THE EFFECT OF SALTWATER CONCENTRATION ON SALTWATER LAMP EFFICIENCY USING DIFFERENT TYPES OF FUEL CELL

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ABSTRAK

ABSTRAK

Matlamat penyelidikan ini adalah untuk menyediakan untuk membangunkan lampu air masin dan mengkaji kesan kepekatan air masin dan rumput laut yang memberi kesan kepada kecekapan lampu air masin. Pencahayaan adalah perkara asas yang penting kepada semua masyarakat. Bagi seluruh masyarakat, pencahayaan adalah keperluan asas. Walaupun Malaysia adalah sebuah negara membangun dengan kekayaan bahan api fosil, mengelektrik seluruh negara masih menjadi masalah yang besar. Malaysia memulakan pembangunan sumber tenaga boleh diperbaharui untuk mengatasinya. Ini adalah bercanggah dengan rancangan Malaysia 2005. Untuk mengurangkan kesan negatif alam sekitar daripada bekalan elektrik konvensional dan bersedia untuk permintaan tenaga masa hadapan, Malaysia telah membuat anjakan yang kukuh ke arah pengurusan tenaga yang berkesan, penggunaan tenaga mampan dan penggunaan tenaga boleh diperbaharui. Inisiatif ini tertumpu sepenuhnya pada SDG 7: Pastikan semua orang mempunyai akses kepada tenaga moden, murah dan boleh dipercayai. Pembangunan lampu air masin adalah usaha selari untuk menjadikan Malaysia sebuah negara neutral karbon menjelang 2050. Evolusi penggunaan lampu berasaskan teknologi sel bahan api memberi manfaat kepada individu di luar bandar, terpencil, Orang Asli, dan komuniti Felda. Kajian ini memberi tumpuan kepada tahap kepekatan berbeza kecekapan air masin pada jenis lampu sel bahan api air masin yang berbeza. Antara kepekatan air laut, 10g, 15g, 20g dan 30g. . Melalui analisis, hasil pengukuran kekonduksian air laut dan larutan air masin pada pelbagai kepekatan pada awal projek menunjukkan bahawa nilai kekonduksian dan kepekatan air masin mempunyai hubungan linear di mana nilai kekonduksian meningkat apabila kepekatan air masin meningkat. 20g menunjukkan prestasi terbaik dalam kedua-dua Sel Bahan Api Al-Air dan Sel Bahan Api Al-Cu. Walau bagaimanapun, Sel Bahan Api Al-Air menunjukkan prestasi yang lebih baik dengan 20g kepekatan air masin dan mempunyai ketumpatan arus tertinggi 210.47 mA/cm2 dengan ketumpatan kuasa 6067.19 W/m2. Kesimpulannya, kepekatan 20g dengan Al-Air Fuel Cell adalah pilihan terbaik mesra alam untuk menerangi lebih daripada 24 jam. Akhir sekali pada ujian ketahanan didapati plat aluminium telah kehilangan hampir 6.21g dan plat kuprum 0.06g pada akhir eksperimen. Oleh kerana sifat-sifat elektrod Aluminium Al elektrod mengalami pengurangan berat yang paling tinggi selepas direndam dan menjalankan ujian dalam 350 ml air masin dan air laut untuk keseluruhan ujian keseluruhan 101.5 jam jam. Plat elektro diramalkan mempunyai jangka hayat untuk bertahan sehingga 150 jam sebelum ia perlu diganti jika ia dihidupkan secara berterusan. Oleh itu, adalah selamat untuk membuat kesimpulan bahawa elektrod boleh menghasilkan elektrik selama sekurang-kurangnya 6 hari.

ABSTRACT

The aim of this research is to prepare to develop a saltwater lamp and study the effect of concentration of saltwater and seawtwer that impacts the efficiency of the saltwater lamp. Lighting is a basic essential thing to all the community. For the entire community, lighting is a basic necessity. Even though Malaysia is a developing nation with a wealth of fossil fuels, electrifying the entire nation remains a significant problem. Malaysia starts the developing renewable energy sources to get around this. This is in contradiction to Malaysia's 2005 plan. To reduce the negative environmental impact of conventional electricity supply and prepare for future energy demands, Malaysia has made a strong shift toward effective energy management, sustainable energy use, and the deployment of renewable energy. This initiative is entirely focused on SDG 7: Ensure that everyone has access to modern, cheap, dependable energy. The development of saltwater lamps is a parallel endeavour to make Malaysia a carbon-neutral country by 2050. The evolution of using fuel cell technology-based lamps is beneficial for individuals in rural, isolated, Orang Asli, and Felda communities. This study focuses on the different concentration levels of saltwater efficiency on a different type of saltwater-fuel cell lamp. Among the concentration of seawater, 10g, 15g, 20g and 30g. . Through the analysis, the results of measuring the conductivity of seawater and saltwater solution at various concentrations in the initial of the project show that the conductivity values and the saltwater concentration have a linear relationship whereby the conductivity value increases as the concentration of saltwater increases. The 20g shows the utmost performance in both Al-Air Fuel Cell and Al-Cu Fuel Cell. However, Al-Air Fuel Cell shows greater performance with 20g of saltwater concentration and has the highest current density of 210.47 mA/cm2 with power density of 6067.19 W/m2. In conclusion, the concentration of 20g with Al-Air Fuel Cell is the best environmentally friendly option to illuminate for more than 24 hours. Lastly on the testing of durability it founds that the alluminum plate had lost almost 6.21g and copper plate 0.06g at end of the experiment. Due to the properties of Aluminium electrodes Al electrodes experienced the highest reduction in weight after being immersed and run the test in the 350 ml of saltwater and seawater for overall total testing 101.5 hours hours. The electroplate is predicted to have a lifetime to last up to 150 hours before it needs to be replaced if it is turned on continuously. Therefore, it is safe to conclude that the electrodes can produce electricity for at least 6 days.

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LIST OF SYMBOLS

%	Percent
°C	Degree Celsius
V	Voltage
A	Ampere
P	Power
ml	Millilitre
min	Minute
hrs	Hours
kWh	Kilowatt-hours
g	Gram
lx	Lux
CO_2	Carbon dioxide
NaCl	Sodium Chloride
H_2O	Water
Al	Aluminium
Cu	Copper
Na+	Sodium ion
Cl^-	Chloride ion
$Al(OH)_3$	Aluminium Hydroxide

LIST OF ABBREVIATIONS

EIA	International Energy Agency
GDP	Gross domestic product
GHG	Greenhouse gas
DMFC	Direct Methanol Fuel Cell
PEMFC	Polymer Electrolyte Membrane Fuel Cell
AFC	Alkaline Fuel Cell
PFC	Phosphoric Fuel Cell
MCFC	Molten Carbonate Fuel Cell
SOFC	Solid Oxide Fuel Cell
LED	Light-Emitting Diode

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CHAPTER 1

INTRODUCTION

1.1 Background Of Study

Global rapid urbanization and population growth necessitate a constant supply of energy. The global market and economic progress are still influenced by conventional non-renewable energy resources such as fossil fuel-based, oil, coal, and natural gas. According to the International Energy Agency's (EIA) Global Energy and CO2 Status Report 2018, nearly 2.3% which is twice the average rate of energy consumption had risen compared to 2010. Statistically, according to statistics, rising global energy demand has resulted in energy-related carbon dioxide (CO2) emissions of up to 1.7%. (Energy Agency, 2018).Due to the COVID-19 pandemic, energy demand was unstable from 2019 to 2020. The world faces the largest drop in energy demand, of about 4%, in 2020. After the first quarter, all over the world started economic recovery plans which pushes energy demand up to 4.6% and increases 1.5% of the global CO2 emission. (Energy Agency, 2021).

Malaysia also facing a common problem as other countries, since it is oil-producing and has the fourth-largest fossil fuel reserves in Asia Pacifica. As the nation is rich in conventional energy, Malaysia had an energy demand of 18,808 MW in 2020, which expected will be increases to 24,050 MW by 2039. This consequently affects the environment with greenhouse gases, temperature rises, and climate change in Malaysia. A review of Malaysian temperature records reveals a temperature-rising trend. Malaysia’s temperature changes range from +0.70°C to +2.60°C, with precipitation changes ranging from -30% to +30%. This Climate change has had negative effects on human habitats in Malaysia, including the energy sector, agriculture, forests, water resources, coastal resources, and human health. (Rahman et al., 2019)

Malaysia is still dependent on fossil fuels, coal, and natural gas in the industrial, commercial, and residential sectors. The energy sector is a lifeline for a country's economy. For Malaysia to sustain and keep developing in the global market Malaysia's Government comes with action to reduce its dependency on fossil fuels so that could meet future demands by adopting green energy technology. According to a recent study, 20.7% of the total electricity production is supplied for residential usage itself. The average electricity consumption per month is about 345kWh and in 2020, the amount of electricity consumed summed up to 143 billion kilowatt-hours(Sena et al., 2021). The electricity supply and consumption for the residential and domestic sector are one of the country's concerns because it influences the economic improvement and lifestyle of the resident of Malaysia. As a developing country, Malaysia faces energy poverty due to a lack of grid-based electricity supply, especially for remote areas, rural sites, coastal areas, and Orang Asli settlements. Only 77% at Sabah and 67% at Sarawak have electricity supplies while all the urban areas in Peninsular Malaysia receives 99.7% decentralized grid electricity supplies.(Rahim et al., 2010)

A study conducted in the area of Kuala Langat Selangor found that out of 852 Orang Asli villages only 545 have the access to electricity (Norhayati M et al., 2018) and 51.2% of households still use kerosene lamps or "pelita" to lighting their homes(Asasi & Semua, 2010). Poor electricity supply and the absence of proper lighting systems in their household directly impact remote place student education. Certain people's daily activities especially at night hindered due to lack of lighting. Aside from these difficulties, people from Felda and also overall Malaysia face electricity cutoff, especially during the flood seasons. Malaysia has flash and monsoon flood seasons whereby usually states such as Pahang, Kelantan, Terengganu, Johor, Sabah, and Sarawak always get affected. During this season the common problem faced by the victim and rescue team is having a proper light system to resources. Mostly during the flood, the electricity is cut off for the safety of people, but eventually, the remote places lack electricity they suffer from even basic need for light during nighttime. The evacuation centers also often encounter a lack of light or lamps in the centers to look after the victims.

Green technology such as fuel cell systems will be very reliable technology to provide an off-grid and sustainable electricity resource for rural, remote, Orang Asli, and Felda community people. The fuel cell is discovered in 1839 by Sir William Grove, and the up-gradation of the fuel cell research had been developed into a proton exchange, membrane in NASA's Gemini space program by using pure oxygen and hydrogen. Now the advancement of Fuel cells became a booming technology that converts chemical energy to electrical energy which has a high potential energy density. Fuel Cell technology has rapidly grown in recent years and continual research has been undertaken to be successfully implemented in various applications. The operation of the fuel cell is accountable for very less emissions and operates in silence from the existing application such as combustion engines, pipes, and turbine technology(Hsiung & Shang, 2001). The fuel cell also is now known as an electrochemical device that produces electricity through the electrolysis process. The redox reaction in this fuel cell generates electron movement that creates electricity that can be supplied to the load. The fuel cell technology enables proving continuous electricity supplies as long the fuel system is supplied. A fuel cell is composed of an electrode called an anode and a cathode that immerse in an electrolyte that acts as the path for the ions to travel. The anode is responsible for the oxidation process where the electrons that produce will travels to the outer circuit by transmitting the electrical power to the load or through the circuit while the cathode completes the process by undergoing reduction.

