International Journal of Advanced Technology in Engineering and Science
Vol. No.3, Special Issue No. 01, November 2015
www.ijates.com
ijates
ISSN 2348 - 7550

NEW TECHNOLOGIES IN RENEWABLE SECTOR

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ABSTRACT

This research paper presents information on how bacteria can be used to harness energy. The three main methods of harnessing energy using bacteria are discussed. One method is the use of bacterial spore coated on rubber. The next two methods involve a Microbial Fuel Cell(MFC) which contains bacteria. Waste Water and Urine is used. The problems related to this method of energy production is along with their possible solutions. This paper also illustrates the practicality of these methods. The primary sources of our information are research papers written by scientists from Harvard University, Columbia University, Penn State University, Bristol University, and Ohio University. Experimental data obtained from various experiments conducted by these scientists was also studied and conclusions were formed based on this data.

Keywords: Bacterial Spores, Microbial Fuel Cell, Waste Water, Hydrogen Fuel, Urine, Energy Crisis

I. INTRODUCTION

It is a fact that the world as of now is facing a major energy crisis. For over 80% of our current needs, we rely on fossil fuels[1]which will get extinguished in the near future. Scientists looked for alternative options and have now found solar energy and wind energy. However, both these sources have their own issues. For example, Solar Energy has storage issues and it is difficult to store it in the form of chemical bonds[2].Wind Energy toohas an adverse effect on the economy and the environment[3]. Recently, scientists found a new way too harness energy. This involves the use of bacteria. Bacteria are microorganisms which can be found everywhere. They could be the answer to some the major energy problems the world is facing right now. Bacteria can be used in 3 different ways to produce energy ie through bacterial spores, waste water, and urine.

II. BACTERIAL SPORES

2.1 Fundamental Information

Synthetic materials are known to respond mechanically to changes in external environment. They have applications in biomedical devices, adaptive architectural systems, robotics and energy harvesting[4]. However, the effectiveness of this method to generate energy is limited when compared to mechanical actuators[5]. However, spores are different .These are dormant cells which have the ability to withstand a harsh environment. Despite their dormancy, they are not completely inactive[6]. They are mainly known to respond to changes in relative humidity. They either expand or shrink and their diameter changes by almost 12%[7]. To find out the energy produced by this expansion or contraction, an experiment was conducted. A cantilever was placed on a bacterial spore to measure the height change and hence the response to contraction and expansion of the bacterial spores.

A thermodynamic cycle consisting of four stages was created. In stage 1, the relative humidity is kept low. After this, in the 2nd stage, the force on the spore is increased without changing the relative humidity.In stage 3, the relative humidity is increased. In stage 4, the force is reduced to zero. The cycle is completed. From this cycle the work done on the cantilever can be calculated. The same procedure was followed for 3 different bacterial spores, B subtilis, B subtilis cotE gerE, and B thuringiensis. As you can see from the graph, maximum work was done by B thuringiensis(area within the cycle is maxiumum). However, to make use of the work done by these bacterial spores, it is necessary for the spores to assemble because the energy possessed by one spore is negligible. B subtilis is a preferable organism that can be used because it does not have an additional outer layer, the exosporium, which is possessed by some species. The exosporium reduces the packing density[10]. To measure the collective impact of these spores, the spores were assembled on latex rubber sheets. In the figure below, due to an increase in relative humidity, the spores absorb the humidity around them and expand changing the curvature of the latex rubber sheet.

To maximize the energy transfer, an optimum ratio of the thickness of the substrate to the radius of spore is required[11].It was concluded that the thickness of the rubber latex sheet should be 0.5mm[9]. In this case, maximum amount of energy could be transferred.

2.2 Practicality of This Method

To establish the practicality of this method in harnessing energy, a humidity driven generator built out of Legos, spore coated rubber sheet, and a miniature fan was used[12]. The coating of the spores was done by first cutting the natural rubber latex sheets into rectangular pieces using scissors. The top surfaces were treated with poly-L-lysine to improve adhesion.A glass of water was kept near the generator. The flowing air carried the moisture near the spore coated rubber sheet. The expansion and contraction of the bacterial spores caused the rubber sheet to flip back and forth. This drove a magnet generating electricity. Instead of rubber sheet, a silicon wafer can also be used with almost the same effect although rubber is better. The energy possessed in only a pound of spores is powerful enough to lift a normal car 1 metre above the ground[16].

