A detailed research on harnessing energy from the ionic concentration difference in fresh water and brine water as a new source of renewable energy

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Abstract: The purpose of this paper was to put forth a model which generates electricity from the ionic level difference in sea water and freshwater. An experiment was conducted to find how different parameter affect the voltage generated and how the electricity generated could be maximized. The results were then used to predict and conclude trends in the voltage generated.

Thus a model has been devised and proposed in this research paper which can be implemented in a large, industrial scale in rivers or lakes, to smaller domestic scale such as in households or water tanks to generate renewable energy which is economically viable. This model will be able to provide electricity from fresh water and brine water and can produce sufficient amounts of energy to run basic appliances. This has major implications in the sustainability of the resources as there will not be any emission of toxic or green-house gases. Thus this research paper views the possibilities on how this new model can be used as a new source of renewable energy.

1 INTRODUCTION

In the modern world the race to generate the cleanest energy and the lowest costs is at the utmost importance. People are moving away from using coal as means of fuel due to the toxic byproducts such as greenhouse gases. Thus a new method needs to be developed which can the potential to generate eco-friendly energy at low costs which can be provided to the masses.

Thus in this experiment a model is created where the concentration difference in the sea water and the fresh water from a river can be used to generate electricity. This can be implemented in the places where the river meets the sea and the fresh water and sea water mix.

The original electrochemical cell invented by Alessandro Volta was based on the concept of redox reactions where the reducing agent comes in equilibrium with the solution as it releases electrons and turns into ions. The charge separation is termed as electrode potential which causes the electrons to flow and generate electricity.

A model of sea water and fresh water, the difference in the concentration of the salt ion in the solutions causes a difference in the electrode potential when connected in a circuit. This can cause electrons to flow and a current to be generated which can be harvested. Thus, I came up with this particular research question to develop a model which can generate renewable electricity, at a bulk quantity, with no emission of toxic gases. When a river meets the sea, the freshwater in the river merges with the salt water of the sea. To explore the possibilities concerning this natural phenomenon, to use the difference in the concentration of salt in the water this research question was generate.

'How much voltage can be generated and what is the optimum set-up for harvesting energy from sea water and fresh water?'

2 DATA FOR CONCENTRATION DIFFERENCE

Lower ion concentration solution (mol dm-3)*	Higher ion concentration solution (mol dm-3)*	Peak voltage generated (V)**	Time taken to reach highest voltage (s)
0	0	-0.074	5
0	1.168	0.255	494
0	2.336	0.279	210
0	3.504	0.282	60
1.168	2.336	0.191	90
1.168	3.504	0.217	60
2.336	3.504	0.201	60

2.1 Conditions

This data was collected by using 250 cm3 of solution of fresh water (tap-water) was used, with 17.06 g of NaCl added (1 table spoon)(1). The salt bridge used in this experiment was newspaper. The salt bridge was left for 5 mins before the experiment to get soaked in fresh water to be able to connect the two solutions. In each new experiment the salt bridge was given 45 seconds to adjust to the new concentrations and get adjusted to the new equilibrium.

The set-up was of two isolated solutions kept in separate beakers connected by the salt bridge and a multi-meter measuring the voltage of electricity generated in the cell.

(The photos of the set-up have been added in the appendix on the research paper)

3 Analysis and observations

By measuring the voltage generated in the solutions of fresh water, a value of -0.074 V was observed, which is taken as zero error for the purposes of the experiment as it is meant to show the voltage generated between a set of solution with different NaCl ion concentration. When a voltage is generated when the concentration of the solutions are the same, it shows the presence of difference concentration of naturally occurring ions in the river water. Thus the voltage generated in each cell must be increase by 0.074 V as it is starting from -0.074 V rather than 0 V.