The major type of fuel cell that attracts current industries is the application of hydrogen fuel cell due to its environmental advantages. Despite the hydrogen fuel cells benefit from producing electricity with zero-emission and high specific energy than fossil fuels, there are some disadvantages that cause challenges to adapting to the hydrogen fuel cell electrification system. The major challenge is the fuel storage system itself. Storing hydrogen gas needs four times more compare with storage than the fuel cell, especially gasoline storage. On other hand, infrastructure and the finances for constructing hydrogen fuel cells must be considered beforehand. (Hosseini & Butler, 2020)

Thus, to get an alternative way for saltwater and seawater utilization as fuel for fuel cell are highly being researched in meantime. Saltwater and seawater are inexpensive and economically feasible as the construction of a saltwater fuel cell are cheaper compares to the hydrogen-based fuel cell. Salt water energy is not new to producing electricity. The saltwater (NaCl) that is formed by dissolving salt in water is the readily high conductive solution. As the salt is an ionic compound will separate into positively charged (Na+) and negatively charged (Cl-) ions as reacted with the water (H2O). The saltwater will act as a bridge for electron movement in the fuel cell. To create electricity immersing two additional dissimilar metals as anode and cathode is needed. Both metals will aid to transport the electrons that are created by freely moving sodium and chloride ions. As the electron passes from one electrode to another ins starts to create electricity through an external circuit and will power the load. (Bani et al., 2019). The efficiency and the energy production of the salt water fuel cell are influenced by the concentration of saltwater as an electrolyte and the type and number of the electrode inside the fuel cell. The simple terminology of electricity production is shown in figure 1 below:

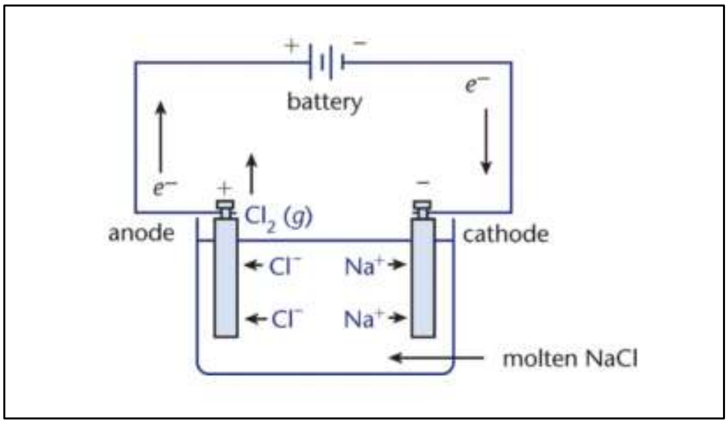

Figure 1.1: Terminology of electricity production using saltwater via fuel cell.Source:(**Hemat More, 2019).**

Saltwater potential to produce electricity intrigue a lot of research to integrate to applicable in powering residential electrical devices. This saltwater lamp is a technology by innovates electrochemical energy through saltwater and Aluminum electrodes to power up the lamp as well to support as a charging device for mobile phones. The focal point of this research is also to develop a saltwater lamp that is cost-effective and produces green off grid electricity to support the rural, remote, coastal, army, jungle tracking, and flood victim community surrounding Malaysia. The investigation of testing of various parameters such as the saltwater concentration effect on the efficiency of the saltwater lamp is comprehensively reviewed. A prototype of the saltwater lamp will be developed as the main outcome of this project. This project is parallel to achieving Malaysia as a carbon-neutral nation by 2050 and also offering off-grid electricity to remote areas.

1.2 Problem Statement

From the year of 2005, Malaysia intensely pivoted the country toward efficient energy management, sustainable energy usage, and the adoption of renewable energy to reduce the environmental impact as well as foresee the needs of future energy demands. The core challenges that the government faces to provide a full grid system for all the remote, coastal, and Orang Asli areas are due to geographical factors. Malaysia's remote, rural, and Orang Asli areas are located around the preserved jungle, mountains, and waterways that don't have similar geography and are far away from the national grid system. Developing the grid system far away from the national grid is not feasible in terms of finances and installation. Building up a grid system will consume high delivery, installation, operation, and maintenance cost.(Vikkren et al., 2017) On the other hand, the social and economic issues faced by the rural and Orang Asli communities. Even providing grid supply electricity can cause financial issues because as the demand increases, the electricity price keeps increasing. Lack of access to electricity directly affects the community's quality of life.

The project Light Up was initiated by ELS Language Centers of Malaysia was reported that 200,000 Malaysian, especially in rural areas still depend on kerosene lamps and candles due to lack of light access. Both types of light resources are highly chance to cause a fire in their house. This is a high threat to the community. On the other side prolonged usage of kerosene lamps causes exposure to substantial amounts of fine particulates, carbon monoxide (CO), nitric oxides (NOx), and sulfur dioxide (SO2) in the user. The after-health effects are impaired lung function and increased infectious illness (including tuberculosis), asthma, and cancer risks. (Lam et al., 2012). Another electricity and lighting constraint highly happens in Malaysia is during a flood disaster. The power provider will normally shut down electric power as a critical service to avert a dangerous occurrence. Daily activities will be disrupted if essential infrastructure systems such as power, phone lines, machines, lighting ((Jamiah Tun Jamil et al., 2018), and other critical infrastructure systems for traffic control, water purification, and hospitals ((Joannelee, 2013) are not available. Bernama news also stated that when there is a flood, the breakdown of electrical distribution machinery might impair energy distribution. Many key tasks or demands cannot be addressed without energy distribution to the building. When a flood happens, it may cause a variety of issues and serious danger(Bernama, 2017). (Suruhanjaya Tenaga (Energy Commission),2015) has identified the hazards of a flood catastrophe to the energy supply system, including power outages, loss of life, and property damage. During this time the victims suffer from not having the basic lighting system for survival.

The potential solution is adapting significant renewable energy (RE) energy resources that could be met. RE is developing energy resources to substitute depletion of fossil fuels and void solutions to overcome climate change. The RE technologies are nobly known for their clean, nondepleting, and low emission of greenhouse gasses. One of the rising green technologies is the development of fuel cell especially hydrogen fuel cell for electricity supplies because it has zero-emission and high energy density. Aside from that, fuel cells have a number of distinct benefits, which are listed in figure 2 below adapted from (Najmi et al., 2009).

1.	Energy conversion efficiency	Potential for a high operating efficiency (typically between 40% to 60% efficiency), and is not dependant on system size.
2.	Scale of design	Highly scalable, modular and compact design based on power requirements.
3.	Fuel/energy sources	Numerous types of potential fuel sources are available, mainly pure hydrogen, natural gas and methanol.
4.	Emissions	Produces zero or near-zero greenhouse emissions.
5.	Moving/rotating components	The cell itself has no moving parts, allowing for quite and highly reliable operation.
6.	Recharge capability	Nearly instantaneous recharge capability compared to batteries.

Figure 1.2: Advantages of hydrogen fuel cells (Najmi et al., 2009)

However, Yet, there are still several challenges that need to be addressed before large-scale implementation. Concerns about its applicability and economic feasibility in the Malaysian context are critical for its effective integration of hydrogen fuel cells into the energy sector. The key hurdles that must be addressed in order to commercialize green hydrogen energy resources are financial and infrastructure issues. The key issue that has to be investigated is the transportation of low volumetric energy density and explosive gas such as hydrogen. As an alternative, liquefaction hydrogen is highly costly and requires a high level of security. Finally, the community's willingness to adapt to this technology is debatable. (Ahmad et al., 2021).

As a result, extensive study has been done on saltwater and seawater as low-cost fuels for harvesting electrical energy utilizing the same principle as the fuel cell technology. Researchers are very interested in using saltwater and seawater energy as a prospective fuel since it is another extremely abundant renewable energy resource on the planet. The difficulty lies in utilizing this resource, which necessitates a thorough examination of the arrangement, size, and placement of anode and cathode that can serve the electricity flow, energy density available with various fuel supply concentrations, and produce appropriate operating output to operate small in-house devices.

1.3 Research Objective

The objectives of this project

1. To design, develop and test the fuel cell saltwater lamp.

2. To determine the effect of concentration of saltwater an sweater on saltwater lamps.

1.4 Scope of Study

This study aims to leverage saltwater energy to power up small devices such as a saltwater lamp. The saltwater battery system is the heart to power saltwater lamps designed in fuel cell working principle to produce an electrochemical reaction which results in electricity production on. The electrochemical reaction in the storage tank happens when the saltwater comes in contact with the electrodes in the saltwater storage tank. The common saltwater battery or sea water battery workers under the galvanic cell principle, where the redox reaction that happens in the storage tank produces chemical energy due to spontaneous reduction reaction into electricity energy. Based on a previous study the electrode that is chosen for the reaction is the Aluminium (Al) and Carbon (C) electrodes combination. This combination recorded the highest voltage output. (Bani et al., 2019). This study focuses on fabricating a small portable type fuel storage tank integrated with an electric circuit that is connected with LED light as a load for this system. Other than that, the study also focuses on investigating various saltwater concentrations to study the effects on the lamp. This the concentration or salinity of saltwater serves bottleneck for the energy density of the fuel cell.

1.5 Significant of study

The principle of saltwater energy exists in the world for over a century but improvising it into a new level of energy can empower renewable energy electricity resources. Saltwater energy is a significant resource that can transform into sustainable energy technology to power up small devices and portable energy storage systems which could beneficial for rural communities. To overcome energy poverty and lack of electricity in Malaysia's rural areas saltwater lamps can be the best alternative portable device. Saltwater lamps are easily accessible low-cost technology that can be adapted by any rural, coastal, or remote area people. On the other side, Saltwater energy is a technological development that restrains intermittent and non-predictable nature since it solely depends only on saltwater or seawater as fuel. This device is very functional for flood victims as well. This device also develops not only concern long-lasting silent power for the community but as emergency lighting to aid flood victims.

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 Conventional Energy Production

The major resources of energy production are fossil fuels, oil, coal, and natural gas. Nearly 80% of these non-renewable energy sources had been fuelling global economies for more than 150 years. The availability of energy is crucial to the growth and sustainability of contemporary society. Energy is a vital component in deciding and managing the progress of every country via social and economic growth, and with it, a good standard of living. Energy is a fundamental input to almost all other consumption and production activities. The increase in energy use and demand is anticipated to coincide with the ongoing modernization of the world.(Koh Kai Seng, 2019)

The same scenario goes for Malaysia. Malaysia having continual huge growth in energy demand for the past decades. Malaysia is noticeable for the constant annual GDP growth which resulted from the significant growth of Malaysia's economy over the last decades. Malaysia is moving forward to be in the process of transforming into a high-income status country. All the initiatives, policies, and planning are associated with the rapid development of this country. This increase in economic activity and growth also denotes a rise in energy demand. As a result, ensuring energy sustainability is crucial for any country, particularly one that is developing as quickly as Malaysia. (Koh Kai Seng, 2019)

Malaysia is a country endowed with tremendous natural resources like fossil fuels. Thus, it should not be surprising that the preponderance of its primary resource for energy supply is produced from fossil fuels. However, the Malaysian government is quite concerned about the rise in energy demand and the severe climate change caused by the high usage of fossil fuels. Malaysia has already begun to change the nation's energy production resources to be more sustainably produced in order to lessen its dependence on fossil fuels. Malaysia is focused on switching to mix energy as well as green renewable energy because it is conscious of the worldwide challenge of climate change and the rise in the global mean temperature. The renewable energy that Malaysia tapping into is solar energy, biomass energy, hydroelectric as well fuel cell technology which is high resilience for future energy demand.

2.2 Fuel Cell

Fossil fuel is the dominant source of energy that produces for application to sectors such as industrial and domestic purposes. The negative impact and the reduction in resilience on fossil fuels cause a paradigm shift in harnessing clean green energy. Renewable energy resources are abundantly available on the earth and can considerably substitute for fossil fuels. Renewable energy is capable of impeding the needs of commercial and domestic usage. One of the potential renewable energy dwellings rapidly in the current renewable energy sector is fuel cell technology.

