wastewater than was used to treat it. With this amount of energy potential there is bound to be a lot of benefits that can be derived from tapping this power from the treatment of wastewater. Microbial Fuel Cells (MFCs) technology uses bacteria to generate electricity from wastewater. Bacteria in a Microbial Fuel Cell degrade organic wastes, effectively generating power from the materials that are usually thrown away. A clean, renewable and sustainable energy can be produced at low cost from this untapped power source (Mercer, 2018). MFCs are highly valuable because there are many applications of their use that help to reduce pollution and save water treatment costs in a sustainable and environmentally friendly way. Currently, Microbial Fuel Cells are used to produce electricity while simultaneously cleaning wastewater (Mercer, 2018). The generation of energy from wastewater present another opportunity to tackle the ever growing need for wastewater treatment and ever increasing energy demand in relation to depleting energy resources. Wastewater containing a high content of organic matter is ideal for producing alternative energy carriers, such as methane, hydrogen, and bioelectricity. A bioelectricity generating wastewater treatment system at a single large food processing plant may power hundreds of American single-family households. Bioelectricity generation from wastewater is accomplished with microbial fuel cells (Angenent*et al,* 2004). This can be buttressed by the fact that MFC installation at a food processing plant had potential to generate 330 kW/day of power on 7,500 kg of waste organics based on 30% efficiency (Logan *et al*, 2006). It is generally accepted that alternative sources of energy are urgently needed to address the ever increasing energy demands. According to (Franks and Nevin, 2010), the present dependence on fossil fuels is unsustainable due to pollution and limited supplies. While much research is being conducted into a wide range of energy solutions, it does not appear that any one solution will be able to replace fossil fuels in its entirety. As such it is likely that a number of different alternatives will be required, providing energy for a specific task in specialized ways and in various situations. The relatively recent discovery that Microorganisms can generate electricity from waste and renewable biomass has gained a lot attention from Scientists as can be seen from Bond *et al* (2002) and Kim *et al* (1999, 2002).

Microbial fuel cells (MFCs) can provide an answer to several of the problems which conventional wastewater treatment faces. They are capable of recovering energy out of the wastewater, while limiting both the energy input and the excess sludge production (Rabaey and Verstraete, 2005).

The increased interest in microbial fuel cell (MFC) technology was highlighted by the naming of *Geobactersulfurreducens*KN400, a bacterial strain capable of high current production, as one of the top 50 most important inventions for 2009 by Time Magazine. The discovery that microbial metabolism could provide energy in the form of an electrical current has lead to an increasing interest and a dramatic rise in the number of publications in the field of MFC research. These systems are very adaptable and hold much promise to provide energy in a sustainable fashion. There is a need for improvement if widespread applications can be feasible (Franks and Nevin, 2010). MFC technology can be applied as a renewable energy source with applications in power generation, wastewater treatment (Dannys*et al,* 2016).

Power generation and situation in Nigeria

Nigeria is a country endowed with abundant natural gas, oil, coal, and several renewable energy resources that could be used to meet the demand for domestic electricity generation. The first electricity supply company in Nigeria was established in 1929 but it was in 1972 that all isolated electricity generating corporations in Nigeria were merged with Niger Dams authority which was the only hydroelectric power station as at that time. The merger was named; National Electric Power Authority (NEPA). In 2005 the Federal government of Nigeria initiated the Electric Power Sector Reform Act (EPSRA) after amending the electricity and NEPA laws which were the prevailing laws as at 1998. The amendments were to remove the monopoly being enjoyed by NEPA and encourage private sector participation (Tunde*et al*, 2016). Nigeria Electricity consumption per capita between 2010 and 2014 was 149kWh which is less than half of Ghana's consumption rate and certainly incomparable to the United States with per capita of 13,246kWh (Tunde*et al,* 2016).

