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Application of Microbial Fuel Cell (MFC) in treatment of and electricity generation from Distillery SpentWash (DSW) : Review

Devyani P. Patil[1],Dr. A.B. Saner[2]

M.Tech Scholar, Department of Technology, Savitribai Phule Pune University, Pune, India[1]
Professor at civil engineering department, Sandip Institute of Engineering & Management, Nashik, India[2]

***Abstract*— In present research article, various research works on the treatment and energy generation from Spentwash using Microbial Fuel Cell (MFC) have been reviewed. The wastewater coming out of one of most pollution creating industry in India, distillery is known as spentwash. This study reflects on performance of various MFC designs, operational conditions, and wastewater treatment parameters such as Chemical Oxygen Demand (COD) removal rate and power density.**

It has been known for many years that it is possible to generate electricity directly by using bacteria to break down organic substrates. The recent energy crisis has reinvigorated interests in MFCs among academic researchers as a way to generate electric power or hydrogen from biomass without a net carbon emission into the ecosystem. MFCs can also be used in wastewater treatment facilities to break down organic matters. The application of MFC in spentwash treatment and variation of results with respect to pH, concentration of substrate i.e. Distillery SpentWash (DSW), temperature, type of MFC, type of mediators, electrolytes, materials used for electrodes also have been discussed in present review paper.

Keywords : Distillery Spentwash (DSW), Microbial Fuel Cell (MFC)

I INTRODUCTION

Today, industrial wastewater management is one of the crucial problems; the world is facing. Different industries produce variety of wastewater pollutants; which are difficult and costly to treat. Wastewater characteristics and levels of pollutants differ from industry to industry. Their handling, treatment and disposal are the major challenges to industries. As per the Central Pollution Control Board, Ministry of Environment and Forests (MoEF), Government of India, alcohol distilleries are listed at the top of ‘‘Red Category’’ industries having a high polluting potential. Distillery spent wash is unwanted residual liquid waste generated during alcohol production and pollution caused by it is one of the most critical environmental issue [1]. It is one of the most complex, troublesome and strongest industrial organic effluents. The polluting strength is very high due to the high content of biodegradable organic materials, such as sugar, lignins, hemicelluloses, dextrins, resins and organic acids. It is approximately 12–15 times by volume of product alcohol. About 40 billion litters of waste water annually discharged from distilleries, known as raw spent wash, which is characterized by high biochemical oxygen demand, chemical oxygen demand, undesirable color and foul smell [2].

Various physico-chemical and biological treatment options are available for the treatment of distillery wastewaters [9]. But an anaerobic treatment makes conversion of the organic wastewater ito sludge and biogas as source of energy. It proves better than aerobic treatment as aerobic treatment requires external energy input.

Microbial fuel cells (MFC) are electrochemical devices that convert the chemical energy contained in organic matter into electricity by means of the catalytic (metabolic) activity of living microorganisms. MFC’s can be used for the treatment of distillery wastewater and can produce electricity. MFC technologies appear to be technically feasible for energy recovery from waste biomass materials.

II WORKING PRINCIPLE OF MFC

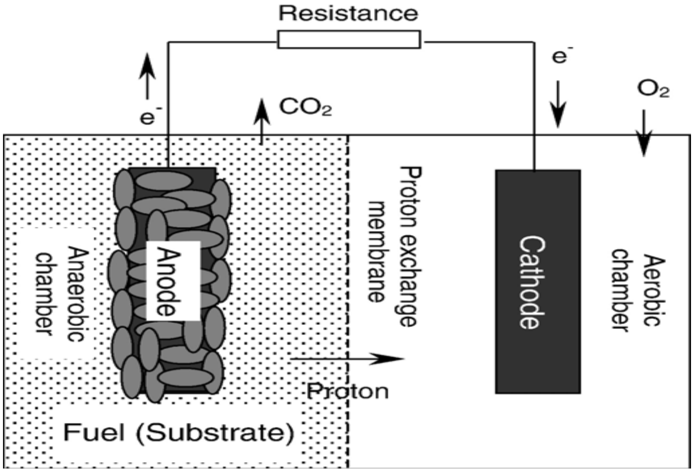

Figure 1. Schematic diagram of two chambered Microbial Fuel Cell [2]

A typical microbial fuel cell consists of anode and cathode compartments separated by a cation specific membrane. A schematic representation of a microbial fuel cell is illustrated in Fig 1. In the anode compartment, organic matter is oxidized by microorganisms, generating electrons and protons. When microorganisms consume a substrate such as spentwash in anaerobic conditions they produce carbon dioxide, protons and electrons. Electrons are transferred to an electric circuit and proton get transferred to cathodic compartment through proton exchange membrane or salt agar bridge.