Thus the new table will be:

Lower ion concentration solution (mol dm-3)	Higher ion concentration solution (mol dm-3)	Highest voltage generated (V)	Time taken to reach highest voltage (s)
0	0	0	5
0	1.168	0.329	494
0	2.336	0.353	210
0	3.504	0.356	60
1.168	2.336	0.265	90
1.168	3.504	0.291	60
2.336	3.504	0.275	60

* - The data was collected from a home set up in which the mass of NaCl added was approximated with a table spoon and an average value of 17.06 g was taken from http://www.traditionaloven.com/culinary-arts/cooking/table-salt/convert-table-spoon-tbsp-to-gram-g.html

** - A multi-meter was used where the least count was till mili-volt with an uncertainty of 0.5%.

4 Observations

In the first experiment conducted with the salt solutions of 0 molar and 1.168 molar of solutions, the salt bridge was initially get soaked in fresh water, thus the increase of voltage measured was rising very slowly to 0.174 V till 278 seconds. However, at 329 seconds there was a sudden increase in the voltage measured and within the next 30 seconds the voltage has risen to 0.294 V. The voltage then rise constantly and became stable at 0.329 V after 494 seconds.

One possible explanation for this behavior is the optimal time for the salt bridge to start working and the time required for the ions to begin flowing and achieve the equilibrium. Initially, the salt bridge being in fresh water didn't contain any salt ions in it. However, in the following experiments the same salt bridge was used, which contained the ions thus reaching the equilibrium faster. Thus from the following experiments 45 seconds were allowed for the salt bridge to achieve equilibrium.

1) The general trend that follows the experiment shows that a higher difference in concentrations of the solutions produces a higher voltage. This can be confirmed as the voltage produce of o molar and 3.504 molar solution produced the highest voltage. And 1.168 and 2.336 molar solutions the lowest. This is also supported by the theory that if the ion concentration difference is greater, the equilibrium state will have a greater movement of ions thus producing a higher voltage.

But why is the voltage generated by 2.336 and 3.504 molar solutions is greater than, 1.168 and 2.336 molar solutions even though the difference in ion concentration is the same?

This can be answered by the fact that because there are more ions overall in the greater concentration solutions, there is a higher movement of ions.

2) Another important trend that is noticed is the time required for generating the highest voltage decreases as the concentration difference increase. This is supported by the fact that as the difference in concentration is high, the rate at which the system changes to reach the equilibrium will be faster. Thus it will reach its highest voltage faster.

5 Implications

These observations help us create a model for harvesting energy from the sea water and river water.

1) Firstly, the mixing of the river and sea cause the gradual increasing in the ion concentration in the river as it approaches the sea due to diffusion of the ion particles. This shows that the voltage generated will be very less as the ion concentration difference will not be big unless the model is very long, which is economically unviable due to the high cost of production and high cost of installation.

2) However, a different model can be prepared. A pipe with small amounts of brine water stored in chamber with an electrode at its end, which is separated from the fresh water at the other end which is flowing in and out. A slat bridge connects the two chambers of the pipe to complete the circuit.

   - This will eliminate the problem of a continuous change in ion concentration in sea and river and make it a sudden change in the concentration which will produce more voltage.
   - Moreover, this model can be implemented anywhere in the river and doesn't need to be near the river-sea merger point. Thus it can be implemented in any river
   - It can also be used in other fresh water bodies like dam water, lakes, ponds as it only requires an input of fresh water which are present in the examples listed above. Thus it can be produced at small scale for home use to put it in a water storage tank or at a big scale for rivers or lakes.

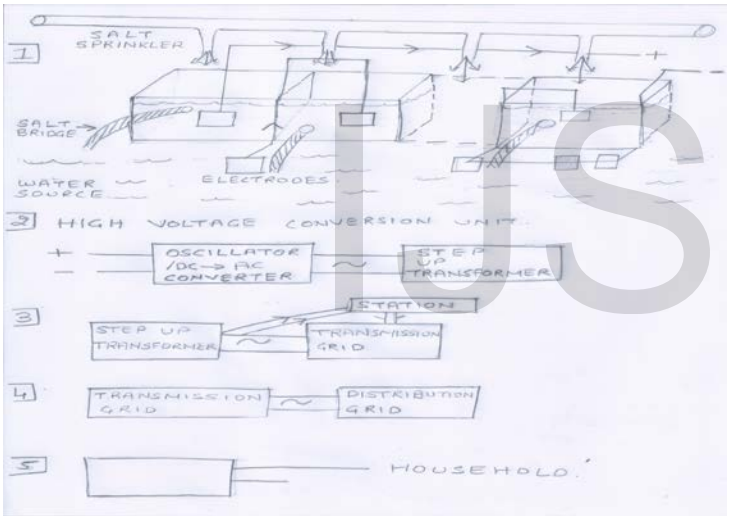
However, this model also has problems associated with it.

