AN EXPERIMENTAL STUDY ON TREATMENT OF DAIRY WASTE WATER USING MICROBIAL FUEL CELL

B.Perumal [1], D.Dhavashankaran [2] , K.Gnana shankar [3]

[1,2,3] *Assistant professor Department of Civil Engineering, Muthayammal Engineering College, Rasipuram, Tamilnadu, India.*

ABSTRACT - *The energy need will be increased day by day in next 20 years and especially cleanly- generated electricity. The adverse effect caused by fossil fuels resulted in severe environmental impacts. In this scenario, renewable energy technologies are emerging as a major alternative to provide long term sustainable and environmental friendly energy source. At the same time pollution also become very serious problem. We are disposing many wastes without any treatment. So, if we convert waste into the energy then it will solve the two problems and also we need to develop the ecofriendly methods for the disposal of this high strength wastewater. A microbial fuel cell (MFC) is an emerging technology. It is a bioreactor that converts chemical energy in the chemical bonds in organic compounds to electrical energy through catalytic reactions of microorganisms under anaerobic conditions. Due to catalytic reaction COD of effluent is reduced. In this project, the electrode optimization is mainly considered to attain the maximum efficiency regarding the electrode and to find the maximum efficient electrode. Graphite plate is used as an electrode in this BFS. Using the waste water for the production of electricity is an economical and sustainable one.*

Keywords*: COD, Electrode, Efficiency, Graphite plate, Reactor.*

1. INTRODUCTION

Milk has important place in human life. The dairy industry involves processing of raw milk into products like consumer milk, butter, cheese etc. The daily volume of water required may vary widely, depending mainly on the availability of water and the control of all water using operation in the plant. Most of the waste water discharged into water bodies, disturbs the ecological balance and deteriorates the water quality. The casein precipitation from waste decomposes further into highly odorous black sludge. Effluent from milk processing unit contains soluble organics, suspended solids, trace organics which releases gases, causes taste and odour, impart colour and turbidity, and promote eutrophication. Which affect and disturb the environment in this regard's aimed to study the physicochemical characteristics of waste water generated from dairy industry with suitable treatment. The process involved in dairy industries as follows

- ✓ Collection of Milk
- ✓ Cooling
- ✓ Pasteurisation
- ✓ Refrigeration

During the Pasteurisation the effluent is produced in the form of milky cloudy white which in turn after treatment becomes as greenish colour

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1.1. OBJECTIVES OF THE STUDY:

- ✓ To design reactor with respect to characteristics of the dairy waste water at economic cost.
- ✓ To reduce the BOD and COD from the dairy waste water at maximum level.
- ✓ To generate electricity at maximum level and to overcome operational parameters affecting the microbial fuel cell.
- ✓ To overcome full scale implementation

1.2 NEED OF MICROBIAL FUEL CELL

Traditional Method requires more electrical energy to digest the dissolved matter. The proven technology is anaerobic digestion but the treatment process faces several problems:

- ✓ Energy cost
- ✓ Footprint for new technology
- ✓ Investment costs
- ✓ Sludge treatment costs
- ✓ Reliability

2. MICROBIAL FUEL CELL:

Microbial fuel cell (MFC) technology is a prospective technology that purifies waste water and converts its chemical energy into electrical energy using bacteria as catalysts. Even with the remarkable improvements in power density, the large-scale application of MFC's has yet to be implemented due to low yields of power generation and high costs. A microbial fuel cell (MFC) or biological fuel cell is a bio-electrochemical system that drives a current by using bacteria and mimicking bacterial interactions found in nature. MFC's can be grouped into two general categories, those that use a mediator and those that are mediator-less.

Microbial fuel cells (MFC's) are devices that use bacteria as the catalysts to oxidize organic and inorganic matter and generate current. Electrons produced by the bacteria from these substrates are transferred to the anode (negative terminal) and flow to the cathode (positive terminal) linked by a conductive material containing a resistor, or operated under a load. By convention, positive current flows from the positive to the negative terminal, a direction opposite to that of electron flow. The device must be capable of having the substrate oxidized at the anode replenished, either continuously or intermittently; otherwise, the system is considered to be a bio battery. Electrons can be transferred to the anode by electron mediators or shuttles, by direct membrane associated electron transfer, or by so-called nano wires produced by the bacteria, or perhaps by other as yet undiscovered means. In most MFC's the electrons that reach the cathode combine with protons that diffuse from the anode through a separator and oxygen provided from air; resulting product is water. However, there is no net carbon emission because carbon dioxide in the renewable. Biomass originally comes from the atmosphere in the photosynthesis process.