For many years, batteries have been the primary tool used to store chemical energy that can be easily converted to electricity. Depending on the use, batteries come in a variety of sizes and components. The batteries used to power small home appliances are the focus issues of this study. Batteries typically function as a mini chemical reactor that reacts when an active electron is allowed to pass freely across an external circuit. Batteries had been divided into two main groups. Primary batteries are the first category. Primary batteries are referred to as "single-use" and non-rechargeable batteries. Dry cells and (most) alkaline batteries are examples of primary batteries are the example of Single-use batteries. Secondary batteries are batteries like Nickel-cadmium (NiCd), lead-acid, and lithium-ion batteries.

The fuel cell technology, which is similar to that of batteries in that both require ongoing fuel and oxidizer additions, has made significant strides in the development of these batteries in order to reduce pollution, hazardous waste, high carbon emissions, and to create an electrical current storage system that is more environmentally friendly compares to existing batteries. In the past few decades, the fuel cell has drawn much attention on a global scale as a viable solution to portable energy storage systems that promises a sustainable energy source that plays a significant role in a low-carbon future. The fuel cell is technically referred to as an electrochemical device or energy conversion device since it uses fuel to convert chemicals directly into electrical energy with zero carbon emissions.(Alaswad et al., 2021)

Based on U.S Department of Energy's fuel cell technologies Multi-Year Research, Development, and Demonstration Plan, stated that in 2009 almost 75000 fuel cells were shipped worldwide and the number increased to 15,000 in 2010. The main sector showing the most interest in recent times in fuel cells is the transportation industry. GM, Toyota, Honda, Hyundai, and Daimler, are the automobile manufacturers who had showed major interest on producing fuel cell vehicles. (U.S. Department of Energy, 2012). The same report had been stated that other applications that focus to be integrated into fuel cell energy storage are to support material handling equipment, portable power, hydrogen vehicles, and auxiliary power applications. The interest in fuel cell technology kept increasing because it is a resilient system that helps all countries from depending on imported petroleum, coal, and natural gas. The fuel cell is also a promising technology for future energy security that is capable to produce clean energy out of emission-free fuels that with a lower impact anthropogenic greenhouse gas (GHG) emission has on climate change.(Gertler, 2003)

2.3 Type Of Fuel Cell

In general, there are six primary categories of commercial fuel cells available. The electrochemical principles that underlie all of it are the same, but certain details, such as the type of electrolyte, membrane, and fuel source, vary. The type of fuel cell are Direct Methanol Fuel Cell (DMFC), Polymer Electrolyte Membrane Fuel Cell (PEMFC), Alkaline Fuel Cell (AFC), Phosphoric Fuel Cell (PFC), Molten Carbonate Fuel Cell (MCFC), and Solid Oxide Fuel Cell (SOFC). Among all this fuel cell now for current trend Aluminum-Air Fuel Cells (AAFC) which is form of metal air cathegory is being highly in demand in market and research low cost, a friendly environment, and a high specific energy. In this experiment fundementadal basic set up of fuel cell with AAFC was used as coparable type of fuel cell.

2.3.1 Methanol Fuel Cell (DMFC)

An electrochemical energy conversion system called a direct methanol fuel cell (DMFC) directly transforms the chemical energy of liquid methanol into electrical energy. Consumer electrical equipment that requires portable power can benefit from using Direct Methanol Fuel Cells (DMFCs). To close the growing gap between energy demand and energy storage capacity, a more energy-dense alternative is needed. DMFCs have difficulties such as decreasing methanol. The reactions that take place inside a DMFC are as follows:

Anode: $CH_3OH + H_2O \rightarrow 6H^+ + 6e^- + CO_2$

Cathode: $32\ O_2 + 6H+ + 6e^- \rightarrow 3H_2O$

Overall: $CH_3OH + 32\ O_2 \rightarrow 2H_2O + CO_2$

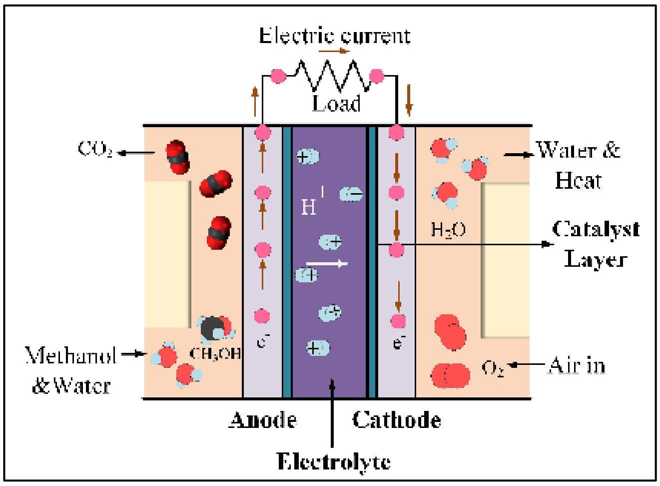

Figure 2.1: Advantages of hydrogen fuel cells Source(Petrovic & Hossain, 2020)

2.3.2 Polymer Electrolyte Membrane Fuel Cell (PEMFC)

A proton-conducting membrane or a polymer electrolyte membrane with strong proton conductivity is sandwiched between two Pt-impregnated porous electrodes in a proton exchange membrane fuel cell, also referred to as a polymer electrolyte membrane fuel cell (Baroutaji et al., 2017). The proton exchange membrane fuel cell (PEMFC) runs between 50 and 100 °C and uses thin polymer sheets as the electrolyte. Membrane-electrode assemblies (MEAs) are the fundamental building blocks and are made of thin polymer. Fuel cells with proton-exchange membranes hold promise for a number of energy-conversion technologies. Due to their high price, which results from the requirement to balance materials, performance, and durability, they have a small market share.(Petrovic & Hossain, 2020)

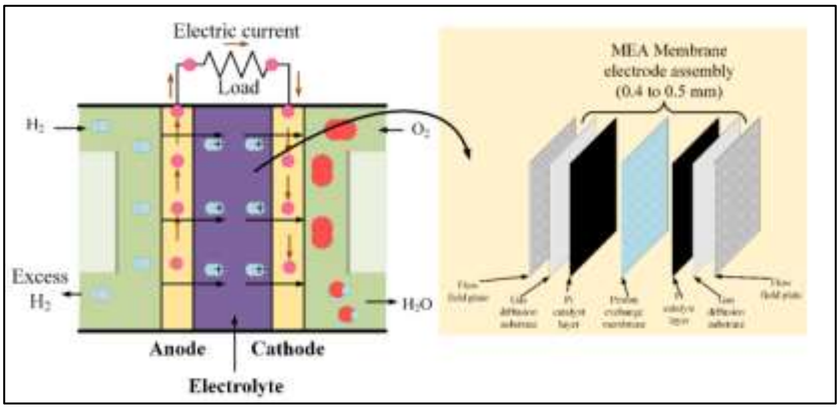

Figure 2.2: Illustration of a PEMFC.Source: **(Petrovic & Hossain, 2020)**

2.3.3 Alkaline Fuel Cell (AFC)

One of the earliest fuel cell types, is alkaline fuel cells (AFC), have a distinguished history of performance in space initiatives. This kind of fuel cell operates between 60°C and 120°C and employs an aqueous, alkaline electrolyte (usually KOH). KOH separates into K+ and OHions in an aqueous solution. On the anode, hydrogen is oxidised, and when it interacts with OHions, it produces water. The load is powered by the flow of electrons through the external circuit. Oxygen combines with water and electrons on the cathode to create OH ions. The electrolyte is therefore not depleted during the reaction. The chemical reaction as bellow :

Anode: $H2 + 2OH- \rightarrow 2H2O + 2e -$

Cathode: $O2 + 2H2O + 4e - \rightarrow 4OH-$

Overall: $2H2 + O2 \rightarrow 2H2O$

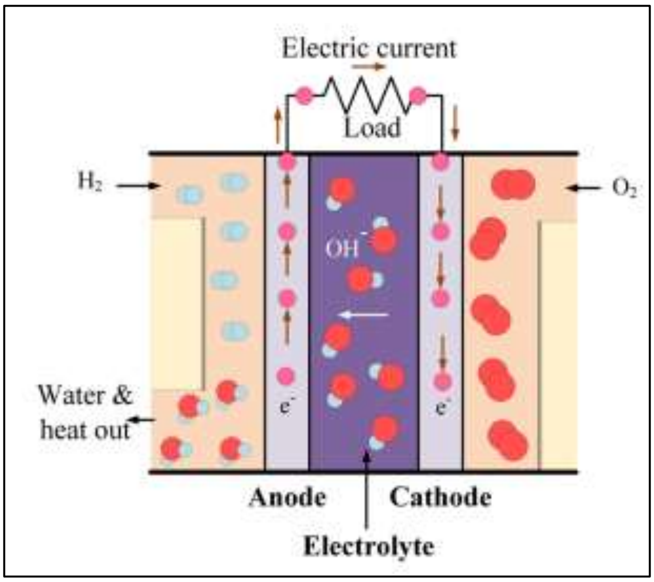

Figure 2.3: Alkaline Fuel Cell (AFC)Source: (Petrovic & Hossain, 2020))

2.3.4 Phosphoric Fuel Cell (PFC)

Phosphoric acid fuel cells employ extremely concentrated phosphoric acid (H3PO4) as their electrolyte, and the platinum catalyst is housed in porous carbon electrodes (Sudhakar, Selvakumar, & Bhat, 2018). Operating at temperatures between 180 and 210°C, phosphoric acid is used as the electrolyte in phosphoric acid fuel cells (PAFC).PAFCs may accept hydrogen fuel with a tiny amount of carbon monoxide because to their greater operating temperature than PEMFC and AFC, which for particular applications can be a huge advantage. PAFC is quite pricey because a platinum catalyst is needed. The public's sense of risk associated with the use of strong acid and the relatively low current density of phosphoric acid fuel cells are their main drawbacks. They have been largely abandoned for these reasons currently, though there are other factors as well.(Petrovic & Hossain, 2020).

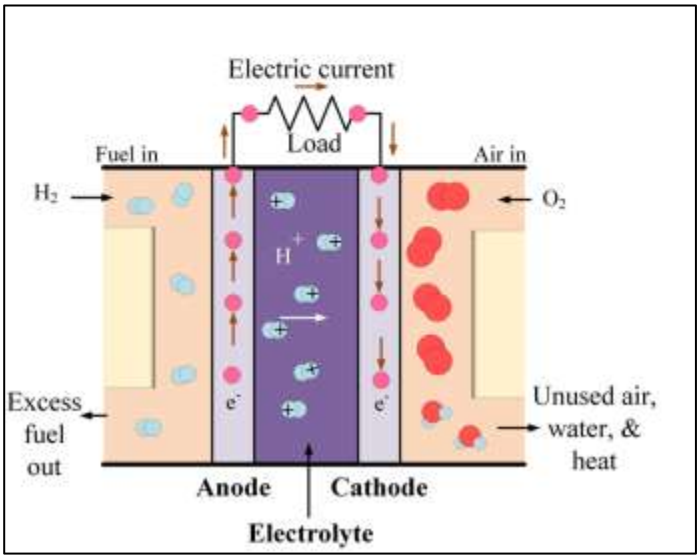

Figure 2.4: Phosphoric Acid Fuel Cells (PAFC)

(Source(Petrovic & Hossain, 2020))

2.3.5 Molten Carbonate Fuel Cell (MCFC)

Molten carbonate fuel cells (MCFC) are also used for identical purposes, and there are prototypes for solid oxide fuel cells (SOFC). The normal operating temperature of molten carbonate fuel cells (MCFC), which utilize molten sodium and potassium, is 650°C. as an electrolyte, carbonate MCFCs can run on fuels besides natural gas, which is transformed into pure hydrogen. Internal reforming, a method, that produces pure hydrogen. MCFCs don't need a pricey catalyst or 100% pure hydrogen and, as a result, are more affordable than other fuels energy cells. In the event that fuels other than pure hydrogen are utilized due to the production of carbon dioxide. These fuel cells are distinguished by especially if the waste heat may be used, by high efficiency used. The reactions taking place in MCFCs are displayed below.