- Firstly, the model is based in the movement of ions from the region of high concentration to a region of low concentration and in the process generating electricity. However, if the solution with the high concentration has is stored, after some time it will come in equilibrium with the other solution as the concentration of ion will become the same. So unless salt is being added to the brine water and a high concentration is maintained after some time it will stop producing electricity. It will be difficult to add salt to the pipe as it will be sealed.

- Moreover, in the experiment it was observed that any turbulence causedtoa system in equilibrium causes the voltage to decrease. This can be explained by the Le Chatelier's principle that any change caused to a system in equilibrium will respond in a way to minimize the effect of the change. This shows that if there is an external input of movement of the particles when the ions are moving, the ions will respond in a way to reduce the overall movement. Thus reducing the ionic movement which cause the voltage. Thus this model cannot be implemented in a flowing river as the fresh water will cause turbulence in the system and it will never be able to achieve equilibrium.

Thus this is also not an optimum set us for harvesting the maximum energy.

3) However, another model can be developed which is better at maximizing the voltage developed. In this model in a big fresh water body numerous floating containers of brine water are released. An electrode for the brine water in on the top whereas the electrode for the fresh water is attached to the body of the container (not touching the brine water) and is submerged in the water body. The salt bridge hangs down and connects the brine water and fresh water. A sprinkler system of salt is attached over the brine water container to maintain the concentration of ions in the solution. Multiple of these cells are attached together to from an alternating positive-negative terminal making it a battery. The diagram for the model and the procedures for the energy to reach the households has been shown in the diagram below.



- This model will eliminate the problem of the depleting ion concentration difference in the solutions and also uses a high concentration difference.
- This can be produced for all required purposes, from a small scale for ponds or domestic water tanks to large lakes or rivers
- This also doesn't face the problem of turbulence. True the addition of salt will create some amount of turbulence however it will be negligible.

However even this is not a perfect system

- Firstly, as noticed in the experiment conducted, addition of salt to the solution with higher ion concentration in a system which is in equilibrium cause an initial drop in the voltage then it rises back to become higher than original. The drop in the voltage can again be explained by Le Chatelier's principle(proof of the principle). As the movement of ion in the concentrated area rises due to the addition of more ions and their interaction with the particles of the solution (while disassociation, interacting with the polar water molecules and the repulsion and attraction of ions present), the system responds in a way to reduce the change, by reducing the movement of the ions. A reduction in the movement of ions across the solution causes a reduction in the voltage for a short period before the equilibrium is achieved again where the concentration difference is greater thus producing more energy.

However, this will not be a problem in the model as the series of multiple cells which make the fluctuation of the voltage generated very small and negligible.

- Floating the containers will use material which can be harmful to the water body such as plastic or thermocol which can harm the marine life if absorbed by the water.
- It is economically not viable to create salt sprinklers across multiple cells and to monitor which cell's voltage is decreasing.

However, as all the container have the same concentration of brine water and are in the same water body, all cells will behave in similar patterns at similar times. Thus if the overall voltage is noticed to be dropped, it will not be because of one cell, rather because of all. Thus by keeping an optimum volume of brine water, a regular time interval can be devised to add salt to the brine water and maintain the ion concentration.

6 Evaluation

The experiment conducted was repeated for accuracy and to reduce the random errors, however, the experiment was conducted without a lab set-up thus there are systematic errors.

Firstly, as it was a home set-up, the experiment lacked the lab equipment such as pipet for measuring volumes, beakers as containers and an accurate weighing machine to add precise amounts of salt in the solution. The substitutes used for these equipments were home objects such as glasses, calibrated containers, and tablespoon (the average mass of salt in a table spoon was taken to be 17g). The measure the volume packed bottles were used to fill the water and transfer it to a glass.

A multi-meter was used to measure the voltage across the the solutions. The measurements were taken up to millivolts. However, the machines uncertaintyis 0.5%.

While recording the data for the experiment, there was a lot of fluctuation in the reading. It was crucial to take the reading of the highest voltage generated, thus enough time was given till the readings were stable for 2 successions or at a difference of 1 mili-volt.

The observation on the effects of turbulence and the addition of additional salt were completely qualitative as it was visibly observed in the live multi-meter the voltage drop. However, due to the lack of appropriate instruments a quantitative data could not be presented and further research in this field in the future will be able to present accurate and precise data of the following observation. Furthermore, due to the lack of computer compatibility of the voltmeter, it was impossible to graph the data with multiple readings to show the effects of different factors.