Despite its large oil and natural reserves, Nigeria's electrification rate is less than 50% of the population; thus leaving approximately 76 million people with no access to electricity. The Nigerian government has unfolded plans to generate up to 40 gigawatts (GW) of electricity capacity by 2020 compared to the 2009 installed capacity of 6 GW. To achieve this feat, there are already concerted efforts by the Federal Government/NIPP/IPP projects for electricity transmission in many parts of the country as shown in fig.1 . To achieve this feat will depend on the ability and political will of the Nigerian government to utilize renewable and environmentally-friendly energy sources—such as solar, biomass, geothermal heat, hydropower, and wind. It is expected that world demand for energy would increase by 30% by 2030 and the share of fossil fuels in energy production will be depleted significantly. It is therefore necessary for Nigeria shift focus to other emerging sources of renewable energy make concerted efforts to be a part of the global trends in energy technology developments (Omowunmi, 2015). Nigeria still looms in pitch darkness while other countries with similar power problems have long overcome the same challenges. Many businesses have relocated from the country as a result of the inability of the national grid to meet their demand while homes have also had to adapt to the epileptic power supply or in some cases total blackout. The few companies operating in Nigeria largely depend on off-grid supply using diesel/gas/petrol-powered electric generators thereby running at huge overhead costs and contributing to greenhouse gas pollution among other harmful environmental problems. (Tunde*et al*, 2016).

The basic principle of a microbial fuel cell

Microbial fuel cells (MFCs) represent a prospective low energy wastewater treatment system that converts chemical energy stored in wastewater to electrical energy. It does not require aeration during operation for the removal of contaminants (BOD/COD, nutrients) as present conventional methods (activated sludge or nitrification) typically use (Kelly, 2013). A microbial fuel cell is a bio-electrochemical system which generates electrical current from the catalytic action of electrigenic microbes on organic compounds and/or metals (Cheng *et al,* 2007; Morozan*et al*, 2007). The microbial decomposition of sugars in aerobic conditions produces carbon dioxide and water (Scott and Murano, 2007).

$$C_6H_{12}O_6 + 6H_2O \longrightarrow 6O_2 + 6CO_2 + 12H_2O \quad (1)$$

The bacterial action under anaerobic conditions result in the production of carbon dioxide, protons and electrons since oxygen is not available to take up the electrons.

$$C_6H_{12}O_6 + 6H_2O \longrightarrow 6CO_2 + 24H^+ + 24e^- \quad (2)$$

To utilize them in electricity generation, the electrons produced have to move from the electron transport chain of the cell and be deposited on an electrode. This can be achieved in two ways. Inorganic mediators such as thionine, methyl blue, methyl viologen and humic acid tap into the electron transport chain and channel electrons produced via the lipid membrane and the outer cell membrane and liberates the electron at the electrode which becomes negatively charged (Strik*et al*, 2008).

A typical MFC reactor as shown in fig.2 is composed of an anode and cathode chamber containing electrodes which are connected electrically. Exoelectrogenic microorganisms (ability to transfer electrons extracellularly), such as*Geobactersulfurreducens*(Reguera*et al*., 2005), are cultivated onto the anode electrode where wastewater (organicor inorganic compounds) is anaerboically oxidized (Logan, 2009). For example, in Equation 3 below, acetate is oxidized by bacteria to produce electrons, protons, and carbon dioxide.

$$CH_3COO^- + 2H_2O \longrightarrow 2CO_2 + 7H^+ + 8e^- \quad (3)$$

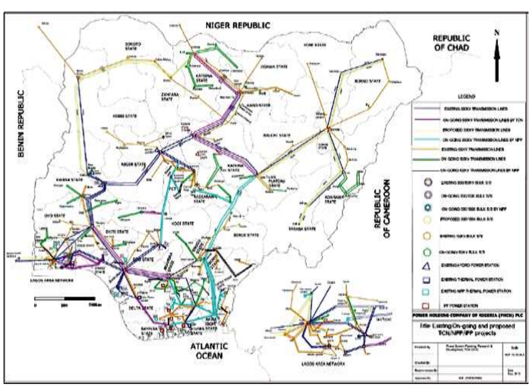

Fig. 1 Map of existing, on-going, and proposed TCN/NIPP/IPP projects for electricity transmission in Nigeria. *Source* TCN (2015), Akpan (2015)

The electrons flow through the external circuit (a load) to the cathode electrode where the protons will migrate through a separator (usually a membrane) to both participate in a reduction reaction. In Equation 4 below, oxygen is reduced by protons and electrons, producing water.

$$O_2 + 4H^+ + 4e^- \longrightarrow 2H_2O \quad (4)$$

The water produced is pure and]thus the process can also be used for remediation and water purification while generating electricity (Logan *et al*, 2006; Scott and Murano, 2007).

