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Electricity Production from Desalination by Algal Ponds using Chlorella Vulgaris

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Abstract: ***The demand for natural resources is rising tremendously as a result of the current urban expansion. Water and energy are the two main focuses of the environmental scientific society due to their anticipated scarcity. A desalination approach using algae ponds along with an electricity generation technique are provided in the present study. This is achieved through the use of Chlorella vulgaris, a fresh water algae residing in ponds, and large scale chamber-less bio- photo voltaic cell (BPV). Chlorella vulgaris was found to generate an electric current from the pond whilst causing concurrent desalination. This study proves the possibility of simultaneous power generation and salt removal using Chlorella vulgaris and opens doors for massive research potential in the fields of renewable energy and desalination.***

I. INTRODUCTION

For the time being, water supply appears more or less sufficient for most population demands. However, it is predicted that lack of water will occur in the near future. Water is a highly essential element for humans and all living organisms, with its importance being of political value. This made it essential to search for alternate water sources, such as fossil fuels, as is the case in many oil-rich countries. Nevertheless, this method is energy depriving and environmentally hazardous.

For fresh water accruing, it is essential to have water body like a fresh water lake or a river. Wells are dug to provide water if near ground water table is available with suitable characteristics. If natural water accruing techniques is not available it is essential to use other methods where the widely available ones are desalination using fossil fuel burning. Fossil fuel is used for desalination in countries rich in oil [1]. These methods disadvantages include air pollution, high cost [2] and marine life threatening in the marine area where the hot brine is discharged [3]. Renewable energy resources is used for desalination and showed a clean way to provide water but is still costly compared to fossil fuels [1].

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Biological treatment methods basically rely on micro living organisms like algae or bacteria to get rid or reduce concentration of contaminants in water. This is done in many various ways as microorganisms may consume contaminants or even absorbs them and then is filtered [me].Algae is one of the oldest living organisms on this planet which is very efficient in photosynthesis easy and clean to grow. Scenedesmus Obliquus algae is used for saline water desalination by several researchers with successful results to produce fresh water with retention time varied between 7 – 21 days according to inlet salinity [4, 5, 6, 7].

Chlorella Vulgaris was found to withstand high levels of salt concentration which is a [8]. However this is a fortunate finding as it is used by this study for electricity production and bio desalination under high salt conditions. This study follows a previous two previous studies one made for desalination and the other is made for electricity production using Chlorella Vulgaris.

A new approach is presented in this article performing desalination of water and increasing out comes by producing electric current at the same time increasing the feasibility of the already clean bio desalinating technique. This is achieved by desalination of water using type of fresh water algae called chlorella vulgaris which was found to desalinate water rapidly then inserting a chamber less cell in the desalinating basing which proved not to interfere with the desalination which is responsible for power generation

For electricity production using algae the use of microorganisms in generating electricity is a new field with great potential, a method that requires the use of microorganism as an electron donor feeding on substrate in a cell called microbial fuel cell (MFC) [9]. A typical MFC may be a double chamber with an ion exchange membrane in the middle between anodic and cathodic chambers. Algae or microorganism used in MFC releases electrons at the anode chamber and water molecules is separated into oxygen and hydrogen. The anode takes released electrons while the hydrogen ions pass through the membrane to the cathode .When electrons travel through the outer connection between anode and cathode electricity is generated [10] .MFCs went through a lot of change to enhance its work and making it more feasible like adding air cathode getting rid of the ion exchange membrane.

Also algae usage may provide an advantage as it uses photo synthesis for its metabolism [11] changing the MFC into Bio-photovoltaic cell (BPV) that relies on sun light. [12]. Electricity production needed the availability of a mediator compounds for electrons to reach to anode BPV this was also eliminated and replace by biofilm formation of microorganism on anode[13].

The anodic material was studied thoroughly and showed that Stainless steel comes after indium tin oxide in electricity output which favors stainless steel for this study[14].
This study is dedicated to investigating the possibility of such system although much work is needed for the enhancement of the output regarding electricity. The benefit that this study point to is very significant in the quest of supplying sufficient resources to the future generation either water or power.

II. MATERIALS AND METHODS

A. GROWING ALGAE

An investigation was held using on a large culture unit made for the sake of this study to get its *chlorella vulgaris* growth rate curve on 8 days using UST a media made from a combination of commercially available fertilizers.
This was essential to know when to harvest algae for use either in desalination or in biofilm formation.

Figure1 Algae Culture Unit

B. Biofilm Formation Generation

Large frames of transparent acrylic glued to stainless steel mesh made for biofilms to attach on with dimensions of96 cm x 30 cm. Solution of algae was added to it UST media and both were left to cover the surface of anode with a 1cm height for 8 days. Biofilms were covered with plastic sheets to reduce contamination possibility.

