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To Study Microbial Fuel Cell with Cavitation

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Abstract: *Microbial cell (MFC) gives a replacement opportunity for the sustainable production of energy of direct electricity from biodegradable compounds present within the wastewater hence allowing waste water treatment. Microbial fuel cell is a device that converts chemical energy to electrical energy by the actions of microorganisms. They are electrochemical devices functioning on metabolic abilities of microorganisms to oxidize organic substances and generate flows of electrons serving the dual purpose of waste management and energy generation. MFC works by allowing bacteria to do what they are best, oxidize and reduce the organic matter and that would be MFC in a nutshell. In Cavitation, cavitation is a phenomenon which is characterized by formation, growth and collapse of bubbles within a liquid. A flowing fluid system also gives cavitation, which is known as hydrodynamic cavitation. Generally cavitation is generated during a flowing fluid passing through a Venturi tube or an orifice plate with a constriction, which leads to hotspot generation. There are various applications of hydrodynamic cavitation but it plays a major role in food industry and waste water treatment. Hydrodynamic Cavitation is considered as one of the high energy demanding process for water treatment. For this study, we used a simple experimental setup to generate cavitation at a low pressure (low energy) so the digestibility by microbes is done at a higher rate in MFC system.*

Keywords: Electricity Generation, Hydrodynamic Cavitation, Micro-Organisms, Waste-Water Treatment, Biodegradable Waste.

I. INTRODUCTION

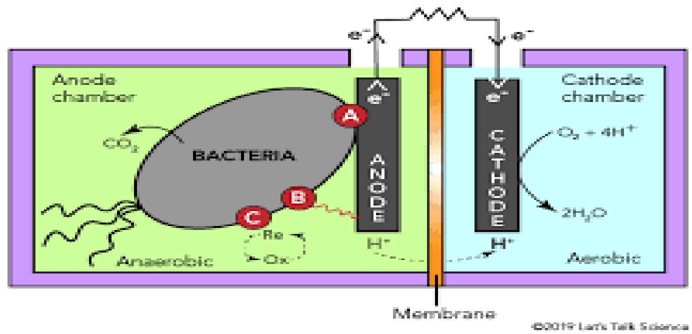
Wastewater may be classified either domestic or as industrial wastewater. Treatment of industrial wastewater has been a long challenge for modern technologies combining high effectiveness of degradation of pollutants with low costs of the process, including hydrodynamic cavitation in microbial fuel cell is effective. Microbial fuel cells are special kinds of fuels which use micro-organism as a biocatalyst instead of high value catalysts used in traditional fuel cells. Cavitation is one such recent technique which has been found to be highly waste beneficial in wastewater treatment and has attracted considerable research interest. MFCS are devices which convert organic matter into energy, using microorganisms as catalysts generally bacteria are used in MFCs to generate electricity white accomplishing the biodegradation of organic matter or waste.

Hydrodynamic cavitation involves generation of vapor cavities inside a liquid medium. It is usually defined as breakdown of liquid medium under lower pressure. Hydrodynamic cavitation occurs when there is a difference in pressure between the outer flow and inside of the attached cavity forces the streamline to curve toward the cavity and the surface beneath it. As a result, the cavity close and the stagnation point is formed.

Microbial fuel cell represents an emerging technology for generating electricity from renewable biomass. This technology hasnot been leveraged for power generation as the existing MFCs demonstrate low performance. Therefore, use of cavitation along with microbial fuel cell will help the eddies formation and electro-atomization will occur between the electrons which will further initiate quick generation of electricity.

The research also has the potential benefit of designing a general design platform for microfabrication, which could facilitate further research.