2.1 Components of microbial cell:

The main components of microbial cell are

- ✓ Anode
- ✓ Cathode
- ✓ Anode compartment
- ✓ Cathode compartment
- ✓ Proton exchange membrane
- ✓ Electrode catalyst
- ✓ Do monitoring system
- ✓ Resistance box

- ✓ Mediator
- ✓ Multimeter

3. MATERIALS AND METHODS

Dairy waste water:

The loading of waste water characteristics is analyzed and tabulated

Parameter	Amount present
pH	6.5 to 7.5
Temperature	30C -35C
BOD	2000 mg/l
COD	3800 mg/l
Total solids (TS)	2500 mg/l
Total dissolved solids (TDS)	2100 mg/l
Total Suspended solids (TSS)	400 mg/l
Alkalinity	600 mg/l

REACTOR DESIGN:

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

$$Vn = QS0 / Lorg$$

Where Vn= nominal (effective) liquid volume of reactor, m^3
Q = influent flow rate, m^3/h
S0 = Influent COD, kg COD/m^3
Lorg = 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

$$VL = Vn / E$$

Where VL = Total liquid volume of reactor, m3
Vn = nominal liquid volume of reactor, m^3
E = effectiveness factor, (no unit)

Rearranging eq., the area of the reactor is

$$A = Q/v$$

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

$$HL = VL/A$$

Where HL = Reactor height based on liquid volume, m

VL= 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 3 m. Thus, the total height of the reactor is

$$HT = HL + HG$$

Where HT = Total reactor height, m
HL = reactor height based on liquid volume, m
HG =reactor height to accommodate gas collection and storage, m

Reactor design calculation:

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 flow rate

$$V_n = QS_0 / L_{org}$$
$$4.25 = Q \times 2 / 10$$
(Assuming V_n = 4.25lit)
$$\mathbf{Q = 21.25\ l/d.}$$

Step 2: To find the total liquid volume of the reactor

$$V_L = V_n / E$$
$$V_L = 4.25 / 0.85$$
(Effectiveness factor= 0.85)
$$\mathbf{V_L = 5\ lit.}$$

Step 3: To find velocity of wastewater

$$V_L = Q / V$$
$$5 = 21.25 / V$$
$$\mathbf{V = 4.25\ m/h.}$$

Step 4: To find the area of the reactor

$$A = Q/v$$
$$A = 21.25 / 4.25$$
$$\mathbf{A = 0.005\ m^2}$$

Step 5: To find the diameter of reactor

$$A = \pi D^2 / 4$$
$$0.005 = 0.785 D^2$$
$$\mathbf{D = 0.101\ m = 10\ cm}$$

STEP 6: To find the reactor height based on liquid volume

$$H_L = V_L / A$$
$$H_L = 5 \times 10^{-3} / 0.005$$
$$\mathbf{H_L \approx 1m}$$

Physical features:

The 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.

Anode Chamber:

The BFC used in the study was made up of acrylic cylinder having effective height of 100 cm and internal diameter of 15 cm. Anode compartment (depth 40 cm) was placed at bottom. The gas escape valve 10mm Ø also given at the top of the anode chamber. It has three valves, one at the side for the tank for feeding. The one is used to electrode connection. Other one is stand by to check the energy production of electrode at different distance.

Cathode chamber:

Cathode chamber was also made of the same dimension. It has also two valves, the two valves for the electrodes connection. Anode compartment (depth 40 cm) was placed at top. The reactor has a cap of four openings for pH, gas collection, air inlet and temperature respectively. Other one is stand by to check the energy production of electrode at different distance. The effluent outlet is at the cathode chamber. Aeration is provided from the top of the reactor to the cathode chamber.

Glass wool:

Glass wool 4cm depth were placed at the upper portion of the anode compartment, supported by perforated acrylic sheet.

Glass bead:

Glass beads also 4cm depth were placed at the upper portion of the anode and glass bead placed on glass wool.

Electrodes in BFC:

Graphite rod and carbon cloth are used as an electrode in the BFC. The distances between the respective anode and cathode electrodes were 50 cm or 60 cm. Two stands by openings are provided to check the energy production at different distances. Total apparent surface areas of identical anode electrodes were 410.64 cm^2. The effluent was supplied from the bottom of the anode chamber and the effluent was discharged through the cathode chamber at top. The electrodes were connected with copper wire. The copper wires are connected to the Multimeter. The stand by openings is corked tightly to avoid the leakage.

