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Original Research

Treatment of Sugar Industry Effluent using Microbial Fuel Cells

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Abstract

Industrial wastewater presents a potential hazard to natural water system. This wastewater contains organic matter, which is toxic to the various life forms of the system. Wastewaters produced from Sugar Industries pose several problems. These wastewaters contain relatively high levels of suspended solids and soluble organics, many of which are recalcitrant. This study was designed a waste water treatment plant with an aim at minimizing and removing of COD, BOD, dissolved solids and toxic compounds, before it releases into a water body. In the present study efficiency of Microbial Fuel Cells (MFC) in removing contaminants was determined. It was found that MFC is much effective and cheaper method for treating waste water and for the removal of TDS, TSS, BOD, COD, Sulphates and Chlorides, Oil and Grease. Batch type aerobic biological treatment plant was constructed and operated for Sugar industry waste water treatment. The hydraulic retention time was 12 days. The treated water samples were collected for every 72 hours and tested for its pH, TSS, TDS, COD, BOD, Sulphates and Chlorides, Oil and Grease to evaluate the efficiency of the plant. Experiments are performed in batch reactor in optimized condition. The degradation of waste water has been investigated in terms of reduction in COD. Various process parameters like pH, TSS, TDS, BOD, Sulphates, Chlorides and Oil and Grease were varied and their effects on MFC of Sugar industry waste water have been analyzed. The results obtained were quite appreciable as it reduced COD to 94.5% and a small amount of 110mV has also been produced.

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INTRODUCTION

Water pollution is a major global problem which requires ongoing evaluation and revision of water resource policy at all levels (international down to individual aquifers and wells). Industrial effluents are discharged into water bodies containing Toxic Chemicals, Phenols, Aldehydes, Ketones, Cyanides, Metallic Wastes, Plasticizers, Toxic Acids, Oil and Grease, Dyes, Suspended Solids, Radioactive Wastes etc. (Hampannavar *et al.,* 2010). The principal types of industries which contribute to water pollution are Chemical and Pharmaceutical Industries, Sugar industries, Steel Plants, Coal, Soap and Detergents, Paper and Pulp, Distilleries, Tanneries, Foods Processing Plants etc. These effluents when discharged through sewage system poison the biological purification mechanism of sewage treatment and pose several pollution problems (Tanksali., 2013). India is the world's largest sugar-consuming country and the second largest in terms of sugar production. Consequently, the amount of wastewater generated from these industries has also increased (Emrah Alkaya *et al.,* 2011).

The main energy source is the combustion, usually bagasse and other low quality fossil fuels with high sulphur content are used (Sajani Samuel *et. al.*, 2011). In sugar production, the water used for processes such as cane washing, clarification of juice, cleaning of evaporators, heaters and purging boilers, cooling systems and sanitary services are discarded. Sugar industries wastewaters are characterized by high biological oxygen demand (BOD), chemical oxygen demand (COD), and total dissolve solids. Wastewater from sugar industry generally contains carbohydrates, nutrients, oil and grease, chlorides, sulphates, and heavy metals. The BOD/COD causes rapid depletion of oxygen content of the waters, creates foul smell, renders the stream unfit for propagating aquatic life, drinking and for other purposes (Ahmad,1982). Forced by the legislation, industries are looking for the low cost solutions for the required reduction of pollution load. Primary treatment of sugar industry wastewater includes filtration, sedimentation, and load equalization. Whereas, secondary treatments are biological methods like lagoons, aerated ponds, up-flow anaerobic sludge blanket (UASB)expanded granular sludge blanket, fluidized bed reactor (FBR). Sometimes combined anaerobic and aerobic treatments are also used for sugar industry wastewater treatment (Nahle, 1990).

Main objective of the present study is to treat Sugar Industry waste water containing recalcitrant or non-biodegradable and toxic compounds which cannot be treated. In an attempt to increase the efficiency of degradation of the impurities present in the waste water to improve the economics of the treatment, the work was carried out to reduce various parameters present in synthetic waste water of Sugar Industry using Microbial Fuel Cells Treatment Method. The study was under taken with following objectives are Characterization of waste water.Microbial Fuel Cell treatment of synthetic Sugar industry waste water.Effect of MFC to reduce the impurities for various parameters.

