International Journal of Latest Engineering Research and Applications (IJLERA) ISSN: 2455-7137

Volume – 02, Issue – 08, August – 2017, PP – 01-09

Design of BFS in up flow Mode Using Synthetic Waste Water for the Optimization of Microorganisms

M. Naveen Kumar

Assistant professor, Department of Civil Engineering, Surya Engineering College, Erode, Tamil nadu, India

Abstract: Energy is the main requirement of this era. We as a developing country depend on energy for a various purposes. Recently, many nations put forth their initiatives on reducing the usage of polluting fossil fuels. It is well known that as a developing country for us. so an alternative fossil fuels we are in need of non-polluting biological means of energy. Our another problem is waste materials produced on various productions in order to couple these two problems researches found technology that uses microbial community to degrade organic compounds in waste water and to create energy. In this current work we have decided to design a biochemical fuel system in upflow mode using synthetic waste water which resembles distillery waste water. The cost of membrane used in previous works are eliminated in the design and provisions have been given for various electrode distances. To increase the efficiency of MFC, the cells operate in two conditions of aerobic and anaerobic. Aerated MFC was further studied by varying sludge volume. The maximum power production efficiency was 55%. Utilizing chemical wastewater for the production of renewable energy (bioelectricity) from anaerobic treatment is considered as a feasible, economical and sustainable process.

Keywords: waste water, micro organisms, energy, electrodes, membrane, GLS, gas.

Introduction

1.1 General

The use of fossil fuels, especially oil and gas, in recent years has accelerated and this triggers a global energy crisis. Renewable bio energy is viewed as one of the ways to alleviate the current global warming crisis. Major efforts are devoted to developing alternative electricity production methods. New electricity production from renewable resources without a net carbon dioxide emission is much desired.

High energy requirement of conventional sewage treatment systems are demanding for the alternative treatment technology, which will be cost effective and require less energy for its efficient operation. In addition, due to global environmental concerns and energy insecurity, there is emergent interest to find out sustainable and clean energy source with minimal or zero use of hydrocarbons. Bacteria can be used in fuel cell to catalyze the conversion of organic matter, present in the wastewater, into electricity Microbial fuel cells (MFC), if used for wastewater treatment, can provide clean energy for people, apart from effective treatment of wastewater. The benefits of using MFC for wastewater treatment include: clean, safe, quiet performance, low emissions, high efficiency, and direct electricity recovery. Traditionally, MFC consists of two chambers, anode and cathode, separated by proton exchange membrane (PEM). Microorganisms oxidize the substrate and produce electrons and protons in the anode chamber. Electrons, collected on the anode, are transported to cathode by external circuit and protons are transferred through the membrane internally. Thus, potential difference is produced between anode chamber and cathode chamber due to dissimilar liquid solutions. Electrons and protons are consumed in the cathode chamber by reducing oxygen, usually from water.

Most of the bacterial species used in fuel cells are known to be inactive for transport of electrons. Hence, for intervention synthetic and natural compounds, called redox mediators, are used, such as, neutral red, methylene blue, thionine, and humic acid With addition of such mediators, commercial application of MFC for wastewater treatment becomes difficult, because most of these mediators are expensive and toxic in nature. Hence, today it is emphasized to develop mediator-less MFC, by enhancing its power production and reduction of its operational cost, to increase its acceptance as wastewater treatment process.

In the operation of mediator-less MFC several factors are considered as limiting steps for electricity generation, such as, fuel oxidation at the anode, presence of electrochemically active redox enzymes for efficient electrons transfer to the anode, external resistance of the circuit, proton transfer through the membrane to the cathode, and oxygen reduction at the cathode. Proton transfer to the cathode chamber can be a limiting factor when proton permeability of the membrane is poor. Under limited proton transfer conditions, microbial activity and electron transfer to the electrode in anode chamber can be reduced due to change in pH, apart from slow cathode reaction due to limited protons supply Application of MFC in large-scale wastewater treatment, containing suspended solids, might be limited due to high initial cost and fouling of the membrane, requiring

replacement. If use of membrane is eliminated, acceptability of MFC for wastewater treatment would increase. A membrane-less microbial fuel cell (ML–MFC) was used by which converted organic contaminants from artificial wastewater to electricity. Such membraneless MFC can improve the economic feasibility and acceptability. Hence, the objectives of the present study were:

(i) To evaluate effectiveness of membrane-less MFC, inoculated with anaerobic sludge, for chemical oxygen demand (COD), biochemical oxygen demand (BOD) and nitrogen removal from synthetic wastewater and actual sewage.