7 Different Parameters

In the experiment conducted, all possible parameter that will affect the voltage produced and were feasible at the home set up were checked. However, further research on in this field can include other parameters which will potentially affect the production of electricity.

Firstly, seawater has many more ions such as magnesium ion (Mg^{2+}), chloride ion (Cl^-), sulfate ion (SO_4^{2-}) and calcium ion (Ca^{2+})(2). This can alter the voltage generated with sea water as the ion levels are different. However, there are impurities in sea-water such as sand and dirt which can hinder the movement of ions in a circuit. It is difficult to predict the interaction of an ionic difference with so many different ions and impurities. Furthermore, a sample would not show an accurate picture as the water from the shore will contain more impurities such as sand thus giving false representation of the voltage generated from sea water. However, with further research and different sea water samples a general trend and conclusion can be produced on the optimal distance from the shore for different seas on the amount of electricity generated.

Another factor which can affect the electricity produced is the salt-bridge used. In the experiment newspaper was used as the absorption rate of newspaper is good. However, a salt bridge with ions present will provide a better result. An optimum salt bridge can be reached upon and how it increases the voltage generated.

In the experiment qualitative observations were made on the effects of turbulence and addition of salt in a system in equilibrium. However, with a lab set-up and accurate readings a better conclusion can be arrived at for the observations made. With quantitative data which can be acquired from trials with a lab set up, one will be able to graph the data. This can not only show different behaviour but might also give an insight on the optimal level of these factors and thus a better model can be created considering the waves in the sea and the flow of water in a river.

Another parameter that can be considered can be temperature as the movement of ions and particles (the kinetic energy of ions and particles) have a direct co-relation with the temperature. However, as the collision theory suggests that the frequency of collisions will increase, it is hard to predict the overall effect of the change in this factor. A set up which is equipped to measure equal temperature gaps and measure the different voltage generated - which is difficult to achieve at a home set up- will allow to find an optimal depth or condition the model can be placed to produce the maximum results.

8 Further scope of improvement

A further scope for improvement on the suggested model can be development of material that can support the floating containers and don't harm the marine ecosystem with their capabilities to pollute the water body.

As noticed in the experiment the concentration difference does increase the voltage generated and reduced the time required to achieve that. However, on close inspection it is evident that the rate of increase in the voltage generated is less than the time it takes to achieve it. Thus further research can be conducted to find the optimal amount of ionic difference -considering the economics like the cost of production of brine (the cost of cost to add and the process of making it homologous)- with respect to the time it takes to reach the highest voltage value.

The concentration of the brine water will decrease and over time the voltage generated will decrease. However, a prolonged research can show the time it takes to have a voltage drop. This can be used to improve the suggested model in which a better system can be implemented to maintain the concentration of the brine solution.

9 Conclusion

The model presented is devised in order to harness the maximum voltage from the ionic differences from fresh water and brine water. After numerous designs this model minimizes many disadvantages of other models and is able to eliminate multiple factors which conversely affect the ionic movement. Nevertheless, this model is still not ideal and perfect. With better lab trials and with consideration of other factors, it is possible to improve the existing model or design a new and better one in order to maximize the electricity generated.

This experiment began with the view to harness energy from the merger of sea and river from their ionic concentration difference. However, after brainstorming, it was possible to create a model which can is applicable in all forms from households in water tanks to big rivers and lakes. This gives the power to every household to support

the environment by producing clean energy, and gives any organization the chance to implement a method to reduce their carbon-footprint. Making it economically viable was another concern with the development of this model in order to provide the cheapest way to harness clean energy. In conclusion, this model can be used by a diverse range of people from different localities and needs (amount of energy required) to harness energy fromfrom brine water and fresh water. This can possible be a new model and source of renewable energy.

10 References

(1)- http://www.traditionaloven.com/culinary-arts/cooking/table-salt/convert-table-spoon-tbsp-to-gram-g.html
(2)- http://oceanplasma.org/documents/chemistry.html

Elements information – The Royal Society of Chemistry
http://www.rsc.org/periodic-table/element/11/sodium
http://www.rsc.org/periodic-table/element/17/chlorine

Appendix