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Electricity Generation from Waste (Urine)

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***Abstract* — The need for new and alternate sources of energy is increasing day by day. In the upcoming days the alternative sources of energy will be applied everywhere.**
In this technology it is proposed to use Urine as a resource to generate power, with the help of Microbial fuel cell (MFC), which is sufficient to glow a light (watts). It is a very cost effective and a renewable energy source which will be adopted for the future.
In proposed system a successful isolation in the electrogenic bacteria which includes bacillus species and pseudomonas species is possible.
The Microbial fuel cell is a biochemical-catalyzed system, which generates Electricity (Bio Electricity) by oxidizing biodegradable organic matter in the presence of either fermentative bacteria or enzyme.

***Index Terms* — Microbial fuel cell, Fermentation, Micro-organism, Proton exchange membrane, Electrode.**

I. Introduction

Now days we are facing a very big problem of electricity because in India we still use conventional energy sources and very little approach towards nonconventional resources as well as renewable resources. The renewable energy resources are the domain in which energy generation from waste products.

Indian government is introducing new policies in renewable energy sources for waste management and providing clean and green environment. Thus a great upcoming field is renewable energy resources, waste treatment and management, generation of electricity.

New approaches for electricity generation and waste water treatment, which not only reduce cost but also produce useful side-products from waste are have recently received increasing attention.

MFCs on the other hand have less exacting demands and proffer promising options. MFC is a device which converts chemical energy to electrical energy during substrate oxidation with the help of microorganisms [1].

Electricity production from microbial fuel cells has been accomplished using acetate and butyrate in domestic wastewater [11]. The microbial fuel cell (MFC) technology offers a valuable alternative to energy generation as well as urine treatment. Microorganisms have proven to be promising agents for electricity generation [2].

We thought of adapting a technology which is a biotechnological solution for the power cuts and in the due course we discovered that MFC technology serves the purpose. A variety of readily degradable compounds such as glucose and acetate, and various types of waste water such as domestic, starching and paper recycling plant waste water, have operated successfully as substrate in MFC. Most could achieve a considerable chemical oxygen demand (COD) removal efficiency accompanied with electricity generation [3].

Hydrogen can be produced from wastewater rich in carbohydrates by biological fermentation but much of the energy remains in the form of soluble products such as acetate and butyrate. One way to recover this lost energy is to use dual-chamber microbial fuel cells (MFC) that feed on the organic acids and produce electricity. The anaerobic and aerobic chambers are separated by a proton exchange membrane that facilitates proton transfer [2,4].

II. Problem Defination

- Generation of Electricity from “Urine / Sewage” as a waste product.
- Development of automated procedure / model for the waste treatment as a renewable energy sources.

III. Objectives

- Collection of urine and filtration.
- Reverse osmosis.
- By products from above process Ammonia converted as Nitric Acid, Water and Hydrogen.
- Microbial fuel cell (electricity generation process).
- Provide automation in system operation and power storage.

IV. Block Diagram And Discription

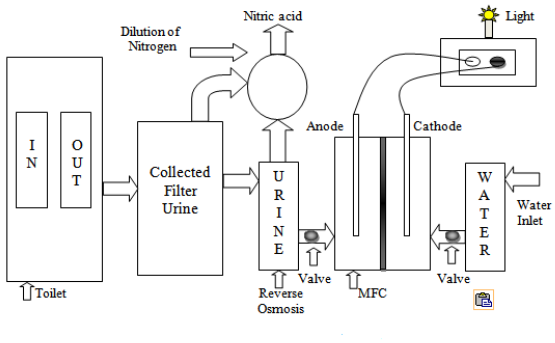

Figure 1. Block Diagram

A. *Discription*

Step 1:- In very first process of urine treatments is collection of urine and filter it.

Step 2:- Then comes under the reverse osmosis process and separate out biodegradable solvent which undergoes to the MFC.

