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Feasibility Study of a Low Cost Saltwater Lamp for Rural Area

Nurul Aini Bani[1*], Mohamad Zaki Hassan[1], Hazilah Mad Kaidi[1], Mohd Nabil Muhtazaruddin[1], Shamsul Sarip[1], Ahmad Hadi Mohamed Rashidi[2], Safiza Saleh[1], Mohd Azri Mohd Izhar[1], Siti Armiza Mohd Aris[1], Siti Zura Abd Jalil[1]

[1]Razak Faculty of Technology and Informatics,
Universiti Teknologi Malaysia, Kuala Lumpur, 54100, MALAYSIA

[2]Coastal and Oceanography Research Centre,
National Hydraulic Research Institute of Malaysia, Seri Kembangan, Selangor, Malaysia

*Corresponding Author

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Abstract: Renewable energy is energy generated from natural resources and cannot be depleted. Solar energy is the fastest growing source of renewable energy but the high installation and maintenance cost of a solar system has restrained the consumers from adopting this technology at their home or commercial building. This is especially true for those in developing countries. A new promising renewable energy source known as saltwater energy that takes advantage of the conductive nature of salt water to generate electricity, has intrigued many people. A study has been conducted to develop and produce saltwater-powered devices especially for rural and remote communities in Malaysia as well as worldwide. To main objective of this study is to determine the factors that affect the performance of the saltwater energy generation such as electrode's combinations, number of cells and the durability of the electrodes. It was found that the choice of electrodes as anode and cathode does affect the voltage output. However, due to the small power produce, the number of cells must be increased to produce enough power to light up a led light and to provide power to USB port. This paper also conducted a cost analysis of using the saltwater lamp and compared it with a solar system. Although the difference in the cost per hour is very small, there are a number of disadvantages of solar system that need to be aware of. The findings obtained from these experiments will be used to design a prototype of the illumination technology for further product development.

Keywords: Green energy, Sustainable energy, Salt water energy, Salt water lamp, Electrode

1. Introduction

Global warming and the destruction of the environment are two major problems related to the use and extraction of fossil fuels. Other issues include sustainability, economic, political and social problems. This has motivated the use of alternative sources of energy, as well as the search for techniques and technologies to make a more efficient use of it (Fisher & Knutti, 2015 & Renewables Global Status Report, 2016). One of the alternatives to fossil fuels is nuclear energy, which is not without drawbacks. These include safety, waste disposal and weapon proliferation issues.

Renewable energy is a term used to describe a group of energy generation technology derives from natural resources that cannot be depleted and can be replenished in a short period of time. In the World Energy Issues Monitor Report 2017 (World Energy Issues Monitor, 2017), a report that provides snapshot of the world energy agenda from 90 countries,

*Corresponding author: nurulaini.kl@utm.my

renewable energy has always been one of the critical issues that have an impact on the energy sector. While renewable energy accounts for a minority share of the world's energy supply, it is also the fastest growing energy supply in the world. Examples of renewable energy sources include solar, wind, biomass, hydropower, geothermal, and tidal.

From the renewable energy sources available, solar has great potential to contribute to satisfy the world's energy needs. However, despite the reduction in prices of solar photovoltaic (PV) modules and the environmental benefits of using renewable energy sources, many people are still reluctant to adopt solar PV systems as their capital cost is still considered to be too high (Haw et al., 2009 & Muhammad-Sukki et al., 2011). A new promising renewable energy source known as salt-water power has kept the researchers and engineers worldwide busy. Salt molecules are made of sodium ions and chlorine ions. When salt is dissolved in the water, the water molecules pull the sodium and chlorine ions apart. These ions are conductive in nature thus provide a complete circuit for electricity to travel from one electrode to the other as long as all electrodes are immersed in the salt water. With the right combination of electrodes, the salt water will be able to assist the generation of electricity that can be enjoyed by many.

Malaysia is blessed with a land area of 330,000 km2 and a coastline of about 4,800 km with half the coastline is beaches and the rest constitute of mangrove fringed and rocky coasts. In 2001, over 60% of the 23 million Malaysian population during that year live along or close to the coasts (Ong, 2001). These numbers have certainly increased over the years. Some have no access to electricity and have been using diesel generator and kerosene lamp which could cause fire, poses several health risks and harmful to the coastal and marine ecosystem. Bajau people of Malaysia for example have been living their life entirely at sea in stilt houses and houseboats. Some of the houses have functioning electricity and most have none at all. However, they are surrounded by endless supply of seawater. Seawater contains dissolved salts in the form of ions thus offer the possibility of electricity generation using saltwater power. Therefore, harnessing the energy generated from the salt water is vital to improve the socio-economic status of those who lack electricity.