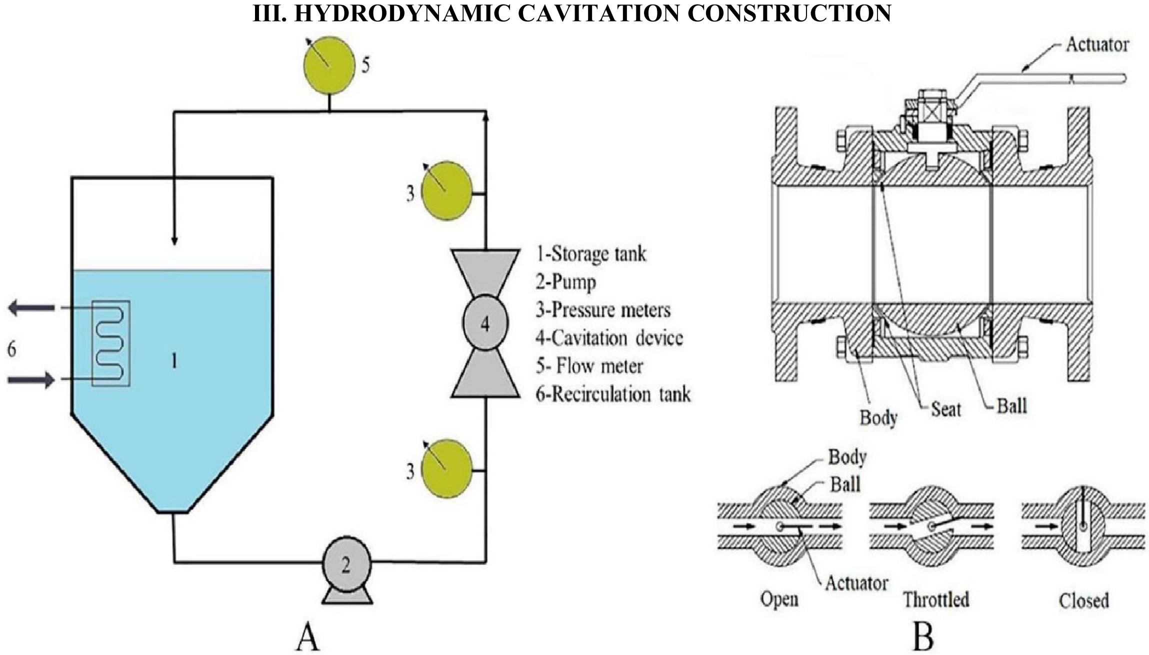
II. MFC CONSTRUCTION



A Microbial fuel cell construction consists of two plastic containers connected to each other by a salt bridge. Graphite rod is connected on the top of both the container with the help of screw or nail. Salt bridge is made by using agar-agar gel (halwa grass). Agar is solution prepared according to requirement of procedures i.e. 40 grams dissolved in e100ml water and we added KCl salt in that mixture. We have used 2 salt bridge for better transfer of ions. One in the middle of the compartment and the other on the top of the compartment in a U shape. MFC is constructed using several components:

- Electrodes in both anode chamber and cathode chambers.
- Proton Exchange Membrane used as one of the least resistive membrane.
- Substrate –Organic matter as source of energy for microorganisms i.e. from wastewater.
- Bacteria commonly used Exo-electrogene

III. HYDRODYNAMIC CAVITATION CONSTRUCTION



Cavitationis the formation of vapor cavities in liquids and this take place in three steps: expansion, refraction and explosion of the cavities. In this method cavitation is generated by the passage of a liquid through a constriction in orifice plates or venturi tubes with one or multiple holes. The passage of the liquid through the constriction causes an increase of the kinetic energy/velocity at expense of the pressure. After the constriction, a pressure drop is formed which creates cavities. As the liquid expands, the pressure recovers and this results in the collapse of the cavities, generating the forces and increase in temperature. In general, devices used for inducing hydrodynamic cavitation can be controlled and measured by varying various parameters such as orifice (size and shape), time, pump power, pressure flow.

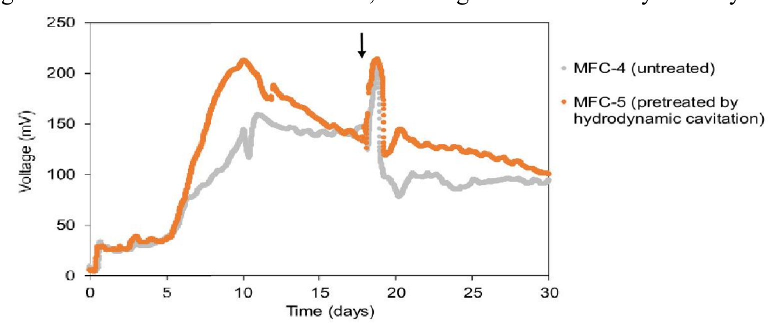
IV. PRE-TREATMENTIN HYDRODYNAMIC CAVITATION

The cavitation system counts on a PKm200 Perollo pump, operating at 220/240v, 13 A , two connecting tubes, a pipe containing the orifice of specific diameter between 2 and 2.5 mm, a pressure gauge a separate 10 L container containing the biomass sample. It operates up to 10 bar pressure and the plastic container operates atmospheric pressure. The device is manufactured by Efficiency Technologies, United Kingdom. To be able to start the pump the pipe was filled with approximately 0.5 L of water and then placed in the box with the diluted substrate (1.5 L) at which the cavitation was started. The total volume in the system was 2 L and the pace of the solution through the system was of 10 L/min. Both energy (source for device) and temperature were noted before and after cavitation, the running time was two minutes. After each run of the cavitator was cleaned by running the system with clean water and then taken apart to remove possible residue of current waste.