Step 3:- The Ammonia is collected from under collection, filtration and RO process is diluted and nitric acid is a byproduct obtained.

Step 4:- MFC is fundamentally an anaerobic treatment process because the bacteria grow in the absence of oxygen in a chamber on an electrode. For generation of electricity, the bacteria oxidize organic matter and pass the electrons to an electrode.

The generation of current, and the voltage between the cathode and the anode chambers, creates the basis of the MFC.

Step 5:- Proper collection of the byproducts generated from the MFC process as 'Water' and 'Hydrogen'.

Step 6:- All the processes are controlled and operated by controlling action using controller and sensors interfacing.

B. METHODOLOGY

Reverse Osmosis: Water is cleaned through the process of reverse osmosis. Then the cleaned water may be used for industrial process. The reverse osmosis is a kind of filtration process ,which uses pressure to force a solution through a membrane, retaining the solute on one side and while the pure solvent to the other side. This is the contrary to the normal osmosis process, in which is the natural movement of solvent from an area of low solute concentration, to the of high solute concentration area through a membrane, when no external pressure is applied.

Role of reverse osmosis: There are in electricity generation from urine the very big problem of the salt content of urine sample, which is deposited on the surface of the anode and form layer which causes slow and further going to stop the anode reaction, because no surface area available for reaction. That's why we can go for the reverse osmosis process. In which urine treatment and salt filtration can be done.

Dilution of ammonia [5]: Urine content ammonia causes very bad smell. While ammonia itself is sometimes used as a fertilizer; it is often converted to other substances for easy handling. First Nitric acid is produced by mixing ammonia and air in a chamber. A reaction occurs, in the presence of a catalyst which converts the ammonia to nitric oxide. The nitric oxide is then reacted in the presence of water to produce nitric acid.

V. PRINCIPLE OF MICROBIAL FUEL CELL SYSTEM:

Microbial fuel cell (MFC) [2,6]: A microbial fuel cell is a device that converts chemical energy to electrical energy by the catalytic reaction of microorganisms. We know that electricity can be produced directly from the degradation of organic matter in a microbial fuel cell. Similar a normal fuel cell, the MFC has both an anode and a cathode chamber. The anode chamber is connected internally to the cathode chamber via an ion exchange membrane with the circuit completed by an external wire.

A microbial fuel cell is a device that converts chemical energy to electrical energy by the catalytic reaction of microorganisms. In normal microbial catabolism, a carbohydrate used as substrate .is initially oxidized an aerobically, when its electrons are released by enzymatic reactions.

The electrons are stored as intermediates (e.g., Nicotinamide adenine dinucleotide NADH, quinines) which become reduced and are then used to provide the living cell with energy. An ending location for an electron is molecular oxygen or dioxygen at the end of the respiratory chain .A MFC uses bacteria to catalyze the conversion of organic matter into electricity by transferring electrons to a developed circuit. An MFC has both an anode and a cathode chamber. The anode chamber is connected internally to the cathode chamber via an ion exchange membrane with the circuit completed by an external wire.

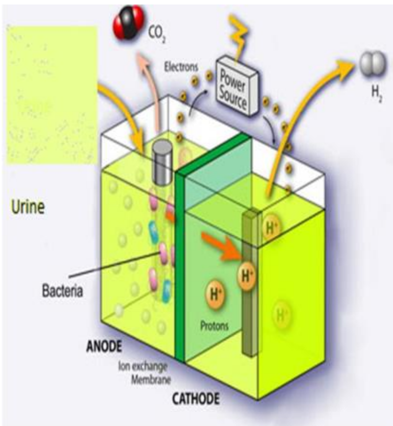

Figure 2. Microbial fuel cell

Microorganism can transfer electrons to the anode electrode in three ways first using exogenous mediators (ones external to the cell)such as potassium ferricyanide, thionine, or neutral red secondly using mediators produced by the bacteria and lastly by direct transfer of electrons from the respiratory enzymes(i.e. cytochrome) to an electrodes. Then these mediators can divert the electrons from the respiratory chain to outer cell membrane, then leaving in a reduced state to shuttle the electron to the electrode.