2.3 Criticism

The main points of criticism of this method is bacterial safety. Bacteria are known to be the chief causers of viruses and a world filled with microorganisms which produce energy is bound to be dangerous. However, as stated previously in this article, the bacterium used in this method of harnessing energyis Bacillus subtilis, known to have a good safety record. It is rarely known to cause food poisoning[13].The European Food Safety Authority has granted this microorganism Qualified Presumption of Safety Status[14]. Conversely, it can be used as probiotic(microorganisms that provide health benefits when consumed) in healthy individuals[15].

2.4 Possible Applications

A possible usage of this method is to power a generator located near the coast. These generators can easily be powered by spores who constantly receive moisture from the ocean and hence their expansion and contraction would cause the rubber sheet to flip back and forth. This energy could possess power a generator.

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ISSN 2348 - 7550

Another possible application of this method is desalinization. Most desalinization plants are located near the coast and hence can easily be powered by bacterial spores which possess a tremendous amount of energy.

III. MICROBIAL FUEL CELL(MFC)

3.1 Introduction

Companies normally are known to spend billions in cleaning waste water before disposing it into any water body. However, what if there is a method to use this waste water to generate electricity? Microbes might provide the answer. For almost 100 years, it has been known that bacteria can produce electricity[17]. A few years ago, it was discovered that Microbial Fuel Cells can be used to generate electricity[18]. A microbial electrolysis cell (MEC) is a type of bioelectro chemical system that uses exoelectrogenic microbes(microorganisms which have the ability to transfer electrons outside their cell) tooxidize organic matter at the anode and produce a chemical ofinterest at the cathode[19]. You will see further in this article that this technology can be used to treat waste water and generate electricity.

3.2 Simultaneous Waste Water Treatment and Generation of Electricity

Treatment of waste water and generation of electricity is possible simultaneously using MFC. A microbial fuel cell consists of an anode and a cathode. Thebacteria are kept at anode isolated from oxygen. The purpose of the bacteria is to oxidize the substrate or the organic matter and to generate the electrons and these electrons are transferred to anode. As this process is isolated from oxygen it is an anaerobic process different from conventional aerobic technologies. Because of the generation of the electrons at anode, there is a potential difference between cathode and anode and because of this potential difference electric current is generated. During this process protons are also generated which are transferred to the counter electrode, i.e. cathode. The two electrodes are separated by a proton exchange membrane which can be a salt bridge or can be a porous ceramic plate[24]. The purpose of proton exchange membrane is not only to transfer protons but also to prevent the flow of oxygen from cathode chamber to anode chamber. Cathode is supplied with water which is aerated with oxygen bubbles[24]. This oxygen is extracted from water and combined with electrons and protons which are transferred from anode to cathode to give water. A catalyst is also used at cathode like Pt or copper for the generation of water[25]. Potential difference generated in MFC is of the order of 0.5-0.8V which is quite low[25]. So, to increase the voltage, reactors are connected in series(Ghangrekar, 2006; Logan, 2005). See the figure below to understand the process.

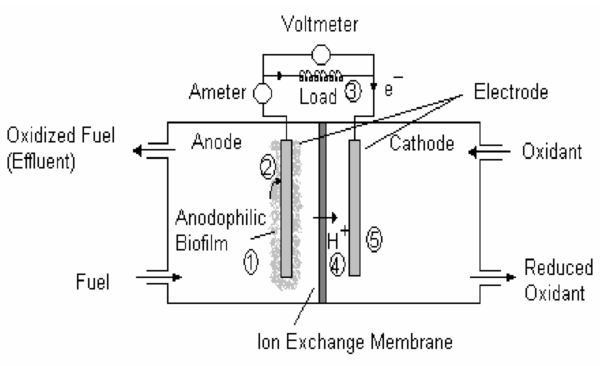

Fig 4: Electricity Generation[26]

The only disadvantage of this system is that its power output and current yield is low. Hence, there is need for improvement in MFC technologies before it can be commercialized. There are various ways to increase the power output. For example, aerated water at cathode can be replaced by air . Advantage of using air is that oxygen is supplied directly to the cathode without dissolving it in water and further there is a significant increase in the power output of MFC . Also if the PEM is removed and glucose is used there was a significant increase in power output, this is because there is a decrease in the internal resistance produced by PEM. Also there is a considerable amount of variation in power output with change in the wastewater concentration.(Logan 2005).