Currently, very limited research has been carried out in Malaysia in terms of harnessing sustainable energy from salt water (Aminuddin et al., 2014 & Liu et al., 2016) and the findings were not well documented. The principle of saltwater energy has been around for centuries. However, the technical issues related to saltwater energy are rarely discussed, as the technology is not fully developed for mass consumption. As saltwater energy comprises of electrodes and salt water, it is important to determine the effect of electrode's combinations, number of cells, durability of the electrodes and salinity of salt water. In light of this issue, National Hydraulic Research Institute of Malaysia (NAHRIM) has collaborated with UTM researchers to explore the potential of salt water as energy source. The main objective of this research project is to produce a cost-effective new illumination technology powered by salt water for rural and remote communities in Malaysia as well as worldwide. Furthermore, this new technology will also functions as a power bank especially in times of flooding which is a common problem in Malaysia during the monsoon seasons. To realize this mission, a thorough investigation on the factors affecting the performance of the saltwater energy product must be undertaken. A prototype of the illumination technology will be developed as the main outcome of this research project.

The new design will consider the users' requirements especially those in rural areas and during flood and it must be designed such that it is functional to generate enough power to light up LED lamp as well as charging up an USB port. The cost to build this product must also be examined to ensure that the new design is cost-competitive, if not low cost, and can be a substitute for the conventional solar applications. Additionally, the new design must also be easily assembled and maintained which minimizes the labour cost and ultimately helps in reducing the cost of the saltwater energy product.

It is expected that this new saltwater energy product has a very potential to become an alternative for renewable energy source considering that 70% of the earth's surface is water-covered with 97.5% being salt water. The final outcome of this project will be a prototype of a saltwater-powered illumination product to deliver stable power supply especially to rural areas allowing a better quality of life.

2. Development of Salt Water Energy Storage

According to United States Environmental Protection Agency (EPA) (U.S. Environmental Protection Agency, 2016) the U.S. citizens throw away billions of batteries annually in the form of single-use batteries as well as rechargeable batteries. This phenomenon is largely due to the rapid increase of usage in battery-operated devices such as mobile phones, remote control toys, laptops and many more. The uncontrollable buildup of batteries waste and improperly disposal of batteries can pose negative impact to the human health and environment due to the toxic components of the batteries e.g. mercury and cadmium.

Recycling of used batteries is one way to reduce the harmful effect of battery waste. However only rechargeable batteries are amenable to recycling, as single-use batteries are more expensive to recycle. Since most recycling facilities are located in Europe and the U.S., which add up to the operational cost of the recycling, the recycling of batteries becomes insignificant in other parts of the world. Moreover, the recycling industries are not without drawbacks. If improper and unregulated method is used to extract the lead or other batteries components, it could produce environmental contamination and pollution, as what has been practiced by many low and middle income countries as shown in Fig. 1 below.

Although lithium-ion battery is more superior to lead acid in terms of performance and more cost effective for long-term consumption, the recycling process of lithium-ion is uneconomical in the meantime. It was reported that less than 5% of used lithium-ion batteries are recycled (Bohlsen, 2018). This is due to the incredibly complex and expensive process of extracting the raw material from the used battery and taking into account all other process involved in the recycling such as neutralization of hazardous compound, smelting and refining of recovered metals, the recycling of lithium-ion batteries is deemed to be unviable (Battery University, 2018).

Saltwater battery is another type of batteries that is suitable for household energy storage. Unlike lead acid and lithium-ion batteries, saltwater batteries do not contain heavy metals that need to be disposed properly at the end of its lifetime. Saltwater batteries rely on the electrolytes process that is safe and can be easily recycled. Moreover, the nature of the saltwater batteries allows them to be discharged fully (100%) without causing any harm to the devices unlike lead-acid and lithium-ion batteries. More studies need to be done in making saltwater battery a safe rechargeable battery and concurrently help to reduce energy cost when using as electrical energy storage (EES) systems (Sangmin et al., 2016).