V. VARIOUS EFFECT OF HYDRODYNAMIC CAVITATION ALONG WITH MFC

The organic matter sample contains large quantity of biopolymer such as cellulose, which are altered to get easily digested by microbes in the MFC system. Pre-treatment is the most powerful tool to improve the digestibility of biomass.

Hydrodynamic Cavitation pre-treatment shows that the crystallinity of cellulose of organic matter decreases by the pretreatment. Hot spots along with high temperature and high pressure is generated in the cavitation system would lead to disruption of hydrogen-bond in cellulose in the biomass, resulting in decrease of crystallinity.



Time course of voltage changes in MFC-4 (untreated) and MFC-5 (pretreated by hydrodynamic cavitation). The electrolyte was replaced at the points indicated with arrows.

The above figure, shows that voltage changes in MFC along with time (untreated) and MFC (pre-treated by hydrodynamic cavitation).(1)

	lowest internal resistance r (Ω)	total charge amount (~day 30) Q (C)
MFC-4	442.1	4.91×10^2
MFC-5	355.1	6.19×10^2

The total electric charges with (untreated) and (pre-treated) MFC'S were found 4.91 × 102 and 6.19 × 102 C, respectively resulting in hydrodynamic cavitation increase the total electric charge by 26%. The Pretreatment of rice bran by hydrodynamic cavitation increases the digestibility of the biomass by microbes near the anode, which results to higher efficiency in electric generation. Pretreatment of biomass has proven to be very important in this system.

VI. OBSERVATION TABLE

Table 2. Characteristics of biomass and inoculum. The numbers of untreated biomass represents raw material before dilution. U= un-treated, T= treated, OLR= organic loading rate

Biomass	Pre-treatment	TS (%)	VS (%)	OLR (g VS L^{-1})
WAS (U)	-	5.0	71	3.0
WAS (T)	Cavitation	3.2	71	2.9
FW (U)	-	5.8	91	4.3
FW (T)	Cavitation	3.6	90	2.6
S. latissima (U)	-	13*	60	5.9
S. latissima (T)	Cavitation	1.6	61	3.0
A. nodosum (U)	-	29.0*	69	6.4
A. nodosum (T)	Cavitation	0.8	73	2.6
Grass (U)	-	25*	89	5.0
Grass (T)	Cavitation	0.4	84	2.3

VII. LITERATURE SURVEY

MFCs are defined as electrochemical devices that uses microorganisms to oxidize fuels, resulting in generating current by direct or mediated electron transfer to electrodes. It consists of the anodic chamber in which the organic matter is oxidized by microbial metabolism and transfers the electrons to the anode. The cathodic chamber, oxygen or oxidized compounds are reduced by microbial activities. Because of the microbial activities on different organic compounds it is used to generate electricity in MFC. There have been early studies on fuels in MFCs which were done on substrates, carbohydrates like glucose, fructose, xylose, sucrose, maltose and trehalose by, organic acids like acetate, propionate, butyrate, lactate, succinate and malate, alcohols like ethanol and methanol and inorganic compounds like sulfate.But in recent years there has been the interest in complex substrates led to tests on starch, cellulose, dextran, molasses, chitin and pectin from Domestic and Industrial Wastewater.