Internal Reformer: $CH_4 + H_2O \rightarrow 3H_2 + CO$

Anode: $H_2 + CO_3^{2-} \rightarrow H_2O + CO_2 + 2e^-$

Cathode: $CO_2 + \frac{1}{2} O_2 + 2e^- \rightarrow CO_3^{2-}$

Overall: $H_2 + \frac{1}{2} O_2 \rightarrow H_2O$

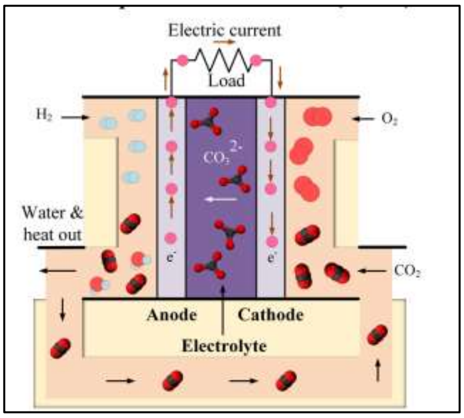

Figure 2.5: Molten carbonate fuel cells (MCFC) ((Petrovic & Hossain, 2020).

2.3.6 Molten Carbonate Fuel Cell (MCFC)

A solid oxide fuel cell (SOFC) is an electrochemical device that uses the propensity of oxygen and hydrogen to react to transform the chemical energy in fuels into electrical energy. Solid oxide or ceramic electrolytes, such as zirconium oxides, are used in solid oxide fuel cells (SOFC) to transport O^{-2} ions. Their operating temperature is greater than 800°C. At the cathode, oxygen is reduced to oxygen ions at such a high temperature. These oxygen ions then move toward the anode through the solid oxide electrolyte and interact with the fuel to oxidise it. Even other hydrocarbons, such natural gas, can be utilised in place of pure hydrogen. Fast reaction speeds and cost effectiveness are two characteristics of SOFCs. Following are the electrode reactions and the total cell reaction:

Cathode: 1 2 O2 + 2e − → O 2−

Anode: H2 + O 2− → H2O + 2e –

Overall: H2 + 1 2 O2 → H2O

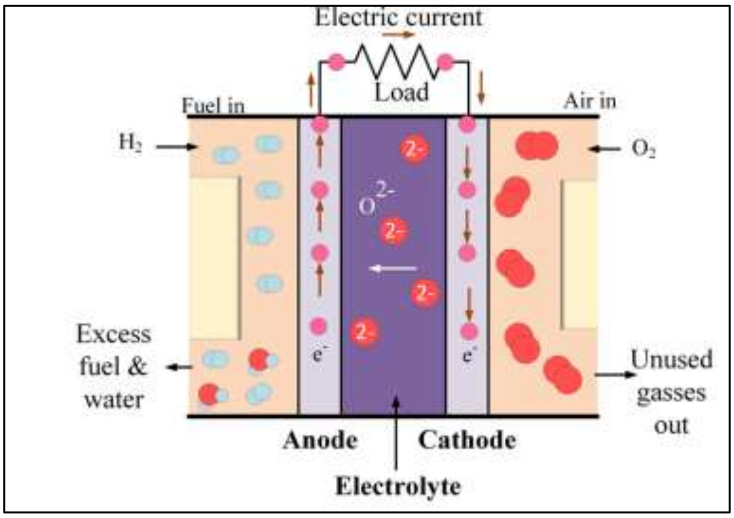

Figure 2.6: Solid Oxide Fuel Cell (SOFC). ((Petrovic & Hossain, 2020).

2.3.7 Aluminium-Air Fuel Cells (AAFC).

Al-Air Fuel Cells are a powerful, lightweight, and inexpensive energy source. In the air, oxygen, and aluminium react to produce electricity and a charge that can be used. For water based AAFC, a neutral or alkaline solution is usually used as an electrolyte. Because the standard electrode potential of Al is lower, about - 2.35 V, alkaline solutions have better discharge performance. However, when the highly reducing Al atoms meet with water molecules (H2O) and hydroxide ions (OH), hydrogen (H2) is quickly released, which greatly reduces the utilization of Al. (Wei et al., 2021). The separator, electrolyte, aluminium anode, and air cathode are the essential components of the aluminium-air battery. To prevent short-circuiting, the anode, and cathode are isolated with a separator. At the air cathode, the primary cathodic reaction is the oxygen reduction reaction (ORR). In the alkaline medium, oxygen is reduced to produce hydroxyl ions (OH). In contrast, electricity will be produced when the aluminium anode reacts with OH to produce Al (OH)4. the battery's overall reaction in aluminium and air. Parasitic loss is a second reaction that takes place in conjunction with the one that occurs on the anode side. Hydrogen will be produced as a side effect of this reaction, which will consume electrons. For aqueous-based aluminium-air batteries that have infinite contact with the aluminium anode and electrolyte, a parasitic reaction is a critical issue. The battery's efficiency and performance will be severely impacted by the corrosion of the aluminium anode. The anode and cathode reaction in AAFC as followed:

Equations for the half and overall reactions:

Anode: $Al(s) + 3OH^-(aq) \rightarrow Al(OH)_3(s) + 3e^-$

Cathode: $O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$

Overall: $4Al(s) + 3O_2(g) + 6H_2O(l) \rightarrow 4Al(OH)_3(s)$

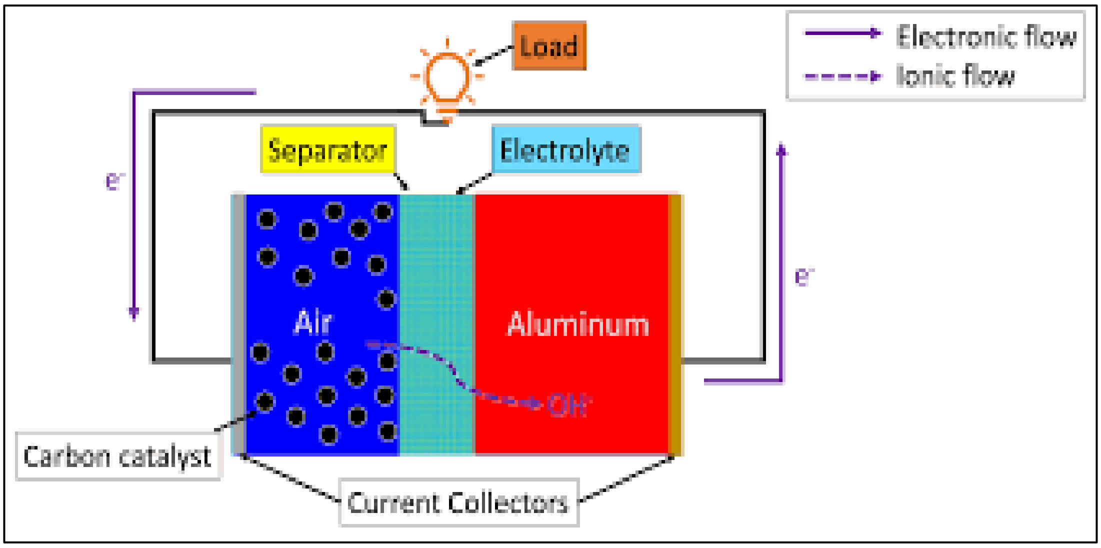

Figure 2.7: Aluminium-Air Fuel Cells (AAFC).

2.4 Electrolysis

A fuel cell works by the electrochemical reaction called electrolysis. Electrolysis is a technique used in chemistry to separate bonded elements and compounds by passing an electric current through them. The electrolysis process happens when two conducting materials are called electrodes with ionically conducting electrolytes. When it comes into contact the two sets of electrochemical reactions will take place at the electrodes. At the cathode, the reduction and anode oxidation will take place. As it is connected with the external circuit the electricity generated through the movement of electrons is used to power up the load. The fuel cell, which is a galvanic-based device that uses spontaneous reactions, chemical reactions are coupled with appropriate half-cell reactions to form negatively charged free electrons for the overall cell process, that can stimulate the production of power through the generation of electricity.

The electrolysis process can be studied through the reaction that happens in a common type of fuel cell energy production such as Proton-exchange membrane fuel cell (PEMFC). In PEMFC hydrogen and oxygen will be used as the main reactant to create an electrochemical reaction between electrodes to produce electricity. An oxygen reduction reaction takes place on the cathode side, while a hydrogen oxidation reaction takes place on the anode side. This entire process can be analyzed through the common hydrogen fuel cell technology as in Figure 2. Hydrogen is the fuel for the fuel cell. Hydrogen is the fuel that acts as the electrolyte that permits the ion exchanges between both electrodes. In a hydrogen fuel cell, there is a catalyst to enhance the ion separation which is called a platinum electrocatalyst. This aids the production of protons and electrons. These electrons will travel through the anode to the circuit and the movement of the electron is called electricity. The cathode is supplied with oxygen and it attracts the proton ions. The reduction of oxygen produces water as a byproduct. The overall process is written in the equation below (Kulkarni & Slaughter, 2015)

The full reaction is mentioned below.

$2H_2 + O_2 \rightarrow 2H_2O$ + energy

Anode Half Reaction:

$2H_2 \rightarrow 4H^+ + 4e^-$

Cathode Half Reaction:

$O_2 + 4H^+ + 4e^- \rightarrow 2H2O$

This electrolysis process has been rapidly growing for the past two decades for electrolytic production, storage, and producing hydrogen as a clean fuel. This electrolysis process known as green chemistry can offers alternate methods for the recycling of chemicals and can give a selective and eco-friendly method for producing electricity. Through the electrolysis process, electrons are redox agents that can carry out clean and quick reactions. Contrary to popular opinion, most applications through the electrolysis process can use cheap reagents or electrolytes for the process. (Scott, 2019).

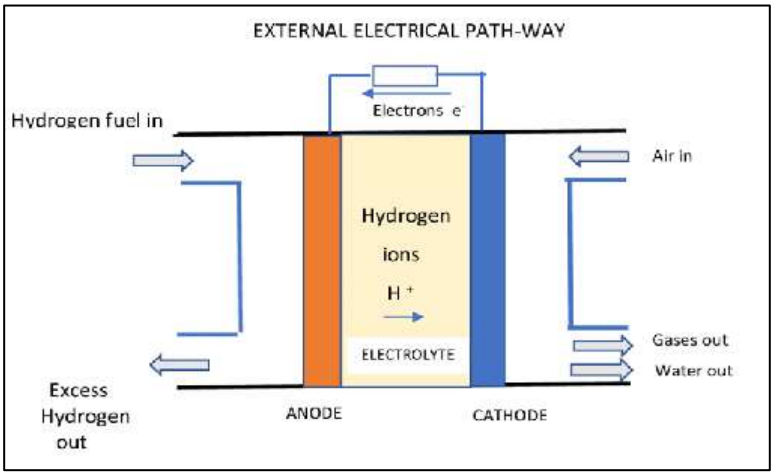

Figure 2.8: Basic Diagram Of Hydrogen Fuel Cell**(Jain & Jain, 2021)**

2.5 Saltwater Energy

The fuel cell is a device made up by constructing with the anode, cathode, and active electrolyte solution to produce the desired output capacity to power up any load. There had been experts conducting various studies on the concentration of the electrolyte, and the development of improved electrode and electrolyte materials. Current major development focuses on improvising and selecting the electrolyte which is the fuel for the fuel cell. The electrolyte is the hearth for the fuel cell that facilitates the electrochemical reaction. The electrolyte's critical function is on transporting the electrons and conducts ionic charge between the electrodes and bridge to complete the fuel cell electric circuit. Another diverse role-play electrolyte in a fuel cell is retaining the ions' ratio between the anode and the cathode exactly in the proper proportion.(*Fuel Cell Handbook (Seventh Edition)*, 2004).