III VARIATION IN RESULTS OF RESEARCH EXPERIMENTS PERFORMED ON SPENTWASH USING MFC WITH RESPECT TO VARIOUS PARAMETERS

1. In an experimental study, the stacking of MFCs connected in series was employed to enhance the voltage generated by MFC. The voltage generated and total power production by 4 MFCs connected in series was 0.817 ± 0.07 V and 349.7 ± 59.38 mW respectively. The working voltage generated by single MFC was 0.126 ± 0.005 V while total power generated by the system was found to be 7.94 ± 0.14 mW. The working voltage was increased to 0.167 ± 0.01 V, 0.419 ± 0.05 V and 0.817 ± 0.07 V when 2 MFCs, 3 MFCs and 4 MFCs were connected in series. Similarly, total power increased from 7.94 ± 0.14 mW to 349.7 ± 59.38 mW when 4 MFCs were connected in series. Hence, MFCs connected in series was successfully used to increase the voltage output and hence the power output when fed with an aerobically digested distillery wastewater. Because of the limitation of data logger, more than 4 MFCs in series could not be connected [3].

2. Proton exchange system can affect an MFC system's internal resistance and concentration polarization loss and they in turn influence the power output of the MFC. Nafion (DuPont, Wilmington, Delaware) is most popular because of its highly selective permeability of protons. Despite attempts by researchers to look for less expensive and more durable substitutes, Nafion is still the best choice. However, side effect of other cations transport is unavoidable during the MFC operation even with Nafion.

In a batch accumulative system, for example, transportation of cation species other than protons by Nafion dominates the charge balance between the anodic and cathodic chambers because concentrations of Na+, K+, NH4 +, Ca2+, Mg2+ are much higher than the proton concentrations in the anolyte and catholyte. In this sense, Nafion as well as other PEMs used in the MFCs are not a necessarily proton specific membranes but actually cation specific membranes. Min et al. (2005a) compared the performance of a PEM and a salt bridge in an MFC inoculated with G. metallireducens. The power output using the salt bridge MFC was 2.2 mW/m^2 that was an order of magnitude lower than that achieved using Nafion. Membranes and Kaolin septum are prone to fouling if the fuel is something like municipal wastewater. Membrane-less MFCs are desired if fouling or cost of the membrane becomes a problem in such applications [2].

3. The effect of anolyte and catholyte pH on power generation in an MFC using post methanation distillery effluent (PMDE) was studied in batch mode. Higher anodic pH (7–9) and low cathodic pH (2) were more favorable and at the optimal cathode: anode pH ratio of 2:8, power density attained was 0.457 W/m3. An initial feed solution pH up to 10 was tolerated by the MFC. However, internal resistance increased 1.5 times and power density decreased by 60% at pH 10 as compared to that at pH 7, the normal anolyte pH. Internal resistance of the MFC was minimum (266 ohms) at cathodic pH 2, thus favoring better power generation. Under low cathodic and high anodic pH ratio of the MFC, a low internal resistance favored both high current density and power density [8].

A single chamber microbial fuel cell (SCMFC) was operated with distillery spent wash (DSW) wastewater and microorganisms in cow-dung as inoculum source from pH 4 to 9. MFC signifies maximum current in the sequence of pH 6 (0.46 mA) > pH 7 (0.4 mA) > pH 8-9 (0.16-0.19 mA); whereas the chemical oxygen demand (COD) removed in order of pH 8-9 (80-81%) > pH 7 (79%) > pH 6 (68%). The losses in coulombic yield were due to alternating electron acceptors and air diffusion through the reactor [22].