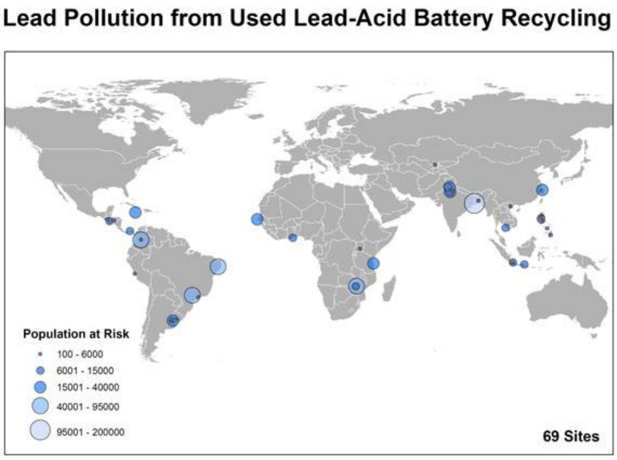
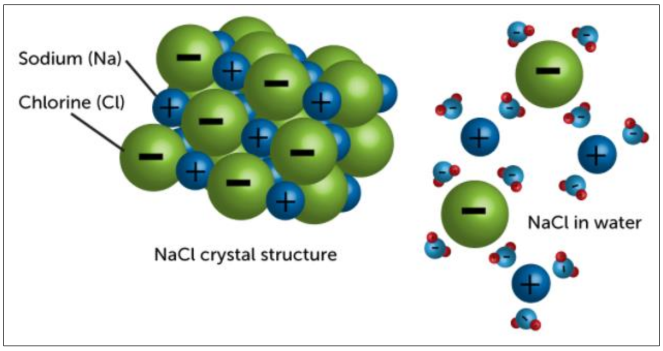


Fig. 1 – World map on the lead pollution from used lead-acid battery recycling. Taken from *Pure Earth* (2011).

2.1 Principle of Salt Water Energy

As the name implies, saltwater energy utilizes one of the many abundant natural resources i.e. salt, either from the seawater or simply mixing up salt and water. Salt or chemically known as sodium chloride (NaCl) is an ionic compound that fully dissolved in water. When the salt is mixed with the water, the water molecules pull the sodium and chlorine ions apart as shown in Fig. 2. These ions are conductive in nature and free to move thus provide a complete circuit for electricity to travel from one electrode to the other as long as all electrodes are immersed in the salt water. With the right combination of electrodes, the salt water will be able to assist the generation of electricity (Ramakanth, 2012). This simple process eventually resulted in generation of cheap energy to be enjoy by many and consequently help to reduce carbon emissions immensely (Gonzales, 2016).



(a) (b)

Fig.2 - (a) The chemical structure of sodium chloride and (b) the separation of sodium and chlorine when dissolved in water. Taken from *CK-12* (2018)

The mechanism of saltwater energy incorporates a galvanic cell, composed of two separate half-cells where each half-cell consists of a metal electrode (known as cathode and anode) and an electrolyte. Both cells are linked together via a semipermeable membrane thus the type of electrolyte used is not necessarily the same. Anode and cathode will be connected to the positive and negative terminal respectively and these two electrodes are required to be submerged in the electrolyte (or in this study, a saltwater solution) for the oxidation reaction to take place. The movement of ions (as a result of oxidation) from cathode to anode create a complete circuit thus allowing the generation of electricity.

2.2 Requirements for Saltwater Lamp

In most of the commercial saltwater lamp available in the market, the galvanic cell is composed of Magnesium (Mg) as anode and carbon air as cathode. Once the Mg electrode has eroded, users will have to purchase the new customized Mg electrode from the supplier of the saltwater lamp. As much as it financially advantageous to the supplier, it creates undesirable problem for those who are living in the rural area. They will have hard time to replace the eroded Mg electrode in order to continue using the electricity due to limited transportation and postal services in their area and since Mg electrode is hardly found in any hardware store, this adds up to the undesirable problem. Therefore, it is vital to develop a saltwater lamp that utilizes electrodes that can be easily found in any hardware store as well as reduced in price. The longevity of a cell also plays an important role in developing an attractive saltwater lamp. For example, assuming a saltwater lamp can generate a maximum of 100 hours of electricity. However this would require the salt water to be disposed from the lamp manually when not in use. If the electrodes are left in the salt water at all time even when not in use, the number of hours of electricity generated will be reduced. Therefore a new approach must be applied that can help to reduce the time-to-corrosion of the electrodes and ultimately help in increasing the life time of the saltwater lamp and eventually reducing the cost of electricity generated from the saltwater energy.

3. Methodology

This section describes the experimental procedure used for this study and the parameters to be studied such as types of electrodes, number of cells, and durability of electrodes. The details of experimental procedure for each parameters to be studied will be explained in this section.