(ii) To study the effect of surface area and distance between the electrodes on electricity production using graphite electrodes.

Materials and Methods

3.1 ARTIFICIAL WASTE WATER:

The artificial waste water was prepared by the following steps

Table: 3.1 Composition of synthetic wastewater

Component	Sucrose	$NaHCO_3$	NH_4Cl	K_2HPO_4	KH_2PO_4	$CaCl_2.2H_2O$	$MgSO_4.7H_2O$
mg/ L	300-450	480	95.5	10.5	5.25	63.1	19.2

3.2 ANALYTICAL PROCEDURE:

3.2.1 Determination of p^H and temperature:

p^H can be viewed as an abbreviation for power of hydrogen or more completely, power of the concentration of hydrogen ion. It says that the p^H is equal to the negative log of the hydrogen ion concentration, or $p^H = -\log [H^+]$.

$p^H = -\log [H_3O^+]$.

p^H values are calculated in powers of 10. The hydrogen ion concentration of a solution with p^H 1.0 is 10 times larger than the hydrogen concentration in a solution with p^H 2.0. The larger the hydrogen ion concentration, the smaller the p^H.

3.2.2 Determination of BOD:

Biochemical oxygen demand or BOD is a chemical procedure for determining the amount of dissolved oxygen needed by aerobic biological organisms in a body of water to break down organic material present in a given water sample at certain temperature over a specific time period.

Uses of BOD incubator:

Heating:

Indirect heating system is provided in our units, comprising of air heaters made of high grade Kanthal A-1 wires of suitable voltage. The warm air is evenly distributed throughout the chamber through efficient motor fans ensuring a very good temperature sensitivity.

Cooling:

An energy efficient cooling unit is installed in our bod incubators to enable bio chemical demand studies at lower room temperatures. We use ISI marked high end CFC free compressors of Kirloskar/Tecumseh make, conforming to latest international standards and guidelines.

Principle:

BOD is measure of biodegradable organic material present in wastewater and can be defined as the amount of oxygen required by the microorganisms in stabilizing the biologically degradable organic matter under aerobic conditions. The principle of the method involves, measuring the difference of the dissolved oxygen concentration of the sample and after incubation it for 5 days at 200 ºC.

3.2.3 Determination of COD:

The COD is considered mainly the representation of pollution level of domestic and industrial wastewater or contamination level of surface, ground and potable water.This is determined in terms of total oxygen required to oxidize the organic matter to CO_2 and water. The COD values include the oxygen demand created by biodegradable as well as non-biodegradable substances because it involves oxidation of organic matter with strong oxidizing chemicals. As a result, COD values are greater than BOD and may be much greater when significant amounts of biologically resistant organic matter is present.

3.2.4 Determination of TS, TDS, TSS, TVS:

Principle:

A well-mixed filtered through a standard glass fiber filter, and the filtrate is evaporated to dryness in weighed dish and dried to constant weight at 179-181℃.The increase in dish weight represents the total dissolved solids.

A well-mixed sample is filtered through a weighed standard glass fiber filter and the residue retained on the filter is dried to a constant weight at 103-105℃.The increase in weight of the filter represents the total suspended solids. If the suspended solids clogs the filter and prolongs the filtration, the difference between the total solids and total dissolved solids may provide an estimate of the total suspended solids.

3.2.5 Determination of alkalinity:

The alkalinity of the water is a measure of its capacity to neutralize acids. The alkalinity of natural waters is due primarily to the salts of week acids.

