Development of IOT Based Dual Chamber Microbial Fuel Cell for Wastewater Treatment and Power Generation

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***Abstract*: The need for electricity and clean water in Pakistan proceeds to increase day by day which triggers the energy crisis and water scarcity in the country. The utilization of oil as an energy source still overwhelms, although oil saves in Pakistan are progressively being drained. Subsequently, there is a need to develop innovative renewable energy sources such as Microbial Fuel Cell (MFC). MFC is a bio-electrochemical reactor that is used to change over the common substrate acquaint in wastewater with electrical essentialness and treat wastewater under anaerobic conditions by utilizing microorganisms as a catalyst. The objective of this study was to develop an IoT (Internet of things) based dual-chamber Microbial Fuel Cell for power generation and COD removal from domestic wastewater. The reactor was developed, incorporating sensors (Temperature, pH, and Voltage) and modules connected with Arduino microcontroller and interfaces cell to PC and android devices. Additionally, the Data Acquisition model (DAQ) utilizing an android platform was utilized for checking and recording results. The productivity of developed double chamber MFC was seen by assessing the removal of chemical oxygen demand and power generation from wastewater. The outcomes of this research showed that COD removal was up to 90 percent and maximum power generation was 2.1 V.**

***Keywords*: Android; Data Acquisition Model; Bio-electrochemical Reactor; Fuel Cell.**

I. INTRODUCTION

Throughout the last few years Pakistan is confronting Energy crisis and water quality issues because of industrial, agricultural and municipal activities. Since the beginning of millennium, electricity got more prominent consideration due to the quick development in its interest. Additionally, the environmental factors i.e., air contamination, lack of water supply, sanitation and deforestation environmental issues faced by the nation which represent a significant issue (P. Martin et al., 2006). To conquer the energy crisis and concern to reduce the environmental pollutants, countries from all around the world are with sharp eye to find sustainable power sources (Muhammad Kamran 2018). One of the results of such endeavors is Fuel cell innovations, creates power with the utilization of valuable metal catalysts without releasing harmful inorganic oxides such as CO2, SOX, NOX and CO. (S.J. Peighambardoust Rowshanzamir, M. Amjadi 2010). Among these innovations, microbial Fuel Cell (MFC) innovation has demonstrated the capacity to change over compound vitality bound in the extensive variety of natural issues to power straightforwardly by the guide of electro dynamic microorganisms Attributed to this potential, there has been a progressing and as yet expanding pattern in the organization of MFC and fill in as a perfect innovation for wastewater treatment and power yield at the same time (B.E. Logan 2009, László Koók et al,. 2017). Double chamber MFCs are commonly utilized in labs, comprise of an anode chamber and a cathode chamber parted by a proton exchange membrane (PEM) (Anup Gurung, Sang-Eun Oh 2012). Nevertheless, it must be said that there is still much opportunity to get better in the reactor arrangements and electrolyte plan of MFCs, for effective working and cost reduction (Rahimnejad et al. 2011). To persistently monitor parameters and voltage generation using MFC an information procurement framework can be created to change over the simple voltage into computerized yield and exchange the prepared information through a microcontroller, for example, Arduino Uno. This can be designed as a stable source for data transmission by incorporating the necessary electronic circuitry with the cell (Nicole Jannelli et al.2016). The objective of this study was to develop a dual chamber remote, android and PC based Microbial energy unit for electricity generation and COD removal from domestic wastewater. Arduino framework was utilized which is associated with sensors such as Temperature, pH and Voltage and connects this cell to PC and android device. For electron exchange and power generation graphite rod was utilized as anode and carbon fabric was utilized as cathode. Additionally, modules such as LCD (liquid crystal display), wifi module and Storage module were incorporated to display output and to make project remote and spare information. Data Acquisition model (DAQ) and android based programming were utilized for monitoring and recording outcomes. The productivity of developed double chamber MFC will be monitored by estimating the momentary Chemical oxygen demand and power generation.

II. MATERIALS & METHODS

A. Hardware Development of MFC

In this study a lab scale dual chamber Microbial fuel cell is developed in which sensors and modules are incorporated to monitor parameters continuously. This has been designed utilizing an Arduino Board consolidating extra modules, for example, Liquid Crystal Display to show the results, a storage module, a real time clock to give the date and time of every estimation. Further, hardware/software DAQ system capable of monitoring pH, Voltage and temperature was designed and outputs are displayed in Computer or android device. Additionally, Wi-Fi module is incorporated in order to monitor outputs remotely via internet.