3.1 Types of Electrodes

The objective of this experiment is to determine the type of electrode's combinations that can generate the highest voltage output. There is no standard guideline for measuring galvanic cell but each cell is arranged in series connection in order to increases the voltage output. The voltage and current of the overall cells are measured using a standard method for any electrical devices. Fig. 3 shows the experimental set up for the saltwater experiment. Types of electrodes used in this experiment include Copper (Cu), Aluminium (Al), Ferum (Fe) and Carbon (C). Several combinations between these electrodes are tested (as anode and cathode) and the voltage outputs are measured using multimeter to determine which combination produces the highest voltage output. On average, the salinity of seawater is about 3.5% or 35 gram/litre. However, in this preliminary study, 200ml of tap water is used with 17 grams of salt for every experiment. Thus the salinity of the salt water is 8.5% or 85 gram / litre. Data are collected for 5 minutes during the submerging of electrodes in the salt water.

The experiment is repeated for every combination of electrodes but with 34 grams of salt (salt-water salinity at 17% or 170 gram / litre) and by interchanging the function of the electrodes i.e. from anode to cathode. Data are collected using multimeter for 5 minutes during the submerging of electrodes in the salt water. New salt water and electrodes are used for every experiment to avoid the effect of residual of particles or charges on the electrode from previous experiment. For consistency, all solution are mixed in the same type of containers (same size and material) and all electrodes are of the same length.

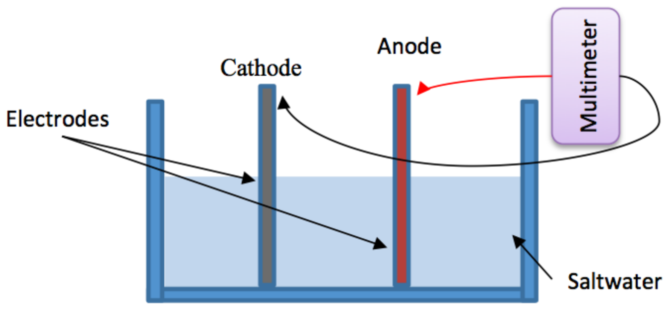


Fig. 3 – Electrolysis saltwater experiment

3.2 Number of Cells

The objective of this experiment is to observe the effect of the number of cells (one cell representing a combination of two electrodes submerge in salt-water solution) towards the voltage output. Once the best combination of electrodes has been obtained, the effect of number of cell is observed by increasing the number of cell with the selected electrodes as cathode and anode (one cell consists of a pair of cathode and anode in a saltwater solution) as shown in Fig. 4. In this study, 5 cells are used. Each cell is placed in separate saltwater solution but each cell is connected in series to increase the number of voltages produced. The voltage and current produced are recorded using multimeter for 5 minutes of submerging the electrodes in the salt water.

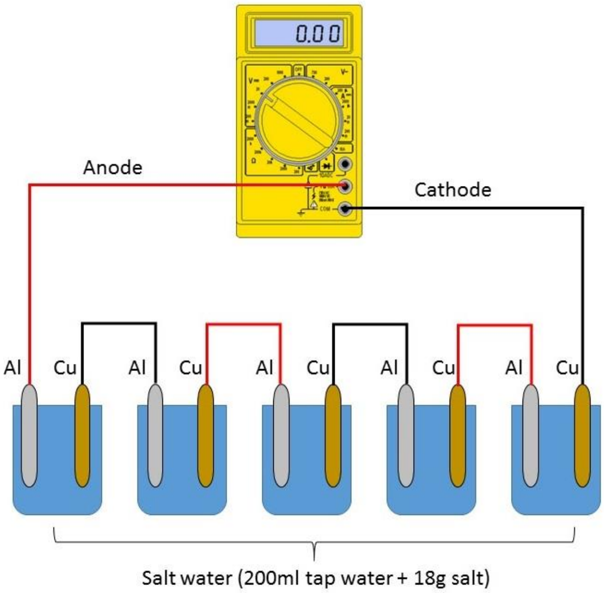


Fig. 4 – Experimental setup for five salt-water energy cells.

3.3 Durability of Electrodes

The objective of this experiment is to measure the durability of electrodes in saltwater solution. To achieve this objective, the changes in the overall weight of the electrode is recorded before and after it is submerged in the saltwater solution for 72 hours. The saltwater solution is made by mixing 200 ml of tap water with 17 grams of salt. Different electrodes of the same length are placed in different saltwater solution.

4. Results and Discussion

4.1 Types of electrodes

Table 1 and Fig. 5 show the experimental result for different types of electrodes combination as anode and cathode. It can be seen that in both saltwater solution (at 17 gram and 34 gram of salt) the combination of aluminium as anode and carbon as cathode (Al – C) produces the highest voltage output. This is followed by the combination of aluminium as anode and copper as cathode (Al-Cu). In the saltwater solution, the aluminum metal oxidizes and reacts with water to form aluminum hydroxide thus produces hydrogen ions and electrons that travel through the outer circuit and generates electricity.