Hydrogen can be produced from waste (urine) rich in carbohydrates by biological fermentation but much of the energy remains in the form of soluble products such as acetate and butyrate. One way to recover this lost energy is to use dual-chamber microbial fuel cells (MFC) that feed on the organic acids and produce electricity. The anaerobic and aerobic chambers are separated by a proton exchange membrane that facilitates proton transfer. Microbial fuel cell consists of anode and cathode compartments separated by a cation (positively charged ion) specific membrane. While in the anode compartment, microorganisms oxidizes the fuel by, generating protons and electrons. Electrons are transported to the cathode compartment through an external electrical circuit, and protons to the cathode compartment through the membrane. In the cathode compartment, protons and electrons are combined with oxygen to form water.

Anode [8]: A Plastic anaerobic container of 1.5 litre capacity was used. It was holed to insert a Salt Bridge. The chamber (container) was filled with different samples such as water waste (urine). Carbohydrates (glucose, sucrose cellulose, starch), volatile fatty acids (Format, acetate, butyrate), alcohols (ethanol, methanol), amino acids, proteins can be used as substrate. The type of substrate fed to a MFC potentially has an impact on the structure and composition of the microbial community. In our apparatus, we have used urine .The following electrodes were used Carbon Rods of length 15cm and Diameter 1.5cm.

Cathode [8]: A Plastic aerobic container of 1.5 litre capacity was used. It was holed at the side to insert a Salt bridge. The chamber was filled with electrolytic solution (saturated salt solution). The electrolytic solution was exposed to air for reduction reaction to occur. The Oxygen combined with protons which passed through salt bridge and the reduction occurred at the point where oxygen, electrons and proton meet. Water is formed due to this reduction reaction. Electrodes were used as same as that of Anode.

Proton exchange membrane [7]: Proton exchange membrane is the mediator (separator) which separates the two different electrolytes from each other and only allow to exchange (conduct) proton from one side to other (one electrolyte to other electrolyte) and prevent the flow of electrons and protected from short circuit in MFC cell.

Desired properties: To achieve high efficiency the membrane must possess the following desirable properties:

To support large currents with minimal resistive losses and zero electronic conductivity, high proton conductivity is desired.

Electrochemical stability, and enough mechanical strength and stability under operating conditions.

Moisture control in stack.

Manufacturing costs well-matched with intended applications.

Electrical generation process: When micro-organisms consume a substance such as sugar in aerobic conditions they produce water and carbon dioxide. In absence of oxygen it produces protons, carbon dioxide, and electrons as given below:

$$C_{12}H_{22}O_{11} + 13H_2O \dashrightarrow 12CO_2 + 48H+ + 48e- \quad (1)$$

Microbial fuel cells use inorganic mediators to tap into the electron transport chain of cells and channel electrons produced. Then the outer cell lipid membranes and bacterial outer membrane is crossed by mediator and; then, it starts to release electrons to from the electron transport chain that normally would be taken up by oxygen or other intermediates.

The now-reduced mediator exits the cell laden with electrons that it shuttles to an electrode where it deposits them; this electrode becomes the electro-generic anode. The release of the electrons is nothing but the mediator returns to its original oxidized state ready to repeat the process and this can only happen under anaerobic conditions; if in presence of oxygen, it will collect all electrons because of its greater electronegativity than mediators.

In microbial fuel cell operations, anode act as a terminal electron acceptor recognized by bacteria in the anodic chamber. Hence, the microbial activity is strongly dependent on the redox potential of the anode. In recent publication, a Michaelis-Menten curve was obtained between the anodic potential and the power output of acetate driven microbial fuel cell. The important anode potential appears to exist at which a maximum power output of a microbial fuel cell is achieved.