B. Procedure of making electrodes

Graphite as anode:

Graphite rod is used as electrode in anaerobic to transfer the electron to cathode chamber. In this reactor graphite rod of 10cm length and 2cm diameter was taken, fit at top of the anaerobic chamber and was wrapped with copper wire. The copper wire was further connected with the voltage sensor in Arduino board.

Carbon cloth as cathode:

Carbon cloth was used as cathode in aerobic chamber. In the reactor carbon cloth having dimensions 7 cm x 10 cm was fit at top of aerobic chamber and was wrapped with copper wire and connected with the negative charge of Arduino system.

Salt bridge:

Salt Bridge maintains the negative and positive charge in the process and ultimately produces the Electricity in terms of voltage, without that electricity balanced drops and it gives zero charge.

Preparation of salt bridge:

Measure 15g of agar, add 0.1 Molar solution of NaCl and agar and dissolve in 350 milliliter (ml) of distill water.
Then boil the solution on hot plate. When water is boiled, shake until agar is completely dissolved. Put the prepared solution in PVC pipe of 10 cm length and 2 cm diameter and give 15 minutes to cool down. Finally to bring it in solid form put salt bridge (PVC pipe containing agar solution) in refrigerator for 24 hours (Parkash, 2016).

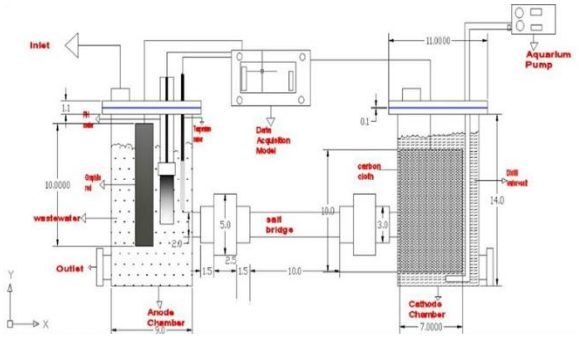


Fig 1: Schematic diagram of Microbial fuel cell

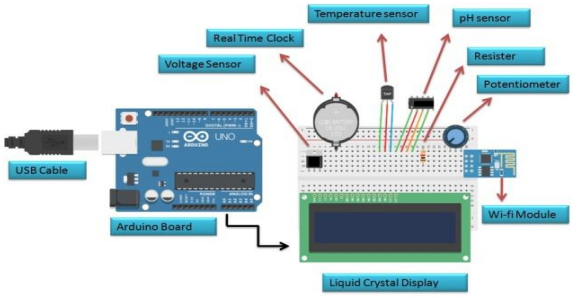
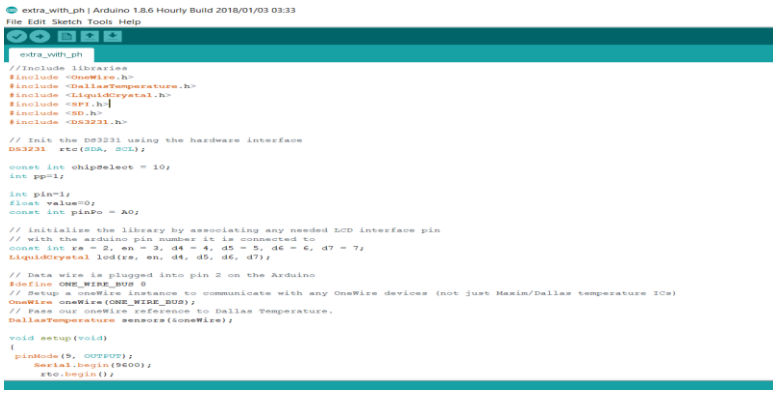


Fig 2: Schematic diagram of Data Acquisition System

Software Development of MFC



```
// read three sensors and append to the string:
 float sensor = sensors.getTempCByIndex(0);
 dataString += String(sensor);


 dataFile.print(rtc.getDateStr());
 dataFile.print("        ");
 dataFile.print(rtc.getTimeStr());
 dataFile.print("          ");
 dataFile.print(kk);
 dataFile.print("          ");
 dataFile.print(vyslednePH);
 dataFile.print("          ");
 dataFile.println(dataString);
 dataFile.close();
 // print to the serial port too:

 Serial.print(rtc.getDateStr());
 Serial.print("    ");
 Serial.print(rtc.getTimeStr());
 Serial.print("          ");
 Serial.print(kk);
 Serial.print("          ");
 Serial.print(vyslednePH);
 Serial.print("          ");
 Serial.println(dataString);


}
```