Generally, the voltage output increases with higher concentration of salt in a solution except for the combination of C-Fe. It is interesting to note that the combination of both carbon as anode and cathode (C-C) produces the lowest voltage output. The working voltage or the cell potential is the difference in chemical potential between the anode and the cathode (Liu et al., 2016). The amount of potential difference depends on the ability of the electrons to travel from anode to cathode through external circuit. Two different electrodes with greater difference in reactivity (in a cell) will produce higher voltage output due to high occurrence of oxidation-reduction (redox) activities that releases energy as electrical energy. Therefore, electrodes from the same element with no difference in reactivity such as the combination of C-C will have very little voltage produced or none at all as can be seen clearly in Figure 3.

Table 1 - Experimental results for different electrode combinations

Electrode Combinations	Voltage Output (V)			
	85 gram/litre (8.5%)		170 gram/litre (17%)	
	Min V (V)	Max V (V)	Min V (V)	Max V (V)
Al - Fe	0.093	0.142	0.15	0.229

Electrode Combinations	Voltage Output (V)			
	85 gram/litre (8.5%)		170 gram/litre (17%)	
	Min V (V)	Max V (V)	Min V (V)	Max V (V)
Al – Cu	0.477	0.514	0.548	0.556
C – Cu	0.335	0.342	0.345	0.44
C – Fe	0.489	0.458	0.56	0.597
Fe – Cu	0.058	0.176	0.318	0.289
Al – C	0.751	0.912	0.875	0.923
C – C	0.006	0038	0.016	0.051

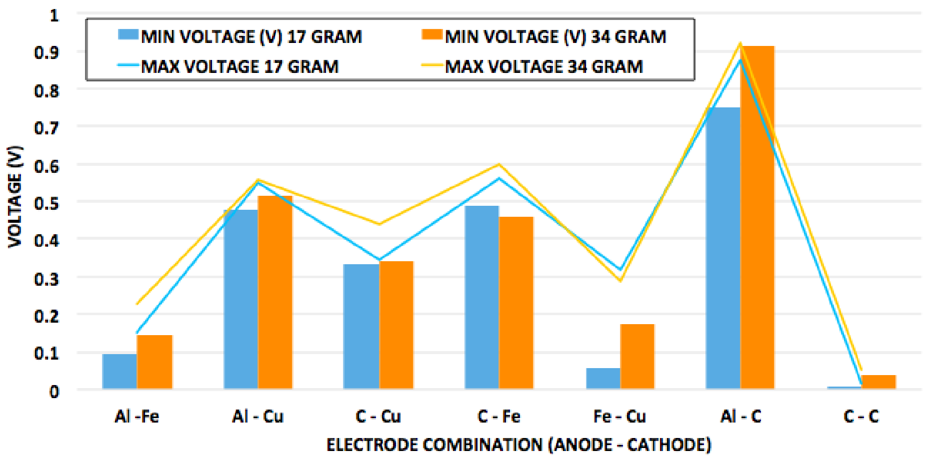


Fig. 5 –The experimental results for different types of electrodes combination

Table 2 and Fig. 6 show the experimental results for interchanging the electrodes combination. It can be seen that the combination of C-Al for both salt concentrations produced the highest voltage output followed by electrodes combination of Cu-Al. Comparing the results from Table 1 and Table 2, the interchanging of electrodes combination produced higher voltage output for combination of Al and Fe, Cu and Fe as well as Al and C. Generally, all electrodes combinations generate higher voltage output as the amount of salt concentration is increased except for the combination of C-Fe, Cu-Al and Cu-Fe. It is noticed that while the salt concentration is doubled, the voltage output did not doubled up, albeit increases slightly (in most cases). Increasing the salt concentration will increase the conductivity and the concentration of ions in the solution. Eventually, it increases the electrons mobility thus contributed to the increased in voltage output.

Table 2 - Experimental results for interchanging the electrodes combination

Electrode Combinations	Voltage Output (V)			
	85 gram/litre (8.5%)		170 gram/litre (17%)	
	Min V (V)	Max V (V)	Min V (V)	Max V (V)
Fe – Al	0.216	0.28	0.32	0.434
Cu – Al	0.508	0.493	0.53	0.536
Cu – C	0.316	0.355	0.329	0.372
Fe – C	0.339	0.379	0.57	0.581
Cu – Fe	0.201	0.17	0.31	0.251
C – Al	0.883	0.918	0.99	0.946