One of the natural and abundant amounts of electrolytes that are available all around the is salt water or seawater. Recently many researchers show their interest my making various research on saltwater energy to power small devices, fishing led nets, power up marine devices as well military devices. Saltwater energy known as the energy

Salt water is an aqueous solution, a mixture of sodium chloride (NaCl) with water. As the NaCl dissolves in water it separates into Chlorine (Cl^-) and Sodium ions (Na^+). When the electrodes are submerged into the saltwater solution natural conductivity is created where the electron flow as well completes the electrical circuit of the fuel cell.

The saltwater in fuel cell it called as brine solution which high in concentration of Na+ and Cl- to initiate the electrolysis process. The ionic equation of saltwater in cell is as follow:

Overall equation: 2NaCl(aq) + 2H2O(l) ==> H2(g) + Cl2(g) +2NaOH(aq)

Ionic equation: 2H2O(l) + 2Cl-(aq) + 2Na+(aq) ==> 2Na+(aq) + 2OH-(aq) + H2(g) + Cl2(g)

When the brine solution reacted with the anode and cathode it produces by product of hydrogen gas, chlorine gas, and sodium hydroxide solution. In the fuel cell, the positive anode draws anions while the negative cathode draws cations toward it. Thus, in saltwater, the cathode attracts sodium ions (Na^+) from saltwater and discharges hydrogen ions (OH^-). At the negative electrode, hydrogen ions are reduced by electron (e-) gain to create hydrogen molecules, which draw in positive ions. The reduction equation is written as below:

Reduction: $2H^+_{(aq)} + 2e^- \Longrightarrow H_{2(g)}$

Negative hydroxide OH- and chloride Cl- ions are drawn to the positive anode from saltwater. Only the chloride ion, which is preferentially oxidized to chlorine, is released in considerable quantities. At the positive electrode, the chloride ions are oxidized by electron loss to produce chlorine molecules, which draw in the oppositely charged negative ions. The oxidation equation is as below:

Oxidation: $\mathbf{2Cl^-_{(aq)} - 2e^- \Longrightarrow Cl_{2(g)}}$ **or** $\mathbf{2Cl^- \Longrightarrow Cl_{2(g)} + 2e^-}$

This reaction creates a free flow of electrons to travel around the external circuit. the movement of electrons creates electricity which powers up the load. The overall reaction can be observed from the diagram below:

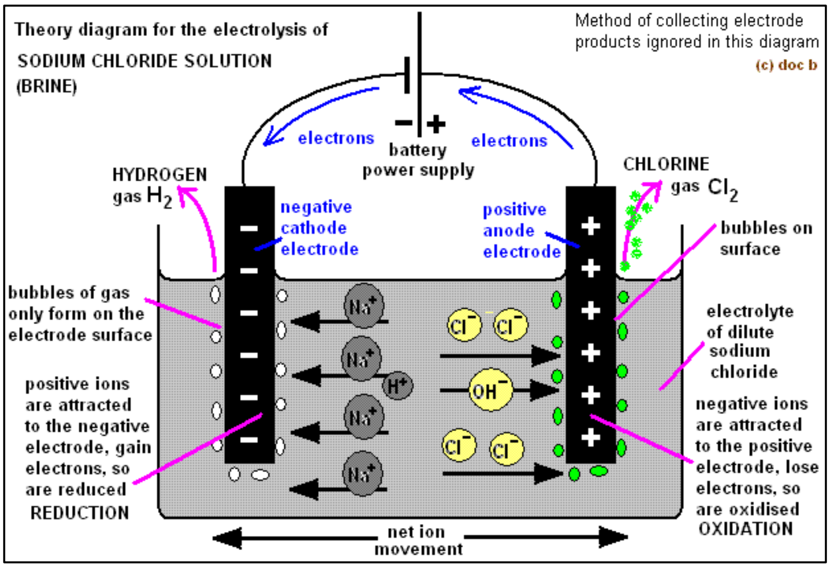

Figure 2.9: Illustration of the electrode reactions and products of the electrolysis of sodium chloride solution (brine). (Source: (Dr Phil Brown, n.d.))

In a saltwater lamp, the electrodes that have been selected to be the anode and cathode are Aluminum (Al) and Copper (Cu). Electrode oxidation and reduction occur as a result of saltwater immersion. When these electrodes come in contact with salt water, Al becomes more electronegative than Cu. According to previous research, in that situation, an electron would flow from the aluminium electrodes toward the LED light, then to the copper cathode electrodes to dissolve oxygen, while in saltwater, an electron-ion would flow from the copper electrode towards the aluminium anode to complete the circuit and replace any lost electrons. In this overall reaction Cu electrode does not really take participate in the reaction, it just aids the electron flows. The anode that consists of an aluminium electrode undergoes an oxidization process by giving up electrons. This reaction causes white precipitation around the cell which is called as Aluminium Hydroxide $Al(OH)_3$. (Chasteen et al., 2008)

Rection at anode: $Al + 3OH^{-} \rightarrow Al(OH)_{3(S)} + 3e^{-}$.

From a study regarding the Study of a Low-Cost Saltwater Lamp for Rural Area had been conducted an experiment on the same combination of aluminium as anode and carbon as the cathode (Al – C). This combination of electrodes is able to produce the highest voltage output. The reaction of aluminum in saltwater produces aluminum hydroxide thus producing hydrogen ions and electrons that travel through the outer circuit and generates electricity.(Bani et al., 2018). This study, it recorded the maximum voltage output was 0.912V in 8.5% saltwater water salinity and 0.923V produced with 17% of saltwater salinity. Another study had proven this combination of electrodes had resulted in 0.7507V and 0.5067A. (Ardel et al., 2019). This proves that saltwater energy is capable to power up small devices like saltwater lamps.

Saltwater as electrolyze can be utilized by a direct electrolysis system. However, according to studies, this system may work under low power density. Using saltwater, causes unmiserable contamination, corrosion, and by-products. Thus, the previous research had been done comparing the electrolysis by utilizing fresh water with low salt content and another test was done using a brine solution. The voltage output of the freshwater cell is 1.84V to 2.25V while brine electrolysis is resultant with 3V TO 4.5V. The summary of the test result is as figure 5. (Abdel-Aal et al., 2010)

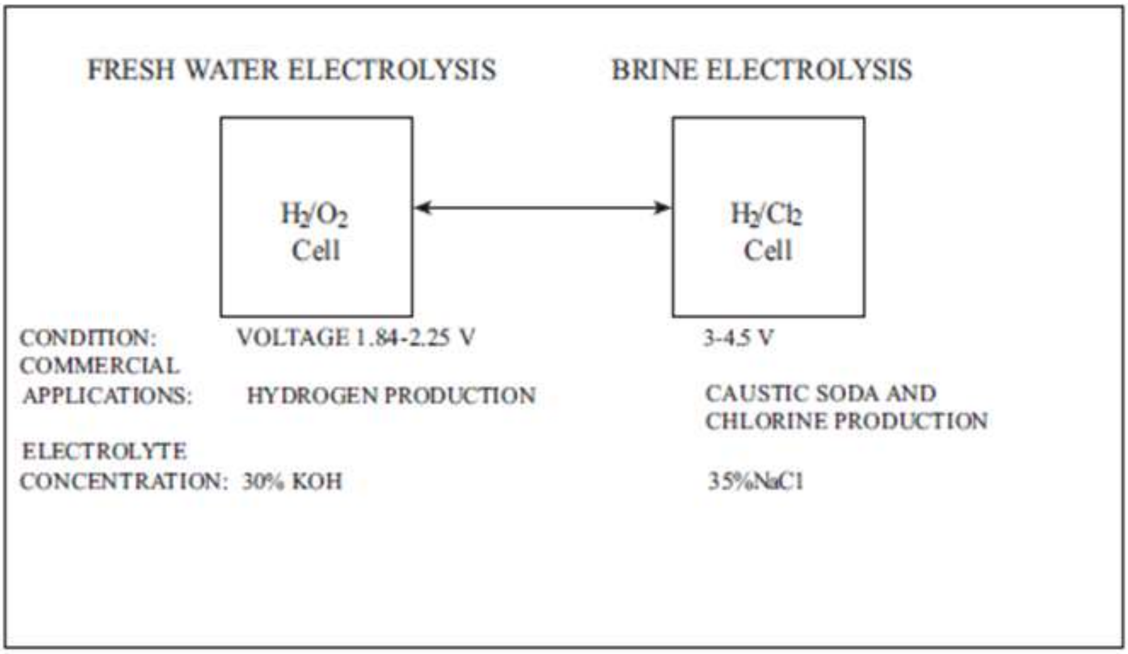

Figure 2.10: Established technology of electrolysis. SOURCE: (Abdel-Aal et al., 2010)

The same research paper had shown the comparison between alkaline water, brine, and as well seawater as electrolytes in a fuel cell to integrate into commercial applications. It shows brine solution which is the salt water is capable to power up commercial devices around 3.0V to 4.5V. The fuel cell able to work under 60°C to 70°C with salinity level 35%. Table 3 below showcase that brine solution electrolysis is a proven technology.

Technology	Conventional Alkaline Electrolysis	Brine Electrolysis	Sea Water Electrolysis
Development sage	Commercial large scale units	Commercial large scale units	Small laboratory scale
Cell voltage (V)	1.84-2.25	3.0-4.5	>2.1
Decomposition voltage(V)	1.47	2.31	2.1
Current density (mA cm^{-2})	130-250	---	25-130
Temperature (°C)	70-90	60-70	23-25
Cathode	Nickel, steel, stainless steel	Ti coated with Pt	Pt
Anode	Ni	---	Pt
Cell type	H_2/O_2	H_2/Cl_2	$H_2/(Cl_2/O_2)$
Electrolyte	25-35% KOH	NaCl	Sea water + drops of HCl
Salinity level	200-400 ppm	35%	3.4%
Chlorine current efficiency	---	95-97%	75-82%
Main product(s)	H_2	Cl_2,NaOH	H_2
By-product(s)	O_2	H_2	Cl_2, NaOCl
Major advantages	Proven technology simple	Proven technology	Low cost
Disadvantages	Low efficiency Low current density Low production cost Corrosive electrolyte	Low efficiency	Within laboratory scale

Table 2.1: Alkaline and Saline Water Electrolysis at a Glance Source:(Abdel-Aal et al., 2010)

Saltwater electrolytes create this much interest from experts on powering up small devices basically because it is an environmentally friendly electrolyte evolution fuel cell system. Seawater is also identified as an electrolyte that cheaper than hydrogen-based fuel cells. A Saltwater energy storage system is integrated to be a saltwater lamp mainly because there is no presence of heavy metals that must be appropriately disposed of at the end of a battery's saltwater lamp. In contrast to lead-acid and lithium-ion batteries, the nature of saltwater batteries allows them to be totally disposed of 100% without endangering the devices.(Bani et al., 2018). Seawater application is well known for low-cost, efficient, and green electricity for various applications that can power even military devices and commercial equipment. Last but not least, saltwater technology is now recognized as a long-lasting, silent source of power for communication devices, lighting for yachts and other marine items, and camping and fishing lantern.(Susanto et al., 2017).