The low redox potential from anodic oxidation and higher redox potential from cathodic reduction ultimately drives the flow of electrons from the anode to cathode generating a voltage typically observed from 0.3-0.5 V depending on energy gain by bacteria and cathodic energy losses (Logan, 2009).

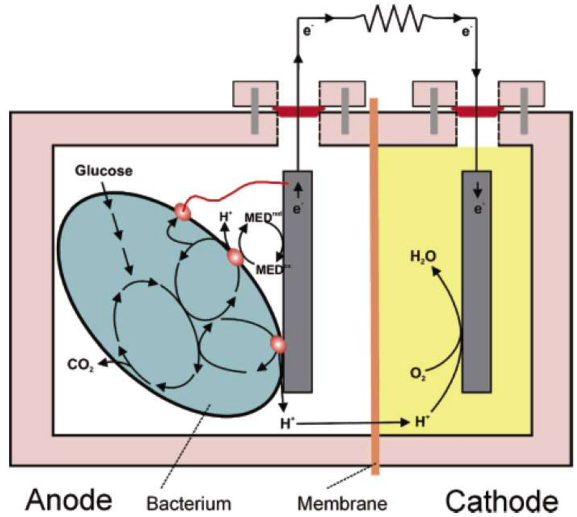

Fig. 2 Two chamber microbial fuel cell reactor principle (Logan *et al*., 2006)

Some Applications of Microbial Fuel cells

The microbial fuel cell has current and potential uses in brewery and domestic wastewater treatment, desalination, hydrogen production, remote sensing, pollution remediation, and as a remote power source. Many new applications are beginning to be tested and may come into widespread use in the near future (Mercer, 2018).

Wastewater Treatment

Brewery and food manufacturing wastewater can be treated by microbial fuel cells because their rich organic contents serve as food for the microorganisms. Breweries are ideal for the implementation of microbial fuel cells, as their wastewater composition is constant and this allow bacteria to adapt and become more efficient (Mercer, 2018).Wastewater from domestic sources can also be converted via microbial fuel cells to decompose the waste organic material contained in it. Research has shown that MFCs can reduce the amount of organic material present in domestic wastewater up to 80% (Liu and Logan, 2004). The electricity production from MFCs can reduce the operating costs of processing wastewater (Logan, 2006).

Source of Power

The researches carried out on microbial fuel cell technologies in the 1980s was mainly geared by the desire to provide cheap and accessible power to remote regions of Africa, where about three-quarters of the population live without electricity (Doty, 2010). Microbial fuel cells that is powered by manure have been developed and tested. The electrical current produced by a simple homemade MFC can recharge a cell phone battery, (Mercer,2018).

Desalination

Desalination of sea water and brackish water for use as drinking water has always been a problem because of the amount of energy required to remove the dissolved salts from the water. By using a microbial fuel cell specially manufactured to perform this process, it could proceed with no external electrical energy input (Fuel cell works, 2010).

Hydrogen Generation

Microbial fuel cells can be used to generate hydrogen for use as an alternative fuel. When used for hydrogen production, the MFC needs to be supplemented by an external power source to get over the energy barrier of turning all of the organic material into carbon dioxide and hydrogen gas (Coates and Wrighton, 2010).

Summary

MFCs present another interesting alternative for harnessing renewable energy by generating electricity from wastewater. Nigeria's power supply still lingers but has not fully harnessed the potentials of renewable energy and wastewater treatment. Some applications of MFCs will help to reduce the use of fossil fuels and allow for energy gain from wastes. MFC technology may not produce enough electricity to take the place of a coal-fired or hydropower plants but would subsequently ensure a more safer environment and bring Nigeria and the world closer to achieve sustainability in managing wastewater and electricity generation.

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