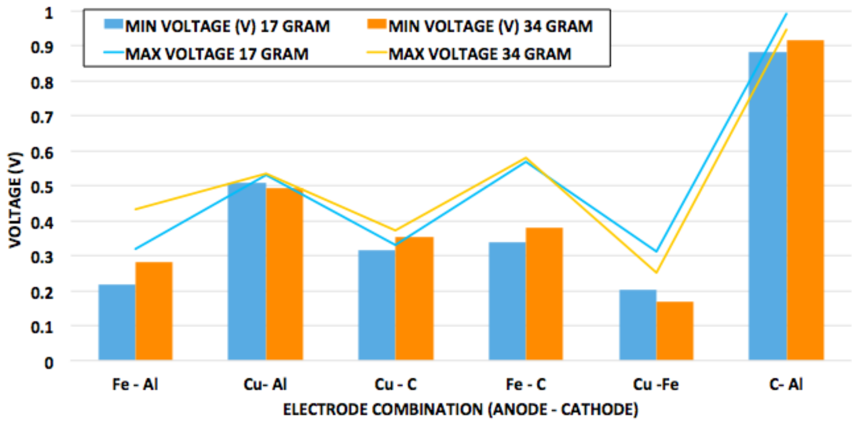


Fig. 6 –The experimental results for interchanging the electrodes combination

The results shown are in agreement with a previous study from (Ramakanth, 2012) where both combination of Al-C and Al-Cu produced maximum efficiency and high voltage output. The study also concluded that the electricity generation from these combinations is cheaper when compared to normal battery (Ramakanth, 2012). This is also supported by a study in (Avoundjian, 2017) where an aluminum/air battery produced an energy density of 8.1 kW/kg at 2.71 V making it superior than other metal/air batteries. Both copper and carbon are commonly used as cathode in galvanic cell for their high efficiency and suitable for the seawater but at the same time can affect the performance of the saltwater energy generation (Hasvold, 1995 & Susanto et al., 2017) Comparison between the experimental results and the standard galvanic series is as shown in Table 3 for combinations of electrodes where the most noble metal is the cathode while the least noble is the anode by referring to a galvanic series table in (StructX, 2014). The value for carbon is referred to graphite since graphite is the most stable form of a carbon. As can be seen from Table 3, there are significant differences between experimental results and galvanic series for all electrode combinations. The differences maybe due to several reasons such as, difference in saltwater salinity, different anode-to-cathode surface area, types of carbon used and many more.

Table 3 – Comparison between experimental results and galvanic series

Electrode Combinations	Voltage Output (V)					
	Experimental (85 gram/litre)		Galvanic series (35 gram/litre)		| Differences |	
	Min V (V)	Max V (V)	Min V (V)	Max V (V)	Min V (V)	Max V (V)
Al - Fe	0.093	0.142	0.18	0.28	0.087	0.138
Al – Cu	0.477	0.514	0.45	0.59	0.027	0.076
Cu – C	0.316	0.355	0.67	0.59	0.354	0.235
Fe – C	0.339	0.379	0.94	0.90	0.601	0.521
Fe – Cu	0.058	0.176	0.27	0.31	0.212	0.134
Al – C	0.751	0.912	1.12	1.18	0.369	0.268

4.2 Number of Cells

Table 4 shows the amount of voltage output for a single cell and for five cells connected in series for electrode combination of Al – C and Al – Cu as these two combinations produced the highest voltage output in the first experiment. As expected, the voltage output increases as we increased the number of cells connected in series. Each cell acts as a single battery cell thus connecting five of them in series increases the voltage output. However the amount of voltage produced is lower than the targeted operating voltage output that is 5V in order to satisfy the charging requirement for a phone battery (using USB 2.0 connection). Therefore, to increase the output voltage, it is suggested that the number of cells is increased or the effect of increasing the electrode's surface area needs to be investigated.

Table 4 – Voltage output for different number of cells

Electrode Combinations	Voltage output (V)	
	Single Cell	5 cells
Al – C	0.751 V	2.7 V
Al – Cu	0.477 V	2.44 V

4.3 Durability of Electrodes

Table 5 shows the weight of Al, C and Cu electrodes before and after being immersed in the 170 gram-saltwater solution for 72 hours. It can be observed that even without the complete external circuit, all electrodes experienced reduction in weight with carbon (C) has the highest reduction in weight and copper (Cu) has the smallest reduction in weight. Carbon is a non-metal element but is very reactive than copper, which is known for its least reactive characteristics. Therefore, the carbon can easily take part in chemical reaction in saltwater solution as compared to copper. This explains the high differences in before and after weight of carbon. From this result, the lifetime of the electrodes can be predicted. Assuming the constant rate of corrosion, the electrodes are expected to last up to 285 days, which is equivalent to 6,840 hours before it needs to be replaced. Therefore it is safe to conclude that the electrodes are able to produce electricity for at least 1000 hours.