MATERIALS AND METHODS

Treatment Procedure

The present study was carried out to investigate the capability of biological process for the treatment of Sugar industry effluent. The experimental work was carried out to reduce the parameters like pH, TSS, TDS, BOD, COD, Sulphates, Chlorides and Oil and Grease. Microbial Fuel Cell is used for the treatment of waste water sample continuously for a span of 12 days taking samples at regular intervals of 72 hours (APHA-AWWA-WEF, 2005).

Microbial Fuel Cell using a Salt Bridge

Dual chambered MFC was constructed using air-tight plastic bottles of 1 liter volume each (anode and cathode chamber) (Prasad *et al.,* 2015). A side opening of 1 cm radius was made at a height of 12.5 cm from the bottom of the bottle (approximately at the center) on each bottle and was connected with a PVC pipe(length=20cm; diameter=2cm). Agar of 2gms along with 2gms of sodium chloride (NaCl) salt was prepared by heating it in a water-bath of 100ml and the molten agar was allowed to cool down and poured into the PVC pipe and sealed at one end using cello-tape. The agar was left undisturbed to solidify. The PVC pipe containing the salt-agar mixture was fixed between the two bottles using epoxy material and behaved like the salt-bridge assisting in the proton transfer mechanism during the MFC operation (Min, *et al.,* 2005), Carbon rods (height= 12cm; diameter = 0.75 cm) were used as electrodes. The distance between the two electrodes was maintained at distance of 20 cm in the MFC setup. Copper wires were used to connect the electrodes to the circuit(Ghangrekar *et al.,* 2006). An external resistance (R) of 10Ω was connected and the readings were measured using a digital multimeter. Constructed salt bridge MFC is shown in Figure 1.

Figure 1: Microbial Fuel Cell for the treatment of waste water

RESULTS AND DISCUSSION

Waste Water Characteristics

Sample was taken from sugar industry waste water to determine its various parameters. The values of various parameters like pH, colour, temperature, Dissolved oxygen, COD, BOD, TSS, TDS, Chlorides, Sulphates, Oil and Grease before the treatment of sample effluent are as shown in Table 1.

Table 1: Characteristics of Synthetic Sugar industry waste water

No	Parameter	Untreated Effluent
1.	Colour	Dark Brown
2.	Temperature	32^0C
3.	pH	7.98
4.	Dissolved Oxygen	1.8
5.	BOD	62
6.	COD	1940
7.	TSS	484
8.	TDS	2600
9.	Chlorides	1200
10.	Sulphates	2469
11.	Oil and Grease	24

Effect of Microbial Fuel Cells

Sample taken from the sugar industry waste water is treated by Microbial Fuel Cells. In the process, two bottles, one having the waste water sample and the other having the tap water is taken. Carbon electrodes are dipped into each bottle and a salt bridge is attached between two bottles through which flow of electrons takes place. Moreover, an aerator is also placed in the bottle having waste water. During the treatment samples were taken at constant intervals of 72 hours to determine its various parameters i.e. pH, Total Suspended Solids, Total Dissolved Solids, Chemical Oxygen Demand, Biological Oxygen Demand, Sulphates, chlorides, Oil and Grease.MFC is known to be one of the cheapest methods for reducing COD values in waste water. In the present operation, the value of COD has reduced from 1940mg/lt to 300mg/lt. Besides reducing the toxicity MFC also produces Voltage. The voltage produced can be checked by connecting electrodes to the Multimeter. The maximum voltage found out to be 110mV. The Figure 2 shows the maximum Voltage could be recorded over a period of 12days.