Figure 2 Large Biofilms during the Settling Process

C. Design And Output Recording

A large scale Biophotovoltaic cell involved three key parts; cathode,anode and a structure to supportcell contentsFigure 3. To creat an anode biofilm was grown on stainles steel mesh and was supported by frame made from acrylic. The cathode was composed of four graphite plates 5 cm x 5cm , lying in an acrylic transparent plate, acting as air cathodes. That allows them to receive oxygen gas directly from the air, also its placemnt enabels it to accuire the hydrogen produced from the algal biofilm attached to anode , This enabels reaction to take place and power generation. Four shafts were used to suuroundthe graphite plates of the cathodeto stop the water from reaching the cathodes, which makes oxygen contact with the cathode possible. The plaastic shafts were used rateherthan just raising the cathode to water level, this will allow water surface waves without interferring with BPV function, as this cell is required to be placed in water bodies with water motion. Six pillars hold thecathodes, anode and acrylic plates, so that the cathodes are above anode. Figure 3 shows the BPV cell put together and figure 4 shows the Bpv cell in action during the power generation process.

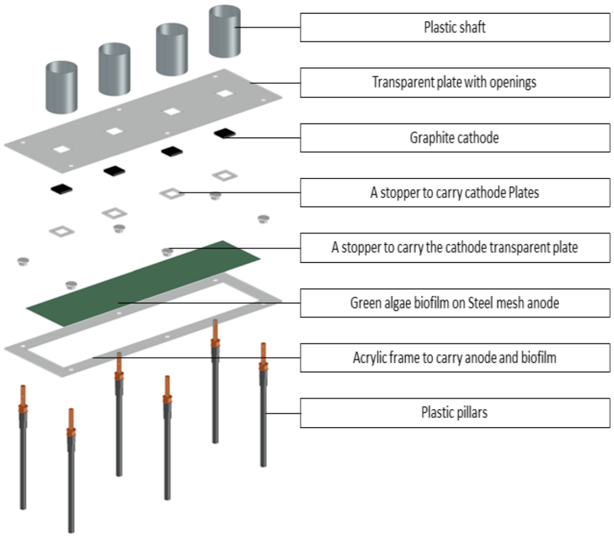

Figure II Components Of The Large Scale BPV

Figure 4 Complete Assembly of Large Scale BPV

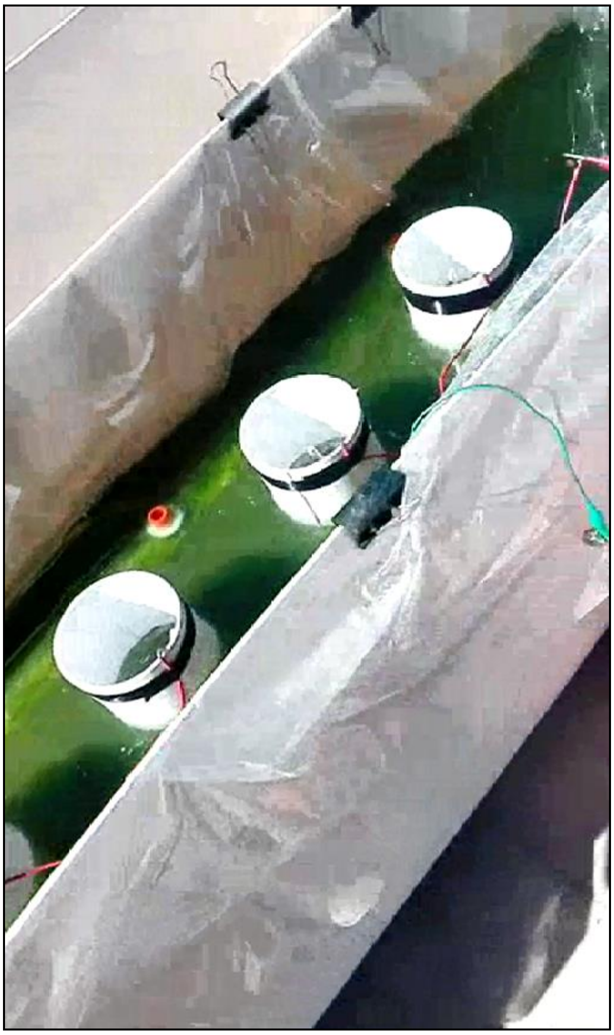

Figure 5 BPV photo in operation

III. RESULTS

Algae was grown in the lab where the cell count started with 7.2 million cell per mL and gave an about 10 times on day 7thisis suitable for algae harvesting in the time between the 6th and 7th day of starting culture .Table 1 show the cell count for every day of the experiment .

Table 1 Algae Culture Daily Cell Count

Time	Mcell/ml	Growth rate	Number of duplicates
Day 1	7.2		1
Day 2	8.4	1.16	1.16
Day 3	12.8	1.5	1.7
Day 4	18.4	1.4	2.5
Day 5	29.2	1.5	4.05
Day 6	67.6	2.3	9.38
Day 7	70	1.03	9.7
Day 8	44.4	0.63	6.16

For the large scale Bpv first sample the highest electric current produced was 20.5 μAmp.This Experiment was held at fresh water. The second experiment was done under salinity level of15 PPT and generated maximum of 100 μAmp. The last one sample was performed under 30 PPT salinity level and generated highest current of 140 μAmp (Table 2).