Table 5 – Voltage output for different number of cells

Electrode	Weight before (g)	Weight after (g)	Difference (g)
Al	10.42	10.31	0.11
C	9.42	9.3	0.12
Cu	34.65	34.58	0.07

The performance of the galvanic cell (or the saltwater battery) will eventually decrease over the time leading to a shorter life span, owing to the deterioration of the cathode or anode catalysts (Ngayoshi et al., 2016) due to prolong submerging in the salt solution. In most cases (Ramakanth, 2012), a protective paint coating or powder coating are generally used to reduce the time-to- corrosion of the electrodes. However, this may not be suitable for the application of any saltwater-powered devices as it may affect the rate of reaction thus lowering the voltage output. On the other hand it will also add up to the total cost of the power generation since aluminium does not hold paint very well thus require primer for base paint or apply powder coating to coat the surface. Therefore, one cheaper way to increase the lifetime of the electrodes is to develop a mechanism that can automatically separate the electrodes from the salt solution whenever the lamp is not in used. This can be done using “push up” or “twist up” mechanism. The effectiveness of each mechanism will be discussed in different study.

4.4 Cost Analysis

The saltwater lamp is chosen for its low level of maintenance but with enough electricity generated to light up LED lamp as well as charging up an USB port. By taking into account the capital and maintenance cost for 10 years life span of the salt water lamp and assuming that the salt water lamp can produce 5.2 watt-hours (8.5 volt x 0.61 amp-hours) for at least 1000 hours;

Cost of electrodes (cathode and anode) / hour = RM6 / 1000 hour = RM0.006 / hour
Cost of lamp / hour (for 10 years) = RM200 / 87,600 hours = RM0.002/hour
Total cost per hour = RM0.006 + RM0.002 = RM0.008

Therefore the electricity could be produced at a cost of less than RM0.01 / hour. If we consider that the lamp is used effectively only during the night of 8 hours, then the monthly cost for the electricity would be RM2.40. To compare with a 5W solar system where the complete solar system includes a solar panel, a battery and an inverter and assuming that it can lasts for 10 years (equivalent to 87,600 hours);

Cost of a 5W solar panel and inverter = RM350
Cost of battery where the battery life span is 2 years = RM80 x 5 times of changing the battery in 10 years
= RM400
Total cost per hour = (RM350 + RM400) / 87,600 hours = RM0.009

Although the difference is not significant (less than RM0.001), it is worth to note that the type of battery commonly used for solar system is made from lithium thus contribute to the global battery waste problem. Solar energy is also very weather dependent. The efficiency and capability to generate electricity decrease in raining and cloudy days. During the night, no power can be stored from the solar panel but instead user consumes power that is stored during the day. The number of hours of electricity during the night is dependent on how much the energy is stored during the day. Moreover, the depth of discharge of lithium battery is less than the saltwater battery. The energy stored in lithium battery cannot be discharged 100% as compared to saltwater battery. If a lithium battery is discharged 100% every time it is used, the life span of the battery will reduce significantly thus increasing the number of times the battery need to be replaced.

5. Conclusions

This study has been conducted to investigate the parameters that have an effect on the performance of the saltwater energy generation such as electrodes combination, number of cells and electrode's durability in a saltwater solution as part of saltwater lamp product development. It is observed that the combination of aluminium and carbon produced the highest voltage output followed by combination of aluminium and copper. Both of these results are substantial since they can be abundantly found in any hardware store in many forms thus meet the requirement for easy access. However, to satisfy the charging requirement of a phone, the number of cells connected in series must be increased. The study showed an increase in the voltage output as the number of cells is increased although the rate of increment is quite slow. The durability test showed small corrosion in the electrodes when immersed in the saltwater solution for a long time. Although there are viable ways to reduce the time-to-corrosion, however further testing must be conducted to observe the effect of these mechanisms to the overall performance of the saltwater energy generation. The cost analysis has been conducted to determine the cost effectiveness of the saltwater energy. By comparing it with solar system, there is not much of a difference cost-wise. However, the saltwater energy poses more attractive solution. The small amount of cost to produce the energy can help to improve people's quality of life. Children can continue learning at nighttime thus raising education levels while adults can continue making crafts under better lights thus increasing their household income.

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References

[1] Fischer, E. M. & Knutti, R. (2015). Anthropogenic contribution to global occurrence of heavy-precipitation and high-temperature extremes. National Climate Change, 5, 560–564.