This is the principle behind generating a flow of electrons from most micro-organisms (the organisms capable of producing an electric current are termed Exoelectrogens). To convert this into a usable electrical supply, this process has to be accommodated in a fuel cell. Also to produce a useful current it is necessary to create a complete circuit, than just shuttling of electrons to a single point.

The mediator and micro-organism, case yeast in this, are mixed together in a solution to which is added a suitable substrate like glucose. Then this mixture is kept in a sealed chamber to stop entry of oxygen, this action forces the micro-organism to use anaerobic respiration. A Electrode is placed in the solution that will act as the anode as described previously.

In the second chamber of the MFC is another solution and electrode. This concern electrode, called as cathode is positively charged and is the equivalent of the oxygen sink at the end of the electron transport chain, and then only it is external to the biological cells. The solution used is an oxidizing agent that picks up the electrons from the cathode. Similar to the electron chain present in the yeast cell, it could be a numerous molecules like oxygen. However, it would require large volumes of circulating gas. For this a more convenient option may be to use a solution of a solid oxidizing agent.

Connecting the two electrodes is a wire (or other electrically conductive path which may include some electrically powered device such as a light bulb) and completing the circuit and connecting the two chambers is a salt bridge or ion-exchange membrane. This feature allows the protons to be produced, as described in Equation.1 to pass from the anode chamber to the cathode chamber.

The reduced mediator carries electrons from the cell to the electrode. The mediator is oxidized while it deposits the electrons. Then these electrons flow through the wire from electrode to the second electrode, which acts as an electron sink. After that they pass to an oxidizing material.

A. Chemical Reactions:

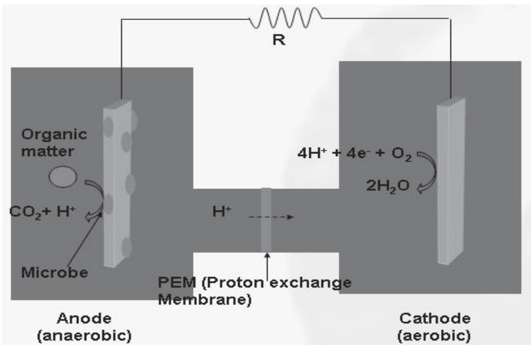

Figure.3 Reaction Diagram

B. Enzymatic Reactions:

The basic reactions are presented below; when microorganisms consume a substrate such as sugar in aerobic condition they produce CO2 and H2O. However in absence of oxygen i.e. during anaerobic condition it produces CO2, H+ and e- .

Anodes reactions:

$C_{12}H_{22}O\ 11 + 13H_2O \rightarrow 12CO_2 + 48H+ + 48e-$

Cathodes reaction:

$O_2 + 4e- + 4H+ \rightarrow 2H_2O.$

Advantages

- Pollution free.

- Natural process.
- No cost of raw product.
- Waste management.
- One time investment.
- Automated.
- Fertilizers as a byproduct for agriculture (Natural green environment).

Applications and Outlook

- The major applications will developments of cells at public locations were high concentration of urine as an organic substrate is available.
- These could be exceptionally valuable in space waste regeneration and in creating bio-sensors. Very useful byproduct Nitric acid obtained from urine treatment which is use as natural fertilizer
- Hydrogen which is used as fuel in vehicles.
- Water also generated used as gardening purpose.
- Provide fissile implementation of renewable energy source.

VI. Conclusion

The study demonstrates the feasibility of bioelectricity generation from anaerobic waste (urine) treatment process using a low-cost MFC consisting of non-coated plain carbon electrodes and mediator as a proton exchange membrane(Nafion117).A significant reduction in the COD during electricity production from real waste (urine) may be consider as the useful feature for clean and green power generation.

The maximum voltage and current generates using the waterless urine. Using mediator in MFC shows the good result.

As per the present set-up we got low voltage which is not sufficient to lighting purpose that's why there will be required voltage booster circuit.

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