Alkalinity (mol/L) = [HCO3-] + 2 [$CO3^{2-}$] + [OH-] – [H+]

3.2.6 Determination of acidity:

Acids contribute to corrosiveness and influence chemical reaction rates, chemical speciation and biological processes. Acidity of water is its quantitative capacity to react with a strong base to a designated pH. The measured value may vary significantly with the end point pH used in the determination.

3.2.7 Determination of total hardness:

To determine the concentrations of Ca^{2+}(aq) and Mg^{2+}(aq) ions in a commercial sample water.

3.2.8 Determination of electrical conductivity:

Conductivity of a substance is defined as 'the ability or power to conduct or transmit heat, electricity or sound. When an electrical potential difference is placed across a conductor, its movable charges flow, giving rise to an electric current. This property is called conductivity. Since the charge on ions in solution facilitates the conductance of electrical current, the conductivity of a solution is proportional to its ion concentration.

3.3REACTOR DESIGN:

3.3.1 Reactor volume and dimensions:

To determine the required reactor volume and dimensions, the organic loading, superficial velocity, and effective treatment volume must all be considered. The effective treatment volume is that volume occupied by the sludge blanket and active biomass. An additional volume exists between the effective volume and the gas collection unit where some additional solids separation occurs and the biomass is dilute. The nominal liquid volume of the reactor based on using an acceptable organic loading is given by

$V_n = QS_0 / L_{org}$

Where V_n= nominal (effective) liquid volume of reactor, m^3

Q = influent flowrate, m^3/h

S_0= Influent COD,kg COD/m^3

L_{org}= organic loading rate, kg COD/m^3.d

To determine the total liquid volume below the gas collectors, an effectiveness factor is used, which is the fraction occupied by the sludge blanket. Taking into account the effectiveness factor, which may vary from 0.8 to 0.9, the required total liquid volume of the reactor exclusive of the gas storage area is given by

$V_L = V_n / E$

Where V_L= Total liquid volume of reactor,m3

V_n= nominal liquid volume of reactor,m3

E= effectiveness factor, unitless

Rearranging eq., the area of the reactor is

A=Q/v

The liquid height of the reactor is determined using the following relationship:

$H_L = V_L / A$

Where H_L = Reactor height based on liquid volume, m

V_L= total liquid reactor volume, m^3

A= cross-sectional area, m^2

The gas collection volume is in addition to the reactor volume and adds an additional height of 2.5 to 3m. Thus, the total height of the reactor is

$H_T=H_L+ H_G$

Where H_T=Total reactor height,m

H_L= reactor height based on liquid volume,m

H_G=reactor height to accommodate gas collection and storage,m

3.3.2 Physical features:

The main physical features requiring careful consideration are the feed inlet, gas separation, gas collection, and effluent withdrawal. The inlet and gas separation designs are unique to the UASB reactor. The feed inlet must be designed to provide uniform distribution and to avoid channeling or the formation of dead zones. The avoidance of channeling is more critical for weaker waste waters, as there would be less gas production to help mix the sludge blanket. A number of inlet feed pipes are used to direct flow to different areas of the bottom of the UASB reactor from a common feed source. Access must be provided to clean the pipes in the event of clogging. Guidelines for determining the area served by the individual inlet feed pipes as a function of the sludge characteristics and organic loading.

3.3.3 Gas collection and solid separation:

The gas solids separator is designed to collect the biogas, prevent washout of solids, encourage separation of gas and solid particles, allow for solids slide back into the sludge blanket zone, and help improve effluent solids removal. A series of upside-down V shaped baffles is used next to effluent weirs to accomplish the above objectives.

3.4 Reactor Calculations:

To determine the required reactor volume and dimensions, the organic loading, superficial velocity, and effective treatment volume must all be considered.The nominal liquid volume of the reactor based on using an acceptable organic loading is given by

Step 1:

To find the influent flowrate

$V_n= QS_0/ L_{org}$

$15 = \frac{Q\ (2K\ g\ SCOD\ \ COD\ /m3)}{(10K\ g\ SCOD\ \ COD\ /m3.d)}$ (Assume $V_{n=}$ 15lit.)

Q = 75 l/d.