Below is a table of the different amount of power generated from different types of waste water.

Substrate	Power(mw/m^2)
Starch wastewater	20
Anaerobic sediments	28
Continuous Large SCMFC	26
Flat Plate	76
Batch, Small SCMFC(with PEM)	28
Batch, Small SCMFC(without PEM)	146
Animal Waste Water	260

Table 1:Comparison of Power Generated from Different waste water

3.3 Energy from Urine Using MFCs

Another interesting method of producing energy from MFCs is using urine. Urine has about 98%of water content and rest of the 2% is comprised of different minerals such as sodium , chlorine, etc[20]. The hydrogen bonding in water is quite strong and requires 1500 to 2500K to break. Whereas, in urine,hydrogen bonding molecules are loosely bonded, and hence breakdown occurs quickly. As everyone knows that, the presence of hydrogen is very essential for all forms of fuel, urine gives a better chance to be used as a fuel. Apart from the complexity in electrolyzing water, it cannot be used as a fuel in the long run. However, urine is different.

Over 7 billion people around world produce 2.8 billion gallon of urine per day[20] which really makes urine a renewable resource. As mentioned earlier, urine can be used to produce electricity by passing through MFC (Microbial Fuel Cell). This MFC contains bacteria which eats up the organic matter present in urine and allows only electrons to pass .these electron accumulation is then used to produce enough electricity to charge a mobile phone[21]. In many African nations, electricity still stands as major driving force for their development. Most of them rely on carbon fuel based generators for electricity. These generators in return produce a large amount of carbon monoxide which is extremely hazardous to human health. A urine powered generator that was invented in Africa by a bunch of Nigerian teenage girls has brought a substantial change in usage of fuel thereby reducing the risk of individuals[27]. You can see an image of the generator below. According to the sources, 1 liter of urine can be used to generate electricity for 6 hours. Unlike the other generators, it only produces water vaporto the surrounding. As a matter of fact it costs only$20 to produce (generator cost not included).

Fig 5: A Urine Powered Generator

3.4 Miscellaneous Use of Urine

There are many other uses of urine. MFCs are not always needed to generate electricity. Urine can be used to fertilize crops, in osmosis, etc. as you can see below.

Urine can be used in fuel based generators as a fertilizer for crops[22]. Agrarian Countries(Relating to or concerning the land and its ownership, cultivation, and tenure[28]) like India needs a huge amount of crop production to fulfill the needs of increasing population . An Indian researcher by the name of SrideviGovindaraj did some research on urine and came out with an idea of using it for growing plants like banana. According to her, Urine is rich with minerals such as nitrogen, potassium ,phosphorous and also contains secondary nutrients which can be used by plants If Indians collected and applied 40 percent of their urine, the country could save $26.7 million (1.2 billion rupees) in fertilizer costs, Sridevi calculates. (Goodier Rob, 2011).

Also, urine can be used in Forward Osmosis Bag (FOB)[23]. It is used by astronauts in space. It involves a waste liquid such as urine which is converted to drinking water using semi permeable membrane and sugar solution. This membrane is used as a filter and lets the urine pass through these pores of the membrane. Safe drinking water is obtained . It also blocks all sorts of pathogens, bacteria, salt and viruses entering the drinking water.

Fig 6: During experimentation, a NASA Specialist injects Liquid into the Forward Osmosis Bag[23]

IV. CONCLUSION

Hence, it can be concluded that we have viable alternatives to the energy derived from fossil fuels in the form of bacterial spores and MFCs. These options, as of now, are not commercialized. However, recent developments have proved that in the next few years, these options will be cheap enough to be commercialized. These alternatives, thanks to their practicality and simplicity are, without doubt, some of the best solutions to the major energy crisis the world is facing right now. The next few years will be an interesting phase in the field of energy and renewable resources. We, as a human race can be hopeful of a bright future ahead of us for us and the next generations.

V. ACKNOWLEDGEMENT

This research paper was made possible through the help and support from everyone. Their guidance and advice helped us write this paper. We would like to dedicate our acknowledgement and gratitude to the following beings.

First and foremost, we would like to thank God for guiding us and helping us when in need.

Next, we would like to thank our parents and friends whose valuable support and advice helped us in times of need.

Last but not the least, we would like to thank professors OzgurSahin and Bruce Logan whose innovative thinking inspired us to research on these topics.

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