Microorganism in BFC:

Geobacter metallireducens is a rod shaped Gram-negative, anaerobic bacteria and can be seen to have flagella and pili. It is 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.

CONSTRUCTION OF REACTOR:

For the construction of reactor, each part was assembled alone and then joined together. The following construction parts are

- ✓ Anode chamber construction
- ✓ Cathode chamber construction
- ✓ Assembling

Anode chamber construction:

Anode chamber has two parts, a feeding valve and electrode slot. The graphite plate was placed inside the chamber and it has been attached with copper wire to multimeter.

Cathode chamber construction:

Cathode chamber has more complex construction process as compared cathode. A drain for collection of water was connected at the top. The aeration has also connected through an aeration pipe.

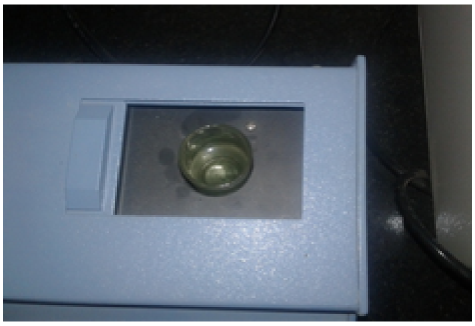
ASSEMBLING:

The chambers are designed and assembled with maximum protection against leakage and effective processing of the reactor. The glass wool and bead placed over on the anode chamber. The reactor was also checked for leakage. Aerator has been connected to the aeration pipe and it was coupled with back up supply from compressor. The BFS is inoculated with the Geobacter metallireducens. This unit was also checked for leakage and aeration capacity. At the top the thermometer is inserted to check temperature periodically.

RESULTS AND DISCUSSION

GRAPHITE PLATE AS ELECTRODE AT 65 CM:

Graphite sheet electrodes are connected with copper wire and it is connected to the Multimeter at the distance of 65 cm.



S.No	Time (min)	Current in µA	P max (mW/m2)
1	0	0	0
2	30	0	0
3	60	0	0
4	90	0	0
5	120	0.1	0.24
6	150	0.18	0.78
7	180	0.34	2.94
8	210	0.42	4.23
9	240	0.46	5.07
10	270	0.74	13.14
11	300	0.85	21.53
12	330	0.9	28.637
13	360	1.40	47.04
14	390	1.5	54.00
15	420	1.5	54.00
16	450	2.1	96.00

GRAPHITE PLATE AS ELECTRODE AT 60 CM:

Graphite sheet electrodes are connected with copper wire and it is connected to the Multimeter at the distance of 60cm.

After complete process the COD removed varying levels. However, the overall efficiencies observed for COD removal demonstrated the ability of BFS as an effective wastewater treatment process.

S.No	Time (min)	Current µA	P max (mW/m2)
1	0	0	0
2	30	0	0
3	60	0	0
4	90	1.7	69.36
5	120	1.9	86.64
6	150	6.1	864.214
7	180	6.4	983.56
8	210	6.7	1040.126
9	240	12.6	3810.00
10	270	12.7	3993.65
11	300	12.8	4704.32
12	330	14.2	8028.58
13	360	18.23	8072.54
14	390	18.31	12962.87
15	420	18.65	13141.28
16	450	23.3	14760.55

After the treatment in carbon cloth and graphite plate is 1082 mg/l and 1879 mg/l respectively.

S. No.	Wastewater Treatment	COD reduction
1	At Carbon cloth as Electrode	**71.52%**
2	At Graphite as Electrode	**50.55%**

Table COD reduction

CONCLUSION

From physiochemical study of Dairy waste it was concluded that Waste water discharged from milk processing unit is white, acidic with higher Turbidity, Salinity, Electrical conductivity and total dissolved solids. Alkalinity recorded is Bicarbonate alkalinity. Higher values of carbon di-oxide and lower value of Chloride was noted for the waste water. Dissolved oxygen in waste water was recorded low value due to higher organic matter and BOD and COD. BOD and COD value were quite higher in the waste water indicates its polluted nature. MPN value was higher again indicates the polluted nature of waste water. All the studied physio-chemical and Biological parameter proved that the water discharged from milk processing unit is of polluted nature. Its disposal without any treatment in to fresh water body may impose the danger of eutrophication as well as serious problems of health and hygiene. After experiment it was finding that BOD, COD is reduced and pH was increase to 7.7.

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