Step 2:

To find the total liquid volume of the reactor

$V_L = V_n/ E$

$V_L = \frac{15l}{0.85}$(effectiveness factor$_=$ 0.85)

V_L = 17.6lit.

Step 3:

To find velocity of wastewater

V = Q/t

$17.6 = \frac{75}{t}$

t = 4.2 m/h.

Step 4:

To find the area of the reactor

A = Q/v

$A = \frac{(75l/d)}{(4.2m/h)}$

$A = 0.0178m^2$

Step 5:

To find the diameter of reactor

$A = \frac{\pi}{4}D^2$

$0.0178 = 0.785D^2$

D = 0.150m

Step 6:

To find the reactor height based on liquid volume

$H_L = V_L/A$

$H_L = \frac{17.6\times10^{-3}\ m^3}{0.0178\ m^2}$

$H_L = 0.988m$
$H_L \simeq 1m$

3.5 Reactor Analysis:

In the operation of mediator-less MFC several factors are considered as limiting steps for electricity generation, such as, fuel oxidation at the anode, presence of electrochemically.Active redox enzymes for efficient electrons transfer to the anode, external resistance of the circuit, proton transfer through the membrane to the cathode, and oxygen reduction at the cathode.A membrane-less microbial fuel cell (ML–MFC) which converted organic contaminants.From artificial wastewater to electricity. Such membraneless microbial fuel cell can improve the economic feasibility and acceptability.

Figure: 3.1 Membrane less Microbial fuel cell

3.6 Microroganisms Used In Microbial Fuel Cell

3.6.1 Geobactermetallireducens:

Geobactermetallireducens are rod shapedgram negative anaerobic bacteria and can be seen to have flagella and pili. The Geobactermetallireducens was isolated from freshwater sediment, and was able to gain energy through dissimilatory reduction of iron, manganese, uranium and other metals. This organism was the first organism found to oxidize organic compounds to carbon dioxide with iron oxides as the electron acceptor. Geobactermetallireducens can also oxidize short chain fatty acids, alcohols, and monoaromatic compounds such as toluene and phenol using iron as its electron acceptor. Geobactermetallireducens also plays a role in carbon and nutrient cycling and bioremediation, enabling the metabolism of soluble harmful contaminants into insoluble harmless forms.

3.6.2 Geobactersulfurreducens:

Geobactersulfurreducens are comma shaped gram negative anaerobic bacteria that are found below the surface and are one of the predominant metal reducing bacteria. Geobactersulfurreducens can oxidize organic compounds and couple that to the reduction of metals. And also oxidizes acetate to carbon dioxide and water while reducing compounds such as sulfur, fumerate, and some metals including iron oxides.
The above two microgranisms were used in analysing the synthetic waste water to producing electrical energy.

Results and Discussion

4.1 Characteristics of Synthetic Waste Water:

Table: 4.1 Characteristics of synthetic wastewater

S.NO	PARAMETERS	VALUE
1.	P^H	4.2*
2.	Total Solids(mg/l)	1350

3.	Total Suspended Solids(mg/l)	190
4.	Total Dissolved Solids(mg/l)	1350
5.	Total Volatile Solids(mg/l)	600
6.	COD(mg/l)	6000
7.	BOD(mg/l)	3300
8.	Acidity $CaCO_3$ (mg/l)	1100
9.	Temperature (℃)	34
10.	Total hardness (mg/l)	1428
11.	Electrical conductivity (µmho/cm)	3450
12.	Alkalinity (mg/l)	600

4.2 Electricity Production Based On Geobacter Sulfurreducens

Electricity produced in the microbial fuel cell was analysed by multimeter using the geobacter sulfurreducen. During this batch sugarcane waste water is used.