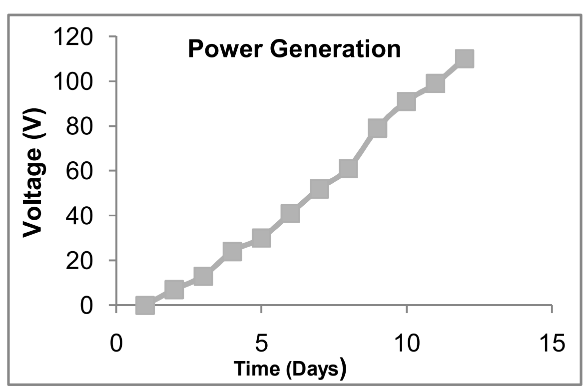

Figure 2: Voltage of MFC with Sugar industry waste water

Effect of MFC on Various Parameters

Effect of pH

pH of the waste water sample was determined using pH meter. The experiments were carried out in the pH range of 5 to 9. The variation of pH of the sample taken at regular intervals of 72 hours is presented in the Figure 3. Results show that pH of the waste water has decreased. The addition of vinegar, which serves as food to microorganisms, is responsible for the acidic nature of the waste water sample. pH has decreased from 7.98 to 6.5 which are in the permissible levels of BIS standards.

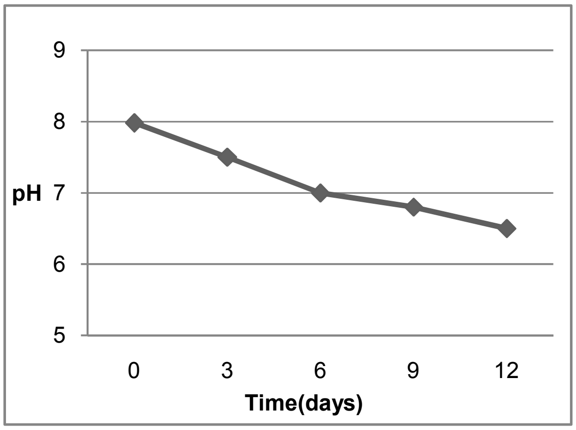

Figure 3: Variation of pH with Time

Effect of Chemical Oxygen Demand (COD)

The Chemical Oxygen Demand test (COD) determines, the oxygen required for chemical oxidation of organic matter with the help of strong chemical oxidant. The COD is a test which is used to measure pollution of industrial waste. The waste is measured in terms of equality of oxygen required for oxidation of organic matter to produce CO_2 and water. COD test is useful in pinpointing toxic condition and presence of biological resistant substance. For COD determination samples were preserved using H_2SO_4 and processed for COD determination after the entire sampling operation was complete. COD of the waste water sample at different time intervals are presented in the Figure 4. Results show that COD of the waste water has decreased from an initial of 1940mg/lt to 300mg/lt.

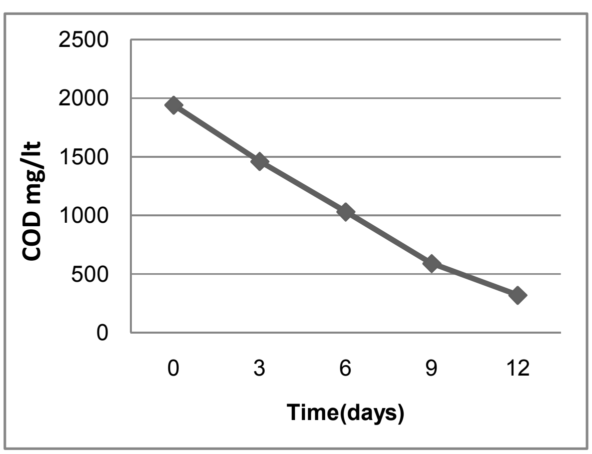

Figure 4: Variation of COD with time

Effect of Biochemical Oxygen Demand (BOD)

Biological oxygen demand is the amount of oxygen required for microbial compounds in water. This demand occurs over some variable period of time depending on temperature, nutrient concentration and the enzymes available to indigenous microbial populations, the amount oxygen required to completely oxidize the organic compounds to Co_2 and water through generations of microbial growth, death, decay and cannibalism. The effect of MFC on BOD of the waste water sample is illustrated in the Figure 5. Results show that BOD has decreased from an initial value of 62mg/lt to a final of 55m/lt. The decrease in BOD is due to continuous aeration and the action of sludge.