Fig 3: Programing for data acquisition system

Setup and Operation of IOT based Microbial fuel cell

The double chamber MFC with working volume of 2.268 L was set up according to lab scale prototype. The prepared anode and cathode are to be fitted at center of the both chambers. In the anaerobic chamber 1-liter wastewater was initially filled without any changes in to its properties and Nitrogen gas is also purged in anaerobic chamber from 3 to 4 minutes to remove oxygen and maintain anaerobic condition. In the Aerobic chamber 1-liter distilled water is filled and air pump is also used to provide oxygen in aerobic chamber. The copper wire of the anode chamber was connected with the positive terminal and copper wire of cathode chamber was connect with negative terminal of data acquisition model and reading of voltage can be noted time to time. The Data acquisition model is later connected with laptop which shows the output voltage generation data. The whole batch process is to be held at room temperature between 25°C to 35°C. No any alteration is to be done with wastewater. The voltage generated can be monitored through the data acquisition model. The hydraulic retention time (HRT) was 8 days, depends and varies from waste type and presence of organic matter in wastewater.

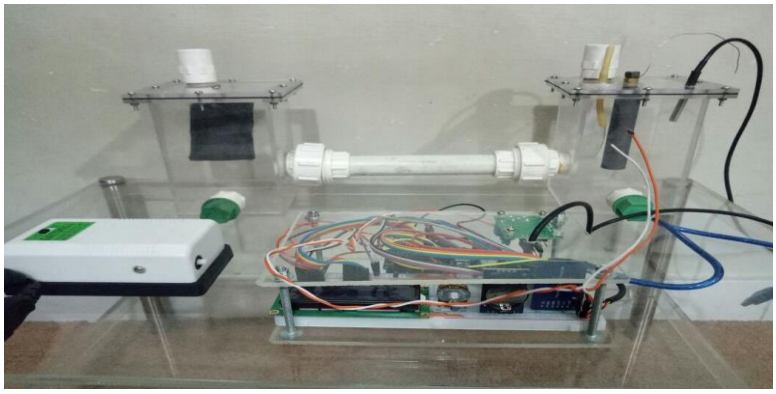


Fig 4: Pictorial view of IOT based Microbial Fuel Cell

III. RESULTS

The primary goal of this piolet scale project is to develop a wireless Microbial Fuel Cell for electricity generation from wastewater and continuously monitor various parameters like temperature, voltage and pH by the system based Arduino programming. Such a system has many advantages, especially when the restricted areas are to be kept intrusion free. It will also useful for getting all information about the water quality parameter in a single piece of device which is easily operable by anyone. This system is a reliable communication system without breakdown because of the use of wireless devices such as PC and mobile phone. All the data can be read by the smart device without interruption and delay because of the efficient use of simple communication algorithm. Employing embedded technology, based on Arduino, the Wireless module (ESP 8266) is designed and implemented.

The power generation was calculated by the the relationship given in the report of Water Environment Research Foundation by Li Baikun and his co-workers (Li et al., 2011)

$$PG = \frac{\frac{V^2}{R}}{CODr * Q}$$

Where:

PG = power generation per COD removal rate

V = amount of voltage generated (V)

R = resistance provided (ohm)

CODr = Removal of COD (g/l), and

Q = substrate volume in batch reactor

The results of electricity generation through microbial fuel cell by using wastewater and variation in electricity

generation with different parameter like voltage, time, temperature and pH utilizing sensors and also change in amount of COD was studied.

Voltage generation and Time

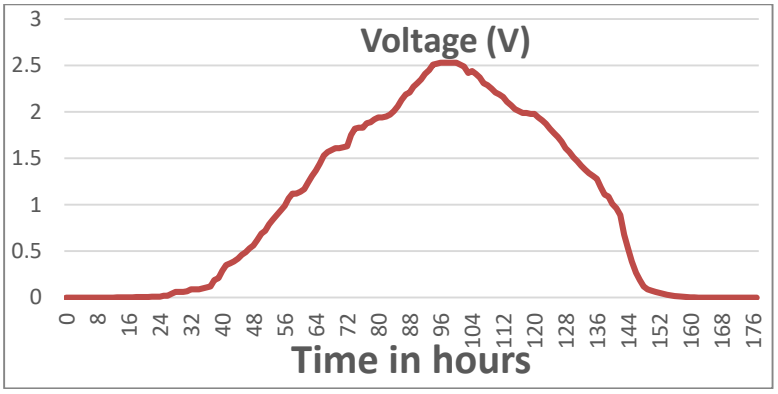


Fig. 5: Voltage generation in Volts with respect to time in hours

The reactor was operated for 8 days and utilizing Arduino model it was observed that at first day there is no voltage generated till 10 hours that was 0.001 V due to starting of decomposition of organic matter present in wastewater. Next day after 24 hours voltage generation started increasing from 0.001 to 0.01V and further increases due rapid decomposition of organic matter and the maximum voltage generation was observed at 4th day (after 96 hours), which was 2.5V. while on 5th day the voltage generation started decreasing, since organic matter degraded within first 4 days. The voltage decreased and on 8th day it dropped to zero.