Table 4.2:Values of electricity production in geobacter sulfurreducens

S. No.	Contact time (Hours)	Current in µA	P max (mW/m^2)
1	0	0	0
2	10	0	0
3	20	0	0
4	30	0	0
5	35	0	0
6	40	0	0
60	255	23.24	13367.446
61	256	23.25	13594.112
62	268	23.30	14760.547
63	269	23.40	14880.240
64	270	23.60	14880.240
65	271	23.80	14880.240

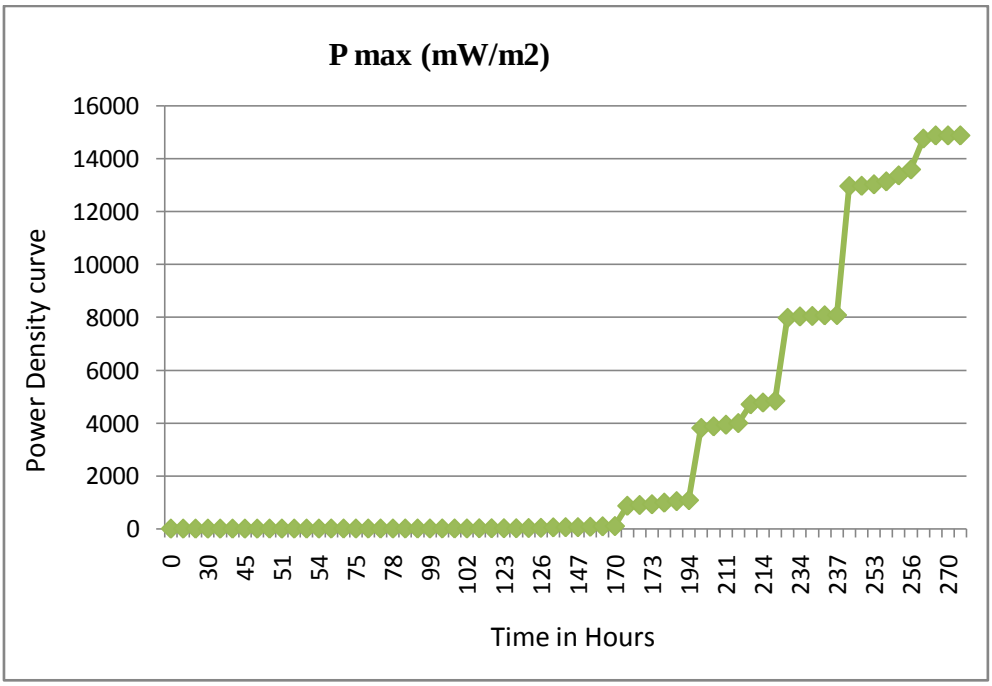

Figure: 4.1Effect of contact time in geobactersulfurreducens

4.3 Electricity Production Based On Geobacter Metallireducens

Electricity produced in the microbial fuel cell was analysed by multimeter using the geobacter sulfurreducen. During this batch sugarcane waste water is used.

Table 4.3: Values of electricity production in geobacter metallireducens

S. No.	Contact time (Hours)	Current in µA	P max (mW/m^2)
1	1	12	3456.0
2	2	18.50	8214.365
3	3	23.40	13141.325
4	4	26.40	16727.695
5	5	26.40	16727.000
6	6	26.40	16727.000
78	293	28.40	19357.400
79	294	28.40	19357.400
80	313	27.00	17496.000
81	314	26.00	16224.000
82	315	25.80	15975.004
83	316	25.00	15000.000
84	317	24.40	14288.660
85	318	24.00	13824.000