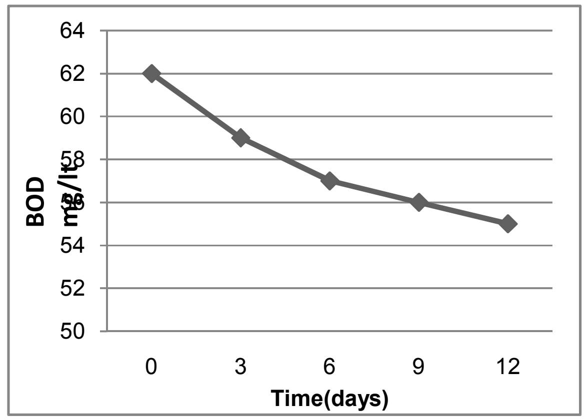

Figure 5: Variation of BOD with Time

Effect of Dissolved Oxygen

Dissolved oxygen analysis measures the amount of gaseous oxygen (O_2) dissolved in an aqueous solution. It refers to the level of free, non-compound oxygen present in water or other liquids. It is an important parameter in assessing water quality because of its influence on the organisms living within a body of water. A dissolved oxygen level that is too high or too low can harm aquatic life and affect water quality.The variation of Dissolved oxygen with time is presented in Figure 6. Results show that dissolved oxygen increased from 1.8mg/lt to 4.5mg/lt. The reason for increase in the Dissolved oxygen of waste water sample is due to decrease in the levels of BOD and COD in the waste water sample and aeration.

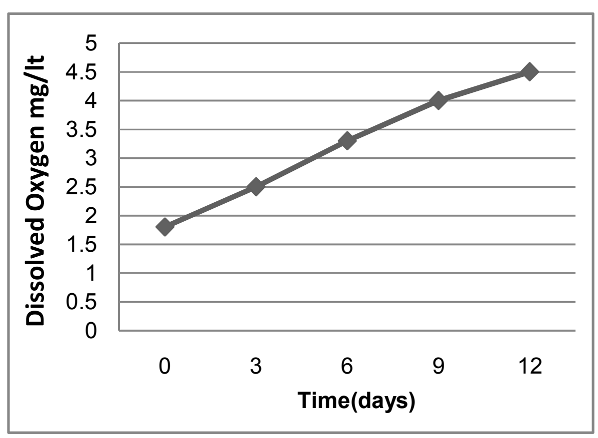

Figure 6: Variation of Dissolved oxygen with time

Effect of Total Dissolved Solids

TDS is the total mass content of all inorganic and organic substances present in liquid in the form of solids, ions, molecules and suspended micro granules. Though TDS is not generally considered a primary pollutant (e.g. it is not deemed to be associated with health effects) it is used as an indication of aesthetic characteristics of drinking water and as an aggregate indicator of the presence of a broad array of chemical contaminants.MFC showed its potential for Total Dissolved Solids removal. The effect of MFC on total dissolved solids of the waste water sample at regular intervals is presented in the Figure 7. Experimental data indicated that dissolved solids were decreased continuously during the 12 day operation. The TDS of the waste water sample has decreased from 2600mg/lt to 2150mg/lt.

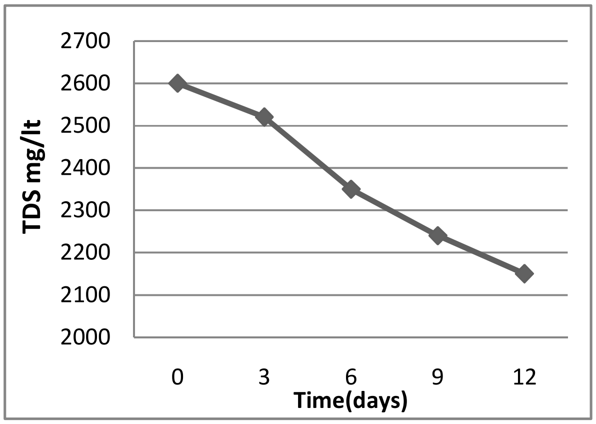

Figure 7: Variations of TDS with Time

Effect of Total Suspended Solids:

Total suspended solids is a water quality measurement usually abbreviated TSS. It is listed as a conventional pollutant in the U.S. Clean Water Act. This parameter was at one time called non-filterable residue (NFR), a term that refers to the identical measurement: the dry-weight of particles trapped by a filter, typically of a specified pore size. Effect of MFC on the removal of TSS of the waste water sample is demonstrated in Figure 8. The Experimental data shows that the amount of TSS in the sample has decreased with the elapse of time. The decrease of the suspended solids in sample may be due to availability of biodegradable substrate in wastewater sample leading to competitive inhibition in microorganisms.