[2] Renewables 2016 Global Status Report. (Paris: REN21 Secretariat) (2016). ISBN 978-3-9818107-0-7. Retrieved from http://www.ren21.net/wp-content/uploads/2016/06/GSR_2016_Full_Report.pdf

[3] World Energy Issues Monitor 2017, World Energy Council (2017). ISBN: 978-0-946121-65-6. Retrieved from https://www.worldenergy.org/publications/2017/world-energy-issues-monitor-2017/

[4] Haw, L.C., Sopian, K., Sulaiman, Y., Hafidz, M., & Yahya, M. (2009). Assessment of public perception on Photovoltaic application in Malaysia urban residential areas using Trudgill's framework for analysis. Europe Jounral of Social Sciences, 8, 589–603.

[5] Muhammad-Sukki, F., Ramirez-Iniguez, R., Abu-Bakar, S.H., McMeekin, S.G. & Stewart, B.G. (2011). An evaluation of the installation of solar photovoltaic in residential houses in Malaysia: Past, present, and future. Energy Policy, 39, 7975–7987. doi:10.1016/j.enpol.2011.09.052.

[6] Ong, J.E. (2001). Vulnerability of Malaysia to Sea Level Change. Proceedings of theAPN/SURVAS/LOICZ Joint Conference on Coastal Impacts of Climate Change and Adaptation in the Asia- Pacific Region. Japan: Asia Pacific Network for Global Research, 89-93.

[7] Aminuddin, M.M.M., Balasubramaniam, M., Omar, H., Misran, M.H., Ismail, M.M. & Othman, M.A. (2014). The correlation between salinity and electric voltage. International Symposium on Technology Management and Emerging Technologies (ISTMET), Bandung, Indonesia, 458-461.

[8] Liu, C., Neale, Z. G. & Cao, G. (2016). Understanding electrochemical potentials of cathode materials in rechargeable batteries. Materials Today, 19, 2, 109-123, 2016. ISSN 1369-7021.

[9] U.S. Environmental Protection Agency. (2016). Batteries, Wastes - Resource Conservation - Conservation Tool, Available at https://archive.epa.gov/wastes/conserve/tools/stewardship/web/html/batteries.html

[10] Bohlsen, M. (2018). A Look At The Lithium-Ion Battery Recycling Industry And Companies. Available at https://seekingalpha.com/article/4139266-look-lithium-ion-battery-recycling-industry-companies
[11] Battery University. (2018). BU-705a: Battery Recycling as a Business,. Available at http://batteryuniversity.com/learn/article/battery_recycling_as_a_business
[12] Sangmin, P., Baskar, S.K., Kyoungho, K., Hwang, S.M. & Kim, Y. (2016). Saltwater as the energy source for low-cost, safe rechargeable batteries. Journal of Materials Chemistry A, 4, 7207-7213.
[13] Pure Earth. (2011). Lead-Acid Battery Recycling, Top Ten Toxic Pollution Problems 2011,. Available at https://www.worstpolluted.org/projects_reports/display/90#Footnotes
[14] Ramakanth, S. (2012). Cheaper Electrodes Having Higher Efficiency Using Salt Water And Salt Vinegar Electrolytes. International Journal of Innovative Research and Development, 1, 8.
[15] Gonzales, J. (2016). Renewable energy of the future: seawater. Online article in Quantum Run. Available at https://www.quantumrun.com/article/renewable-energy-future-seawater
[16] CK-12. (2018). Ionic and Covalent Solutes. Available at https://www.ck12.org/c/physical-science/solute-and-solvent/lesson/Solute-and-Solvent-MS-PS/
[17] Avoundjian, A., Galvan, V. & Gomez, F.A. (2017). An Inexpensive Paper-Based Aluminum-Air Battery. Micromachines, 8, 222.
[18] Hasvold, O. (1995). Seawater cell with increased efficiency. U.S. Patent 5 405 717.
[19] Susanto, A., Wisudo, S.H., Baskoro, M.S., Riyanto, M. & Purwangka, F. (2017). Seawater Battery with Al-Cu, Zn-Cu, Gal-Cu Electrodes for Fishing Lamp. International Journal of Renewable Energy of Research, 7(4), 1857-1868.
[20] StructX. (2014). Galvanic Series (Scale of Nobility). Available at http://structx.com/Material_Properties_001.html
[21] Nagayoshi, U., Naoko, S., Mayu, S., Atsushi, K., & Kazuya, W. (2016). Sizes of Anode and Cathode Affect Electricity Generation in Rice Paddy-Field Microbial Fuel Cells. Sustainable Bioenergy Systems, 6 (1), 10-15.