2.6 Salinity

The number of interacting electrolytes has an impact on the fuel cell's effectiveness. The pH level and impendence solution, which in turn generates polarization in the concentration and affects the electrolysis process' efficiency, can modify the final product and output of the electrolysis process.(Merrill & Logan, 2009). Salination is the term for a saltwater concentration. The study of concentration is directly related to Faraday's Law. Faraday's Law stated that the amount of electricity transmitted or charge (coulombs) is directly proportional to the amount of chemical reaction (equivalents) that has occurred at an electrode. The amount of electrical charge that has gone through the electrochemical cell is directly proportional to the mass of a substance created by a redox reaction at an electrode. The same amount of power results in fewer moles of the element with a higher oxidation number for elements with differing oxidation values. Thus, the increases in the electrolyte will increase the number of free ions that is anticipated in allowing a high amount of electrons to produce high voltage.

The concentration of the electrolyte is very essential because, after a prolonged period of operation, increased chloride concentrations would cause the metal components of the fuel cell to corrode and release more free metal ions into the fuel cell storage tank. As a result, the fuel fumes in the cathode would allow metal ions to pass through the cell membrane. This causes the membrane to get contaminated, which has a significant effect on the membrane's conductivity and water transfer coefficient.(Yan et al., 2011).

On the other hand, salinity concentration has a big influence on the conductivity of the electrolytes. Precious study on NaCl conductivity had experimented with 2.5% to 20% of concentration. In that study, it shows the range of conductivity of NaCl solution increases almost more than 300% of the electrical conductivity of the solution. This happens due to the increase in charged ion increases the flow of electrons that creates electricity. Experimentally, conductivity will rise with concentration over wide conductivity ranges.(Shrestha et al., 2017).

A prior investigation of the relationship between saltwater salinity and voltage output was conducted. The findings of this investigation demonstrated that a saltwater battery's voltage output is linearly correlated to the salinity level of the saltwater as it approaches saturation. The study of The Correlation between Salinity and Electric showed the increment of 627 g/1 and 715 g/l of salinity, respectively resultant in producing electricity of 0.396 V and 0.412 V, respectively. (Aminuddin et al., 2014). This can be seen from the result of the experiment below:

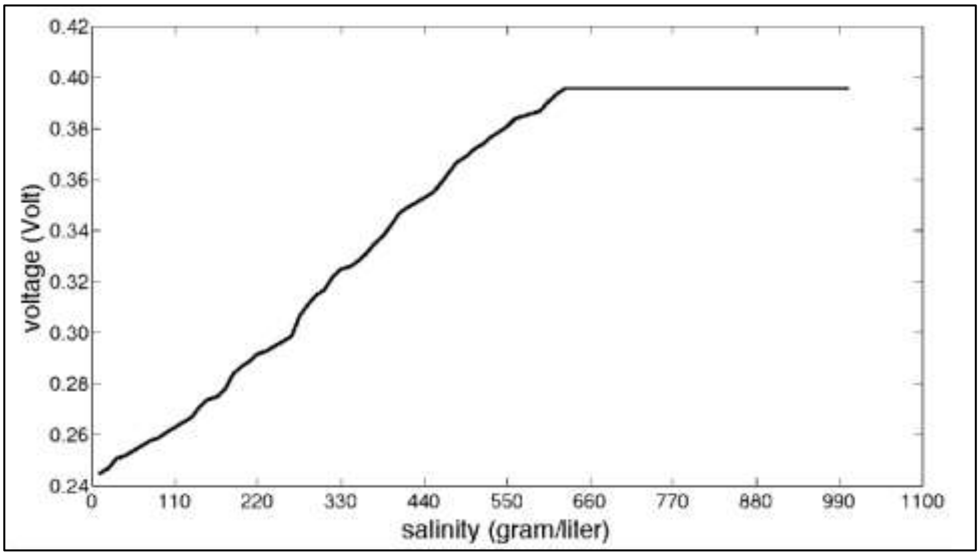

Figure 2.11: The results of voltage measured from white salt water

Source:(Aminuddin et al., 2014).

Similarly, the study on saltwater lamps also showed salinity concentration has a significant impact on the electrical output of fuel cells. This experiment, it shows the voltage output has been doubled when the concentration has doubled. The salt salinity increases when added more salt in the saltwater. This eventually increases the concentration of ions in the solution. As consequence, it creates higher conductivity and electron mobility in the saltwater that rises the voltage output. (Bani et al., 2018).

2.7 Durability of Electrodes

In prolonging the usage of fuel cells, the electrodes which are known as the electrochemically active surface area will start to degrade. The electrolysis process can cause corrosion which knows as a reduction in the weight and thickness of the cathode electrodes. A study showed that the electrodes that are immersed in saltwater over 72 hours have undergone a reduction of surface area and weight loss. In this experiment, the copper has the lesser reduction because it doesn’t take much part in the reaction while Aluminum losses almost 0.11g in total. The combination of electrodes had been studied for a constant rate of corrosion of about 285 days which is equal to 6840 hours proving that the electrodes are durable for a longer period.(Bani et al., 2018)

CHAPTER 3

METHODOLOGY

3.1 Research Work Plan

For this research project, a series of tasks will be carried on. The materials and the experimental procedure had been prepared to develop the saltwater lamp as well as determine the concentration factor that affects the efficiency of the saltwater lamp. All the setup and analytical methods had been clearly shown with details of experimental outcomes. The research framework below in figure 3.1 provided a clear picture of the work until the research will be completely done. In this experiment the voltage and current production due to different concentration of saltwater will be tested using voltmeter and ammeter. The output of power from the saltwater concentration will used to determine the energy density that able to produce buy saltwater lamp. The initial weight of electrodes and final weight of electrodes will be analysis by using weighing scale to determine the corrosion or weigh loss of electrode. Finally, the total duration of the saltwater lamp able to switch on will be determine in term of hours.

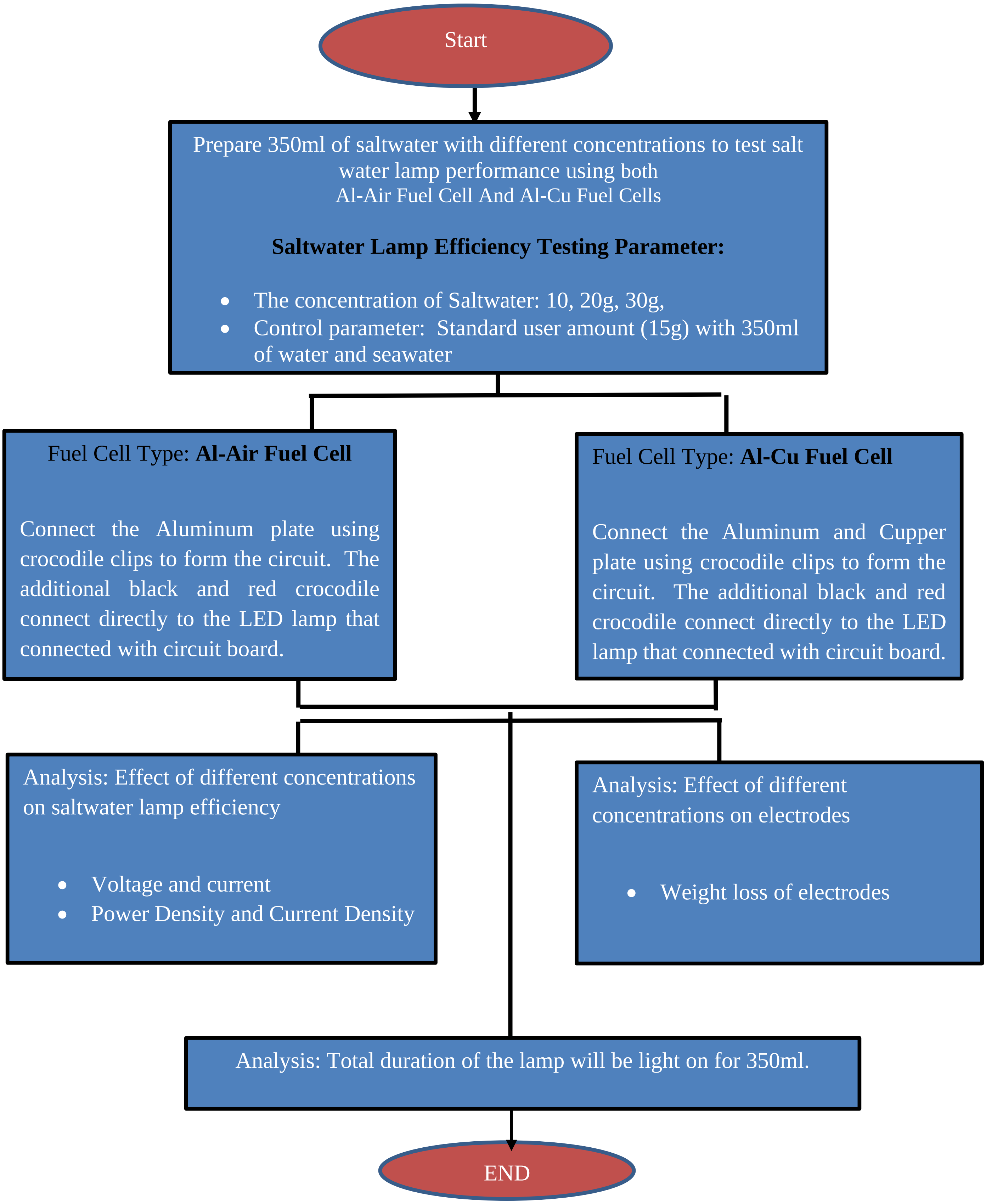

Figure 3.1: Research Flow Work

3.2 Experiment Set-up

Then the circuit bord will be fixed on the water tank by connect to the connector which hold the electrodes. The connector will hold electrodes. The external part of the lantern which is made from collapsible rubber will be fixed with the handle to hold the lantern lamp. Finally, the entire set up will be check on the connection made with the circuit board by using digital multi-meter and crocodile clip. The crocodile clips hold all the electroplate while the the pin from multimer will be sue directly to the wire of led to take the reading.

3.3 Parameter Studies

The effect of salinity concentration of salt water on the efficiency of saltwater lamp will be investigated. To isolate the influence of a given parameter on degrading efficiency some factors must be held constant during the research of these parameters. The electrolyte will be prepared by using 350ml of freshwater every time to prevent any contamination. The testing period of current and voltage production will be tested interval of 5min about overall period of 30min.

3.4 Salinity Concentration

Using digital weighing scale 10g, 15g, 20g, 25g and 30g measured separately. The salt that prepared separately will be added into five 500ml beakers with 350ml of water. This electrolyte will be stirred until the salt is completely dissolves. One additional beaker will be filled with seawater that will be collect from beach located at Teluk Cempedak, Kuantan, Pahang for set as standard solution. Every solution is maintained at room temperature with pH value of 7 for optimum electrical conductivity to be created. Every electrolyte concentration, salinity, electrical conductivity will be tested by using Waterproof IP67 Salinity Meter and will be recorded.

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3.5 Sample Analysis

The sample analysis will start by testing using 350ml of seawater the standard electrolyte solution. The voltage and current reading will be recorded using multimeter by clipping the multi-meter clips to the connector of the saltwater lamp that connected to the circuit board and holds the electrodes. While light illuminance will be measured by using Lux Meter. All parameters will be recorded in time interval of 1 min and 5 min. The same procedure will be repeated for 10g, 15g, 20g, 25g and 30g of salt solution. The decreases in voltage and current output as the experiment prolonged from 1 min to 5min due to the discharge characteristic. (Bani et al., 2019). For each mole of saltwater solution, 2 moles of electrons are passing the electric circuit. According to the Faraday's constant number of electrons and charge commonly used is F = 485,96 coulombs/mole of electrons. As per this experiment is to turn on the load, the LED light by supplying current through the fuel cell. The power deliver by saltwater in the fuel cell will be calculated using the equation 1. The current density of the saltwater lamp produce will be measured using the equation 2. With the power determined the rate of energy transfer per unit volume (energy density) will be calculated using the formula in equation 3.