Voltage generation and pH:

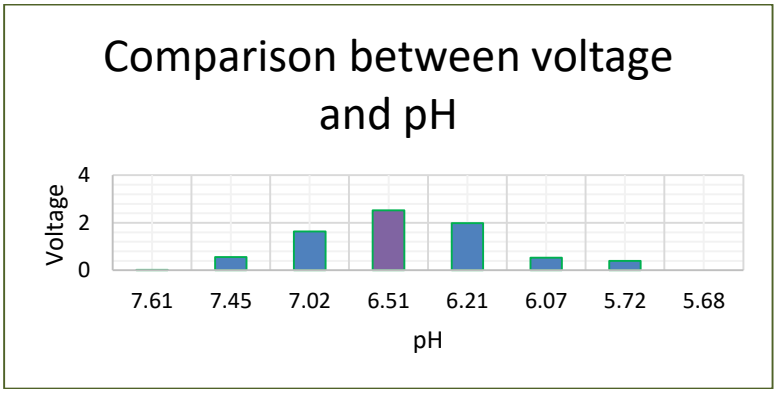


Fig. 6: Voltage generation in Volts with respect to pH

The reactor was operated for 8 days and utilizing Arduino model pH was observed momentarily. Initially pH of wastewater was 7.63 and no voltage generation was observed at first day. After 24 hours pH started decreasing and voltage generation rate started increasing, since of organic material in wastewater started degrading, results decreasing in pH value due to releasing Hydrogen ions (H+). And the maximum voltage was observed at pH between 7.02 to 6.3.

Voltage generation and temperature:

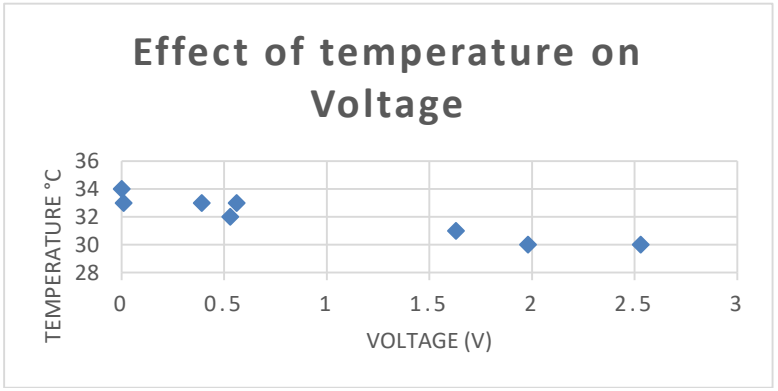


Fig. 7: Voltage generation in Volts with respect to pH

Utilizing Arduino platform temperature of anode chamber was monitored. Not much variations in temperature were observed throughout the cycle. Initially temperature was 34.5 °C and decreased up to 29°C during operation of reactor. The maximum voltage generation was observed at 30 °C, due to favorable temperature for bacterial growth.

IV. CONCLUSIONS

- In perspective of constrained investigations in Pakistan, inquire about on MFCs has not gotten much consideration yet in research organizations.
- Scientists can bear on this work and distinguish the particular culture to begin working with MFCs to treat the wastewater and acquaint the way of life with work on MFCs like different nations are doing.
- The precise next examination could be recognizable proof of the particular microscopic organisms in the household wastewater and furthermore investigated the likelihood of treating the local wastewater in common place Pakistani conditions, these dynamic microorganisms can accelerate the COD decrease process by decomposing organic material.
- There is an assortment of territories for Pakistani analysts to deal with MFCs.
- Diverse local materials can be utilized as anodes and MFC chambers to contribute in all out-cost decrease of the framework.
- In future, despite working with a solitary anode, MFC having more than one cathode could be set up; past examinations have indicated expanded power results with such frameworks.
- The automation and remote monitoring of this reactor can remove the need of manual labor and thus saves time and money and the DAQ system utilized can be used in large scale projects and water distribution systems in order to monitor Real time data.

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