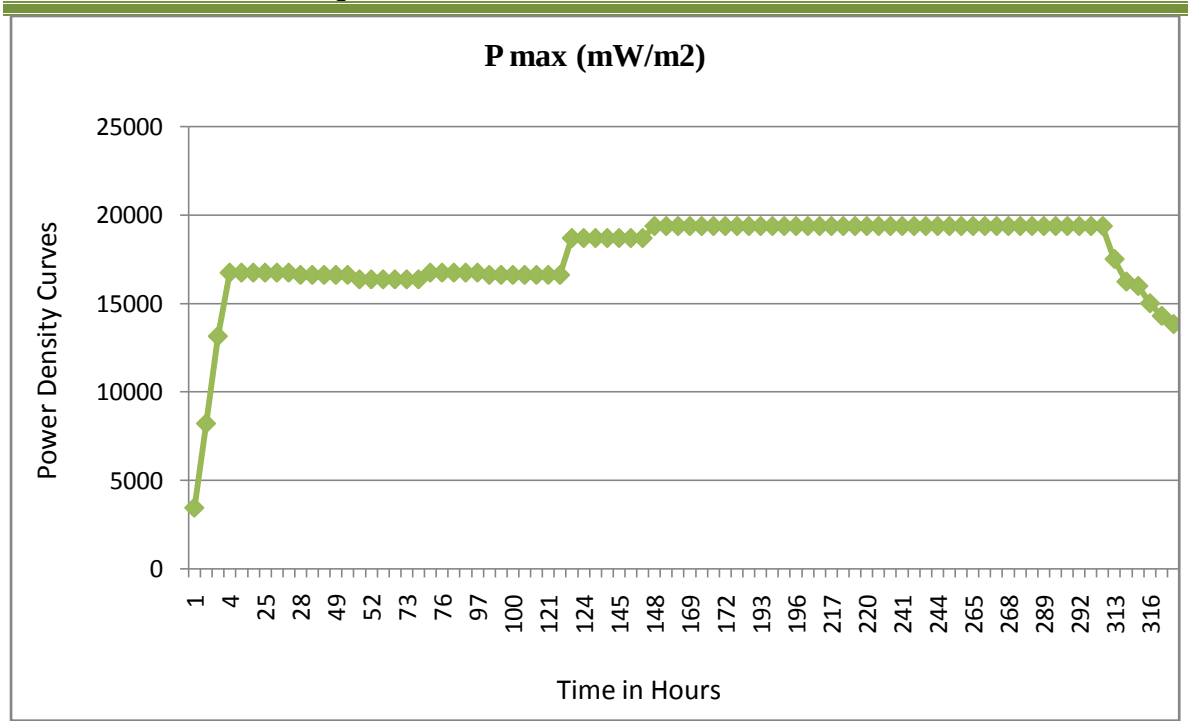

Figure: 4.2 Effect of contact time in geobactermetallireducens

In the batch experiment produced the powervery low as such cannot be shown in the graph. Log graph showing total current produced in all batches.

4.4 Performance of the Ml-Mfc for Cod Removal

The ML–MFC was operated at influent COD concentration in the range of 50000–60000mg/l. After completion aerated and unaerated treatment of operation, when steady state condition for COD removal reached, the COD and BOD reductions were 81% and 85%, respectively. The observed COD removal efficiency was on the higher side of the maximum reported efficiency in the range of 80–90%. Further studiesare required to explore maximum volumetric loadingrate capacity for this ML–MFC.The COD removal percentage in anode chamber was47% and remaining COD was getting removed in thecathode chamber.

Lower COD removal efficiency observed in this case could be attributed to the mixed culture used as inoculums. Further investigation would be necessary to enhance the COD removal in anode compartment and, hence, to increase current production. However, the overall efficiencies observed for COD and BOD removal demonstrated the ability of ML–MFC as an effective wastewater treatment process.

Table 4.4 Removal efficiency of COD and electricity

S. No.	Wastewater Treatment	COD reduction	Columbic efficiency
1	Geobactersulfurreducens	82%	50%
2	Geobactermetallireducens	76%	45%

Discussion and Conclusion

The membrane-less microbial fuel cell, inoculated with mixed anaerobic sludge demonstrated its effectiveness as a wastewater treatment process along with electricity production, without incorporating any costly component, such as mediator and membrane. The COD, BOD removal were achieved at varying levels. Granulation of biomass was observed in the anode compartment of the ML–MFC. Maximum power density was observed spacing between the electrodes and optimizing microorganisms. Further studies would be necessary to optimize the electricity production from this ML–MFC. With further improvements and optimization, it could be possible to increase power generation. Also MFC as a continuous reactor can also be used. Going further toward the condition to be maintained in the reactor, aerated condition produces more electricity and it is instantaneous. In case of unaerated chamber, the current production is delayed by some time, due to inability of the reactor to complete the reaction in both chambers. 6-8 weeks of sludge is recommended for reaction. Thus,

the combination of wastewater treatment along with electricity production might help in compensating the cost of wastewater treatment.

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