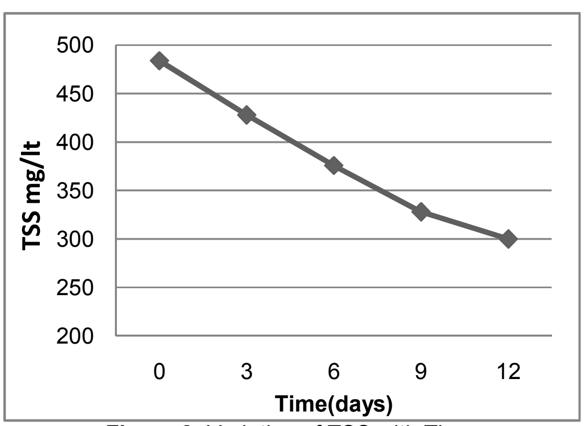

Figure 8: Variation of TSS with Time

Effect of Chlorides

Chlorides are generally present in natural water. The presence of chloride in the natural water can be attributed to dissolution of salts deposits discharged of effluent from chemical industries, oil well operations, sewage discharge of effluent from chemical industries, etc**.** The effect of MFC on chlorides of the waste water sample is presented in Figure 9. The experimental data shows that chlorides content has decreased from 1200mg/lt to 450mg/lt. The removal of chlorides in the sample may be attributed to the availability of biodegradable substrate in wastewater sample leading to competitive inhibition in microorganisms.

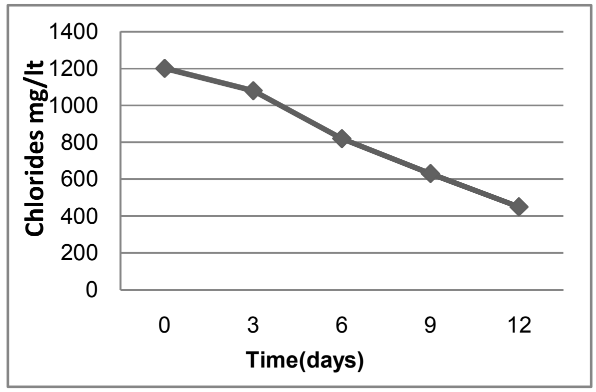

Figure 9: Variation of Chlorides with Time

Effect of Sulphates

Sulphate is one of the major cation occurring in natural water. Sulphate being a stable, highly oxidized, soluble form of sulphur and which is generally present in natural surface and ground waters. Sulphate itself has never been a limiting factor in aquatic systems. The normal levels of sulphate are more than adequate to meet plants need.The effect of MFC on Sulphates is shown in Figure 10. Results clearly show decrease in Sulphates from 2469 to 1100 mg/lt. The removal of Sulphates in the sample may possibly due to the availability of biodegradable substrate in wastewater sample leading to competitive inhibition in microorganisms.

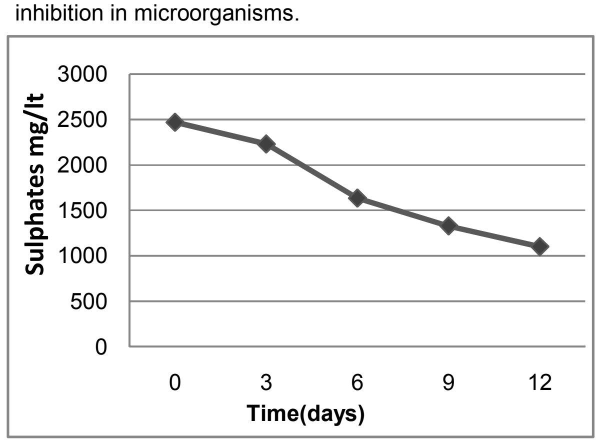

Figure 10: Variation of Sulphates with Time

Effect of Oil and Grease

Oil and grease are found in wastewater either as an emulsion or as free-floating agglomerates. Chemicals, such as detergents and solvents, and mechanical agitation can cause oil and grease to become emulsified. According to the Water Environment Federation's