Power (P)= (V) * (I)………eq(1)

Whereby,

V = Voltage

I = Current

$$\textit{Current Density} = \frac{Current\ (mA)}{Surface\ Area\ (cm^2)} \quad \text{……………eq(2)}$$

Power Density = $\frac{\boldsymbol{OUTPUT\ POWER\ (kw)}}{\boldsymbol{FUEL\ CELL\ VOLUME\ (m^3)}}$***........eq(3)***

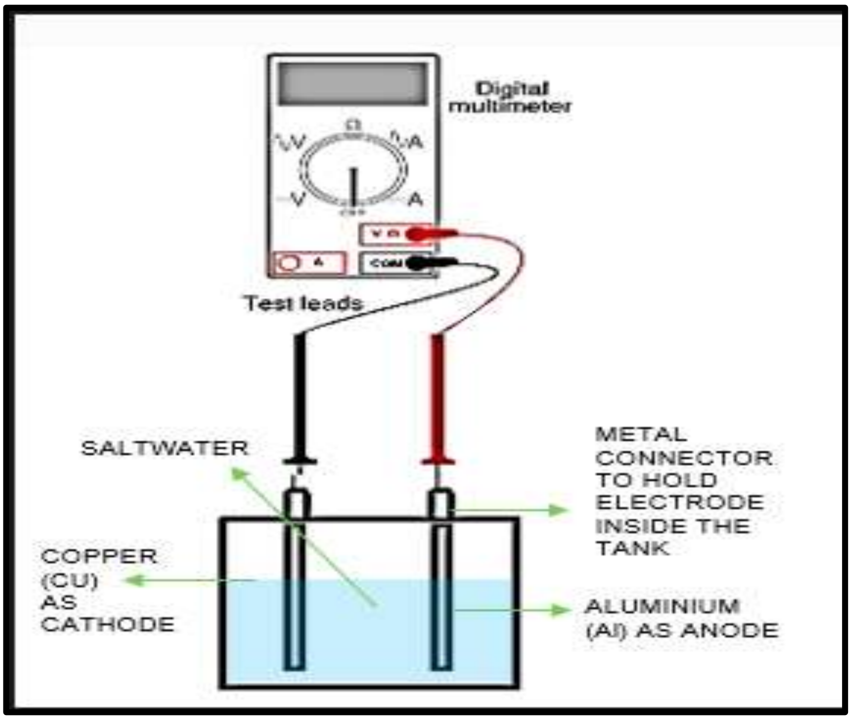


Figure 3.2: Sample Analysis Set Up

3.6 Durability and Saltwater lamp running duration.

The saltwater lamp that connected with electrodes will be tested on potential operational time in term of hours. The constructed saltwater lamp will be kept feed with saltwater solution till the electrodes undergoes galvanic corrosion whereby the the electrode electrically conductive in saltwater solution and gives ups atom. As the time the electrode completely degraded in saltwater, the duration will be taken as duration where the saltwater can completely run before the replacement of new electrode needed. These durations will be calculated in term of hours.

3.7 Expected Outcome

1. Develop and provide saltwater lamps that can replace kerosene and dry-cell batteries to become environmentally friendly.

2. Saltwater lamps can operate within 24 hours with the appropriate amount of salt.

3. Develop portable and user-friendly Saltwater lamps that can be easily used by the local community.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This study was carried out in order to achieve the three main objectives outlined in section 1.3. The study's results are presented and discussed in this chapter in relation to the study's goal, which was to analyse effect of concentration of saltwater and sweater on saltwater lamps lamps. Moreover, the data discussed from the second objective of the study which was evaluating the efficiency of different type of fuel cell when the concentrations varied. Lastly, the study aimed to determine the durability and the changes on the electroplate. It is also to determine the lifespan of electrode before it need to be change. These aspects were discussed in the previous chapter, which presented the study's methodology. Throughout this chapter, the results for each area elaborated on and discussed.

4.2 Salinity Concentration of salt water (Electrolyte)

This section discussed the first objective of the study which was to determine the effect of different concentrations on saltwater lamp efficiency in terms of the electrical conductivity of the electrolyte as well the voltage production. The data was collected in two different setups. The first set-up was with four aluminum electrode plates while the second set-up was with two aluminum and 2 copper plate. For both set up the concentration of the electrolyte was standardized. For standard electrolytes, seawater and 15g of salt were used. 15g salt is approximately 2 spoons of salt that has been used to light up the saltwater lamp available in the market. For the future study 10g, 20g and 30g of salt were diluted in 350ml of water to create a different concentration of the salt solution. The unit of measurement used was in ppt, the number of parts, or grams, of salt per thousand parts (ppt), or kilogram (1,000 g), of seawater, is known as parts per thousand. The symbol for parts per thousand is similar to the symbol for percent (%), which is parts per hundred. With an additional zero in the denominator **ppt** is a common abbreviation for parts per thousand. Thus, in this experiment all the concentrations in part per thousand (ppt)(US Department of Commerce, n.d.). The average salinity of seawater is close to 35 grams of dissolved salts per litter. It is expressed as 35 ppt, or 35 grams per kilogram of seawater. The average ocean salinity is between 33 and 37 grams per litter. Throughout the experiment the respective concentration starts to change as the during electrolysis reaction occurs to produce voltage. The respective range of the concentration of the salt solution is listed in table 4.1 below:

Amount of salt	**Before Testing Theoretical salt Concentration (ppt)**	**During of salt Max Concentration (ppt)**	**During Testing Min Concentration (ppt)**
Seawater	3500	29.5	13.6
Standard user (15g)	$5.25x10^{7}$	31.7	20.5
10g	$3.5x10^{9}$	62.6	17.1
20g	$7.0\ x10^{9}$	67	25.8
30g	$1.05x10^{10}$	68.1	58.6

Table 4.1: Salt concentration of saltwater and seawater

4.3 Salinity Concentration and Electrical Conductivity of Saltwater Lamp Over Time Analysis

The concentration of salt solution plays a major role in the electrical conductivity level as good the production of voltage in the saltwater lamp. As previously discussed, the concentration of salt is referred to as salinity, indicating that there are significant amounts of dissolved salts in the water. In contrast, conductivity refers to the capacity of water to carry an electrical current. The dissolved ions serve as the conductors. In simple words the capacity of an aqueous solution to transmit an electrical current is known as conductivity. Positive and negative ions are formed when salts that dissolve in water react with one another. In a fuel cell, this dissolves ions in the electrolyte and is free to move while negative charged particles migrate toward the positive electrode. The migration of the charged particles causes the electric current to flow in liquid.(Golnabi et al., 2009) Thus the conductivity and salinity measurements are related because dissolved ions increase both. Through the analysis, the results of measuring the conductivity of seawater and saltwater solution at various concentrations in the initial of the project show that the conductivity values and the saltwater concentration have a linear relationship. As can be seen in Figure 4.1, the conductivity value rises in proportion to the concentration.

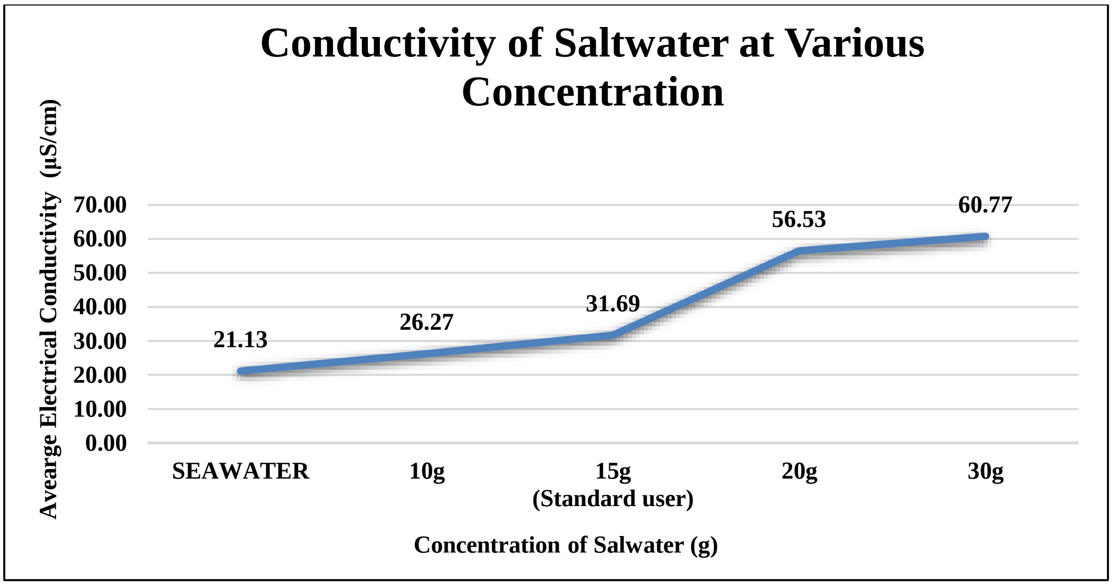


Figure 4.1: Conductivity of Saltwater at Various Concentration

According to theory, measurements showed that the conductivity of the solution increased with increasing concentration of solution. Ion migration in NaCl solution will be accelerated by the high concentration of NaCl. As a result, the solution's conductivity value will rise in proportion to its concentration.(Widodo et al., 2018)

4.4 Salinity Concentration and Electrical Conductivity of Saltwater Lamp Over Time Analysis

To study the conductivity level and voltage production the LED saltwater lamp was run with different concentrations for a total time of 30 minutes with an interval of 5 min. The table 4.2 and 4.3 shows the electrical conductivity of the saltwater in µS/cm and voltage in volts which is respective to the Aluminium-air fuel cell (Al-Air Fuel Cell) as well as the Aluminium-copper fuel cell (Al-Cu Fuel Cell.)

TIME (min)	*PARA-METER*	*SEAWATER*	*USER LEVEL (15G)*	*10G*	*20G*	*30G*
0	EC	139.8	187.8	107.8	127.8	227.8
	V	3.21	2.71	2.71	3.26	2.83
5	EC	123.8	187.8	119.8	103.1	235.8
	V	3.23	2.79	2.72	3.26	2.83
10	EC	163.8	171.8	51	107.3	235.8
	V	3 .30	2.81	2.74	3.44	2.82
15	EC	143.8	171.8	30.6	183.8	227.8
	V	3.31	2.8	2.74	3.41	2.82
20	EC	155.8	175.8	55.6	191.8	219.8
	V	3.31	2.82	2.76	3.42	3.2
25	EC	147.8	163.8	56.6	119.8	227.8
	V	3.38	2.83	2.77	3.62	3.8
30	EC	155.8	155.6	23.8	195.7	274.8
	V	3.56	2.85	2.77	3.92	4.05

Table 4.2: Electrical Conductivity and Voltage of Aluminium-Air Fuel Cell (Al-Air Fuel Cell