4. In this study single chamber MFC and double chambered MFC were compared for the distillery wastewater treatment and generation of electricity. Microorganisms present in distillery wastewater and sewage were used as inoculum, and distillery wastewater acted as substrate. Single chamber MFC was efficient and found to be producing maximum current of 0.84 mA, power density of 28.15 mW/m ^{2} where as double chambered MFC produced a maximum current of 0.36 mA and power density of 17.76 mW/m ^{2}. Double chambered MFC was efficient in the removal of COD (64% removal) when compared with single chamber MFC which attained 61% COD removal efficiency. The removal of dissolved solids in both single and double chambered MFC was found to be 48%. Five varied feed concentrations were loaded to both the single and double chambered MFC and the systems were stable [1].

IV CONCLUSION

Since very less work is done with spentwash treatment there’s lot future scope for working in generation of electricity from highly organic spentwash using Microbial Fuel Cells.

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Table 1 Summary of some experiments performed on SpentWash using MFC

SR. No.	WASTE-WATER	TYPE OF MFC & MEDIATOR	ANODIC CHAMBER	CATHODIC CHAMBER	INOCULUM	COD REMOVAL	POWER DENSITY	REF.
1	DSW	SC MFC DC MFC	Graphite rods from pencils & DSW	Graphite rods from pencils & Potassium permanganate	Microorganisms present in distillery wastewater	61 % 64 %	28.15 mW/m^2 17.76 mW/m^2	1
2	DSW	Double Chambered MFC with salt agar bridge ; 4 MFCs connected in series	Graphite Rod & Standardized solution of DSW	Graphite Rod & 200 mL of 100 mM potassium ferricyanide prepared in 100 mM phosphate buffer of pH 7	Endogenous microflora from anaerobically digested distillery wastewater	-	349.7 ± 59.38 mW	3
3	DSW + Cow dung manure	Double Chambered MFC with agar salt bridge	carbon cloth electrode & DSW + Cow dung manure	carbon cloth electrode	Saccharomyces cerevisiae M-9	-	Max voltage 230 mv/l.	4
4	Sugar industry wastewater	with a proton exchange membrane (Nafion TM 117, DuPont Co. USA).	plain carbon paper as anode & sugar industry wastewater	Graphite rod & 100mM phosphate buffer	artificial wastewater containing glucose as carbon source	-	Max current - 11.37 mA	5
5	DSW	Double Chambered MFC with agar salt bridge	Graphite rod & DSW	Graphite rod & Potassium permanganate (0.2 g/ L)	Micro-organisms present in domestic sewage	64 %	18.35 mW/m^2	6
6	DSW	Double Chambered MFC with salt agar bridge	Copper Electrode & DSW	Copper Electrode & Dilute Acetic Acid	Saccharomyces cerevisiae culture in organic slurry	54 % at 10 days	656 mV at 10 days	7
7	DSW (Post-methanation distillery effluent)	Double Chambered MFC with Nafion membrane (Sigma–Aldrich US)	Graphite Fiber Brush & Post-methanation distillery effluent	Graphite Fiber Brush & 2 g/L potassium ferricyanide solution	cow-dung slurry	-	0.457 W/m^3	8
8	DSW	Double Chambered MFC with agar salt bridge	Graphite rods from pencils & DSW	Graphite rods from pencils & Potassium permanganate	mixed consortia from domestic sewage	64%	18.35 mW/m^2	9
9	High strength molasses wastewater	Single Chambered MFC & Membrane-less (UASB–MFC–BAF integrated system)	100 g granular graphite (1–5 mm) with a graphite Rod & molasses WW	Air cathode as carbon paper that consisted of a catalyst layer (containing 0.5 mg/cm2 of Pt) on the water-facing side and a polytetrafluoroethylene (PTFE) diffusion layer on the air-facing side	anaerobic sludge taken from the UASB reactor	53.2 %	1410.2 mW/m^2	10
10	DSW	Single Chambered MFC with Pre-treated NAFION-117 (Sigma–Aldrich)	Plain graphite plates	Plain graphite plates	enriched mixed consortia (3.6 g VSS/l) through distillery wastewater (0.5 l)	72.84 %	124.35 mW/m^2	13
11	DSW	Double Chambered MFC with salt agar 12bridge	Graphite Rod & DSW	Graphite Rod	-	68.5 %	25194.8 mW/m^2 & max voltage of 206 mV	14
12	DSW	Single Chambered MFC	Carbon cloth	Air cathode – Carbon cloth	cow-dung	68 %	29 mW/m^2	22

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