Pretreatment of Industrial Wastes, Manual of Practice FD-3, Grease is a general classification for grouping such materials as fats, oils, waxes, and soaps according to their effect on wastewater collection and treatment systems or their physical (semisolid) forms.The effect of MFC on Oil and Grease is presented in Figure 11. The data shows that the oil and grease has decreased from 24mg/lt to 16mg/lt. The decrease in the content of Oil and Grease in the sample may be attributed to the availability of biodegradable substrate in wastewater sample leading to competitive inhibition in microorganisms.

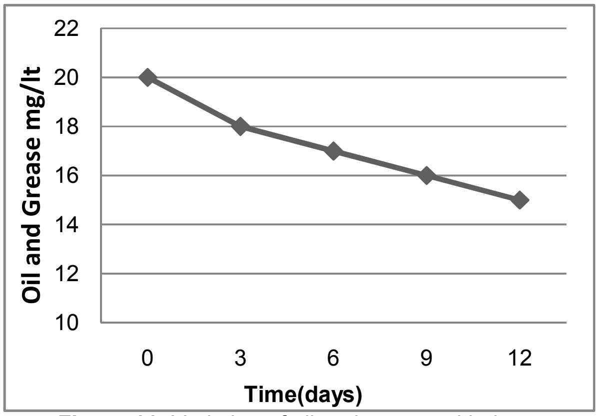

Figure 11: Variation of oil and grease with time

The values of the sample after the treatment are shown in the Table 2. Here, the values of some of the parameters like pH, TSS, Dissolved Oxygen and Chlorides are well below the BIS standards. But, the values of some of the parameters like COD, BOD and Oil and Grease are slightly higher than the standard values.

Table 2: The Physico-chemical parameters of treated and untreated sugar industry effluent

No	Parameter	Untreated Effluent	Treated Effluents	BIS standards
1.	Colour	Dark Brown	Light Brown	--
2.	Temperature	32°C	30°C	--
3.	pH	7.98	6.5	6.5-9.0
4.	COD (mg/lt)	1940	300	250
5.	BOD(mg/lt)	62	55	50
6.	Dissolved Oxygen (mg/lt)	1.8	4.5	4-6
7.	TDS(mg/lt)	2600	2150	2100
8.	TSS(mg/lt)	484	300	600
9.	Chlorides (mg/lt)	1200	450	600
10.	Sulphates (mg/lt)	2469	1100	1000
11.	Oil and Grease (mg/lt)	24	16	10

CONCLUSIONS

The focus of the present study was to review biological method involved in the treatment of waste water. In this physical study, Microbial Fuel Cell was selected to improve the waste water quality. The amount of TSS, TDS, BOD, COD, Sulphates and Chlorides, Oil and Grease are decreased when compared to initial characteristics of waste water. The MFC was effective, cheaper, easy to maintain and does not require any skilled worker. They undoubtedly have potential in terms of energy recovery during wastewater treatment. They may occupy a market niche in terms of a stand-alone power source and also in the direct treatment of wastewater.It was observed that the basic principle guiding for the removal of toxicity and the production of electricity is the availability of bio-degradable compounds present in the waste water sample. The COD removal denotes the function of microbes, present in wastewaters in metabolizing the carbon source as electron donors. It was observed that MFC has succeeded in achieving the COD removal efficiency of 84% and also in generation of 110mV.The study demonstrated that microbial fuel cell technology was able to treat Sugar industry wastewater successfully, and microorganisms present in the wastewater are for removal of COD, BOD and other parameters. MFC technology may provide a new method to offset wastewater treatment plant operating cost, making wastewater treatment more affordable for developing and developed nations. Thus, the combination of wastewater treatment along with electricity production may help in saving money as a cost of wastewater.

Conflict of Interest

Authors declared no conflict of interest.

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