For the desalination algae was added to water and was left in the basin for 4 hours where salinity level was taken after filtration every hour. Fresh water had the same salinity for the whole experiment type. The 15 PPT experiment showed 1ppt salt removal in the second hour and maintained this salinity for the entire experiment .The last experiment which had salinity level of 30 ppt showed immediate salt removal after the first hour however salt removal depleted again after 4 hours.

Table 2 Produced Current from Three Different Cells in Three Different Salinities

Sample	Fresh		15ppt		30ppt	
Time (hrs)	Current □□	TDS	Current □□	TDS	Current □□	TDS
1	20	0.2	100	15	140	29
2	16.3	0.2	79.4	14	120	27
3	15.4	0.2	75	14	88.2	27
4	20.5	0.2	85	14	99.5	28

IV. DISCUSSION

Resources are being drained out of earth due to severe consumption .Fossil fuels are being used by all sorts of industries for desalination and power generation. The dependence on fossil fuels is causing their depletion, not to mention,pollution. Therefore, current research is dedicated to finding alternatives to acquire energy and water in a clean feasible manner.

Algae cells were cultured in the lab and it was noted that the most effective time for harvesting is between the 6th and 7th day to obtain a sufficient number of algae for our experiments.

That is, it reached nearly 10 times its original cell count on the 6[th]day which makes the presented method of culture an appealing method. Another study, using a different type of media, reaches the same number after almost 14 days [15].However, the mentioned study had a continued cell population rise in contrast to the depletion of cell count in this study after the 7[th] day.

Rapid salt removal was observed in our study, achieving 1 ppt of salt removal from the 15 PPT sample and 2 PPT from the 30 PPT sample within one hour. While the first sample maintained its salinity removal, the second one released salts at the fourth hour .This agrees with our former study that shows that *Chlorella* releases the absorbed salts back after some time. It is essential to filter water from algae at the right time to maintain the salt removal progress [16].

The purpose of the large scale BPV experiment was to check the possibility of simultaneous power generation and salt removal using *chlorella vulgaris*. This should not be confused with microbial desalination cells (MDC) which use the produced current from sea water electrolysis to desalinate water, thus producing one output [17]. In the present study, two independent techniques (desalination and output generation) were done in the same system in parallel. .

The study's target was met, as electric current was produced from the BPV. A maximum of 140 µAmp current intensity 100 µAmp and 20µAmp were recorded at salinities of 30, 15 and zero PPT respectively. This study shows that salinity is directly proportional to electricity generation which makes this technique suitable for use in treatment ponds and water bodies with high salt contents. Also, it is clear that in each same experiment, and the electric current is variable. This may be due to the change of salt content in the solution due to algae activity, initially absorbing salts in, and then gradually releasing them again. Thus, it can be observed that the salinity curve for each experiment relatively follows the current curve as illustrated in Figure 6. It is also worth noting that the relatively low current produced may be due to the use of a stainless steel mesh rather than a sheet, for the anode, or due to small cathode to anode ratio. Despite this, the suggested BPV design, compared to other studies [14, 18], is the largest to date and thus more applicable for large-scale operations.

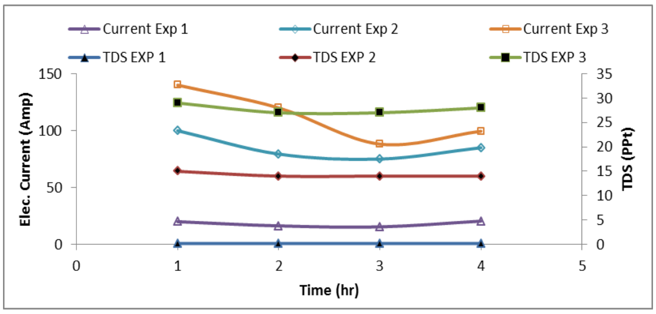

Figure 6 Results of the three pilot experiments

V. CONCLUSION

Three experiments were performed to execute electricity production as well as desalination at the same time. The first experiment was made in fresh water which produced an average current of 18 µAmp. The second one used 15 ppt salted water and produced average of 84 µAmp and 1 ppt salt removal then the last one was 30 ppt which produced average of 112 µAmp and 3 ppt salt removal. Also it is clear that in the same experiment the current changes with the change of salinity of the solution due to algae activity at first sucking in salts then gradually releasing them again.

Results of the current study showed the ability of algae to desalinate salty water and generate electricity in the same place at the same time. This success gives potential for a whole new area of research which is obtaining multiple outputs from the same system. This intends to increase the feasibility of desired systems especially in the area of environmental engineering. Since clean power production is a bit pricy, increasing system output may be the solution. That being said, further research should be made to enhance power generation through this design and also construct a system that allows for algae separation from water.

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