For e.g. from starch, wastewaters coming from the meat packing industry, swine farms, cereal potato-producing units. Solid agricultural wastes such as corn stover, manure even is used. Solid organic compounds are excellent constituents of waste for electricity generation in MFCs. In MFC's there is higher need of energy density than soluble organic compounds. For eg. In case of rice industry, the major by product is rice bran which has various applications because of its bioactive ingredients such as polysaccharides, proteins, minerals, and other micro-nutrients. Rice bran has potential source material for being used in MFCs due to its rich nutrient and organic compounds. But the major problem is that rice bran contains cellulose, which has a crystalline structure and is difficult to degrade. For substrates containing more complex polymers, such as lingo cellulose, this is the most desirable phase to optimize since it becomes a rate limiting step. To obtain an effective hydrolysis some substrates needs pretreatment so that the biomass becomes more accessible for the microorganisms. As a result, efficient pre-treatment of rice bran is required which is done by the process of HYDRODYNAMIC CAVITATION. Hydrodynamic cavitation offers new possibilities thus it is less energy demanding, has a simple construction and less operational costs in comparison with acoustic cavitation that is commonly applied today. In comparison with other pre-treatment no chemical is needed, the method can be applied on several biomasses with different characteristics and enhances the production. Not only Hydrodynamic cavitation is shown to be energy efficient, studies of waste activated sludge and food waste have showed promising due to its ability of cell disruption which enables more efficient biodegradability. Hydrodynamic cavitation is an innovation which is commonly applied as waste water treatment and for food processing. It has been studied that the benefit of acoustic cavitation as a pretreatment has been demonstrated in term of cell disruption and particle size reduction. In addition to these studies of cavitation have showed that the extraction of organic compounds contained in plants improves after treatment with hydrodynamic cavitation, which is an indication of successful degradation. A study shows that the impact of the pre-treatment on particle size distribution was evaluated by comparing the mean diameter value between treated and un-treated sample. After hydrodynamic cavitation treatment a reduction in particle size could be seen on all the organic substrates. This is an indication that cavitation successfully reduces the particles which would be advantageous in subsequent process and also results in a particle reduction with the help of hydrodynamic cavitation. The comparison between the biodegradability indexes for un-treated and treated waste shows there is also an increase of degradation of the biomass treated with cavitation by 25%.This could be a proof that the pre-treatment of hydrodynamic cavitation has worked it purpose to degrade the biomass to make it more available for the microorganisms in the first step of Anaerobic Digestion (AD).Because of large particles of biopolymer such as cellulose,they should be altered so that it can be easily digested by microbes in the MFC system. Thus, pretreatment is that the most powerful tool for efficient digestion by microorganisms.

The degrading bacteria cooperatively function for effective electricity generation in the MFC system. We thus study that the pretreatment of biomass i.e. organic waste by hydrodynamic cavitation, is more efficient for the pretreatment of lingo cellulosic biomass.

As a result, the pretreatment of biomass by hydrodynamic cavitation apparently increases the efficiency of MFC in voltage generation.

VIII. MAIN APPLICATIONOF MFC

A) Generating Electricity

Microbial fuel cell (MFC) is one of the best methods for the Generation sustainable energy, in the form of direct electricity from biodegradable compounds present in wastewater. In the MFC system, substrate (organic matter or biomass) is oxidized anode chamber producing, protons and electrons. In recent, study is going on generating electricity from solid rice bran using mud of the bottom of a pond as a bacterial source. After Carrying Out a Examination on a Prototype, where Electricity was Generated by First Pretreated Solid Rice Bran & Later using it in the Hydrodynamic Cavitation Process.

B) Waste-water Treatment

Microbial Fuel Cells are also used in the field of waste-water engineering. Microorganisms can Discharge the Dual Duty of Generating Electricity and Degrading Effluent. When microorganisms get oxidize, organic compounds which are present in wastewater electrons are released yielding a steady source of electrical current. In near Future, there are high chances of power generation by this method along with this microbial fuel cells may provide a new method to reduce the operating costs of waste water treatment plant, which will make advanced waste water treatment more affordable all around the Globe.

IX. FUTURE OF MFC + CAVITATION

For some substrates, such as WAS, hydrodynamic cavitation can be used as a pretreatment method. However, more studies are needed to evaluate the design of the equipment as well as the process parameter. Hydrodynamic Cavitation has a Good Potential of degrading organic pollutants effectively to a certain level.

X. CONCLUSION

Hydrodynamic cavitation is a new, advanced technology to be used in combination of MFC for the decomposition of complex compounds and for generating voltage out of by-products or wastes from domestic or industrial wastewater/effluents. The modern use of this technology is in environmental engineering which allows processes to be greatly effective during water and waste treatment. Microbial fuel cells (MFCs) along with cavitation shows an emerging technology for voltage generation from renewable biomass. However, MFC technology hasn’t been leveraged yet for power generation because existing MFCs demonstrate low performance and have expensive core parts and materials. Rather, special applications to (i) power battery-reliant devices that consume reasonably small amounts of energy and (ii) facilitated studies of microbial behavior might be more applicable and potentially realizable. As a result, microscale MFCs are rapidly gaining attention in a wide variety of applications such as portable power supplies, analytical study tools, energy storage devices, and toxicity biosensors. The combination of MFC along with HYDRODYNAMIC CAVITATION can be proved to be very useful in various sectors of industries.

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