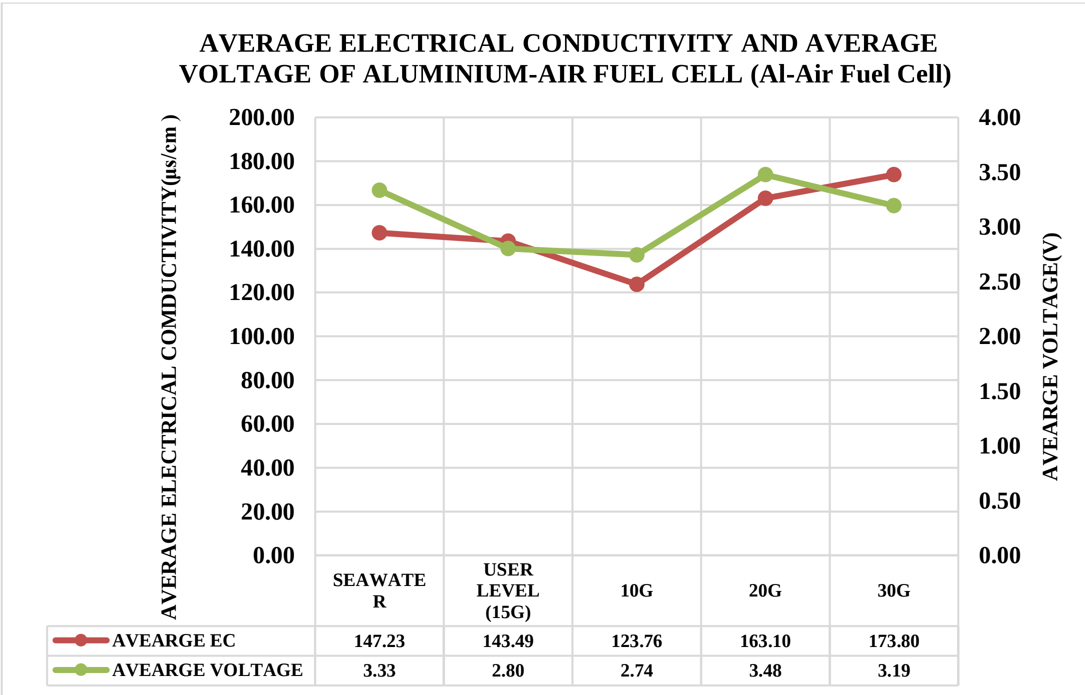


Figure 4.2 : Average Electrical Conductivity And Average Voltage of Aluminium-Air Fuel Cell (Al-Air Fuel Cell)

TIME (min)	*PARA-METER*	*SEAWATER*	*USER LEVEL (15G)*	*10G*	*20G*	*30G*
0	EC	83.80	79.8	147.80	191.80	215.8
	V	2.79	2.68	2.89	2.70	2.66
5	EC	83.80	83.80	147.8	183.80	227.8
	V	2.79	2.67	2.92	2.63	2.62
10	EC	78.20	78.20	151.6	179.80	215.8
	V	3.27	2.67	2.77	2.58	2.22
15	EC	70.60	70.60	111.00	183.80	203.8
	V	3.7	2.69	2.94	3.26	2.48
20	EC	75	75	136.80	187.80	219.8
	V	3.73	2.66	2.87	2.58	2.48
25	EC	76.60	76.60	147.80	183.80	219.8
	V	3.74	2.8	2.96	2.64	2.45
30	EC	73.4	73.4	191.00	187.80	219.8
	V	2.79	2.72	2.79	2.70	2.44

Table 4.3: Electrical Conductivity and Voltage of Aluminium-Copper fuel cell (Al-Cu fuel cell.)

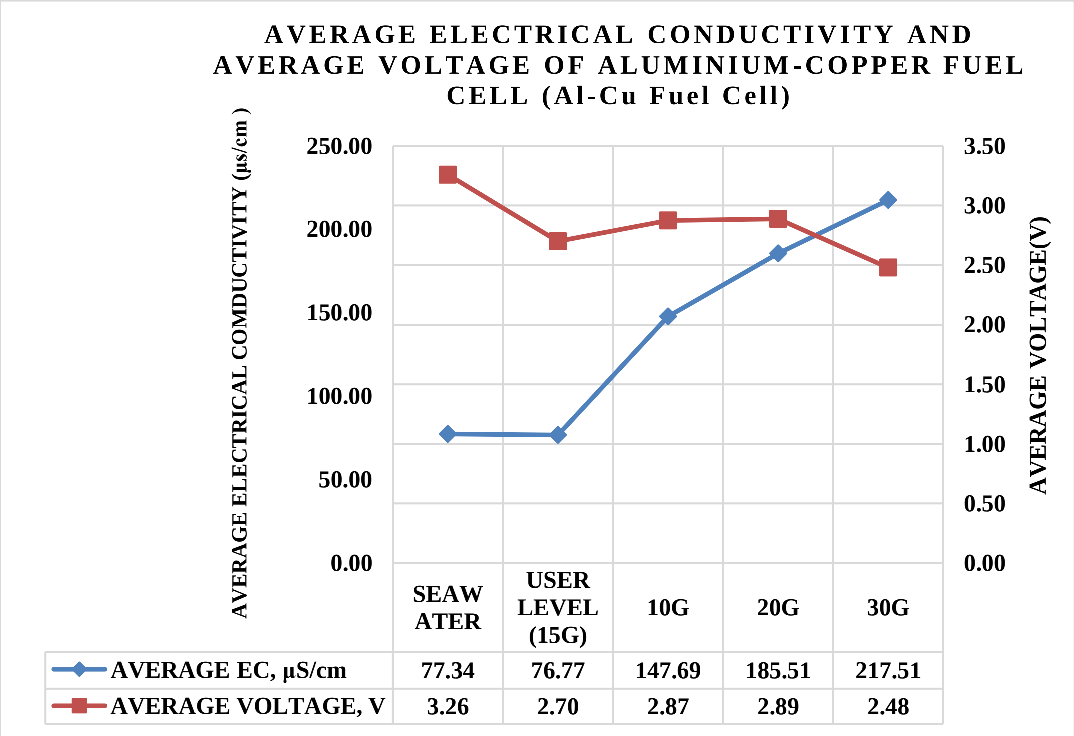


Figure 4.3: Average Electrical Conductivity And Average Voltage of Aluminium-Copper Fuel Cell (Al-Cu Fuel Cell)

Based on the result from table 4.1 the highest electrical conductivity while usingr in Al-Air Fuel Cell was 155.8µS/cm but it produces 3.21V only. The highest voltage that able to produce by seawater was at its 20th min with 75µS/cm, which was about 3.73V. The standard user amount in the market which is 15g has shown the highest reading on its 30th minute with 155.6µS/cm that produce 2.85V output voltage. Other than this concentration Al-air fuel cell's highest output voltage for 10g, 20g, and 30g was 2.77V, 3.62V, and 4.05V. All the highest voltage recording was in the time range of 25 minutes to 30 minutes of the experiment. During the time range, the electrical conductivity for 10g, 20g and 30g was 56.6µS/cm 195.7µS/cm, and 274.8µS/cm respectively. For the Al-Cu Fuel Cell, the highest electrical conductivity while using seawater was 83.80µS/cm from the beginning till 1st 5 minutes. However, the highest voltage output of 3.74V was produced at 25th minute with 76.60µS/cm. The standard user amount has shown the highest output voltage of 2.8V on its 25th minute with electrical conductivity rate of 76.60µS/cm. The highest voltage output for Al-Cu Fuel Cell also similar with the Al-Air Fuel Cell's time range whereby from 25th minutes to 30th minutes. During the time range the 10g, 20g and 30g has the highest voltage power of 2.77V, 3.92V and 4.05V.

To study the trends of the electrical conductivity (EC) and output voltage(V) of both Al-Air Fuel Cell and Al-Cu Fuel Cell, the average EC and Voltage values were determined over a complete 30min of experiment and plotted in the graph presented in Figure 4.2 and Figure 4.3. Figure 4.2 can analyze the lowest average EC reading by 10g of salt which produces the lowest voltage output of 3.48V. The highest EC value was by using 20g of salt which gives an optimal voltage output of 3.48V. The seawater as standard concentration has the second highest voltage output of 3.33V. when we compare this data with figure 4.2 for Al-Cu Fuel Cell, the user standard amount of 15 g produces the lowest voltage of 2.70V with 76.77µS/cm of EC value. The optimal output voltage produced by the fuel cell was 2.89V with 185.51µS/cm of EC. For the seawater, the performance of the fuel cell gives out of 3.26V which is higher than the standard user level of 2.70V. This comparative analysis shows 20g of salt produce the highest voltage output for both type of fuel cell system, however, the Al-Air Fuel Cell has the optimum output voltage to light on the light.

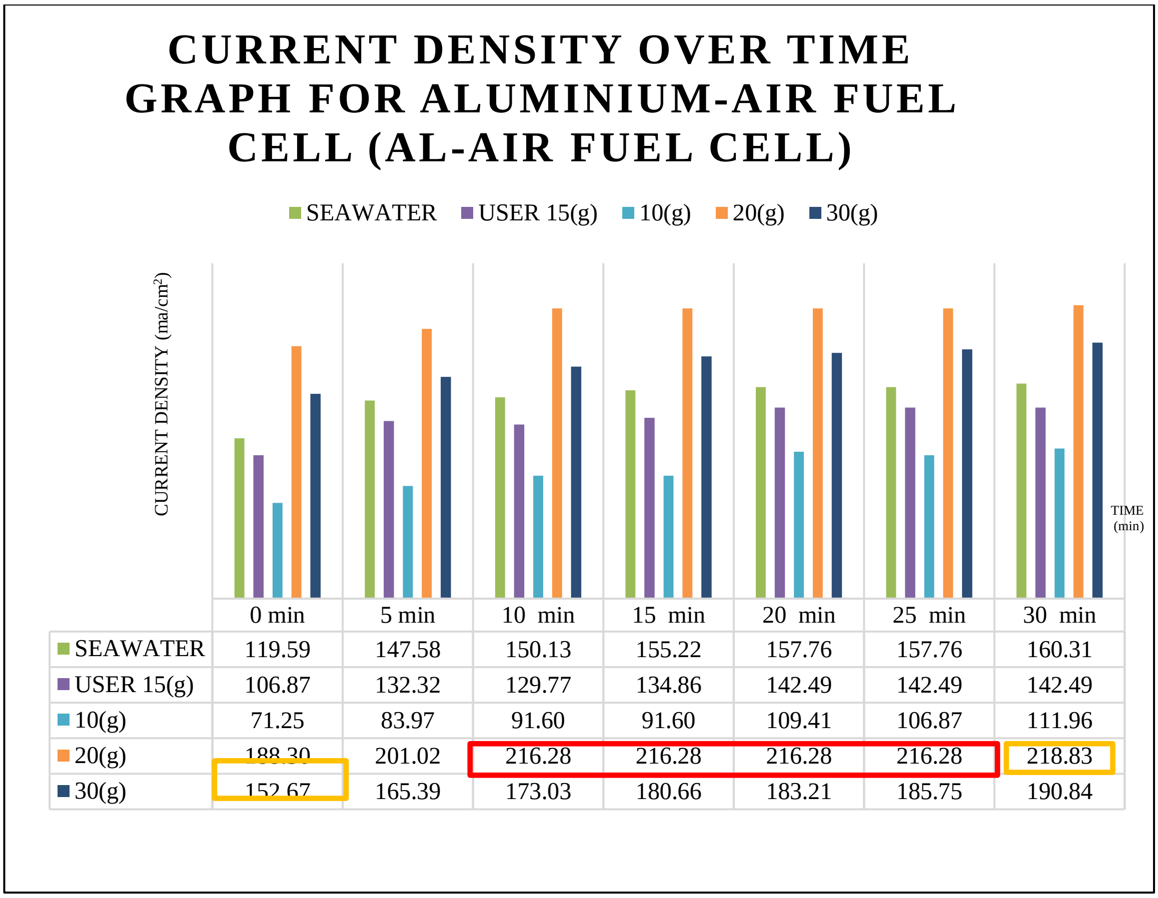
Moreover, through the analysis, it is understandable that the different concentration over a certain period has an influence on the electrical conductivity and the voltage. Mostly the concentration of the saltwater reading at the beginning of the study is lower compared to the last 25th to 30th minutes. The retention or immersion time of the electroplate is play role in this. The concentration of the 30g of salt water with a higher EC value still produces lesser voltage than the 20g even with the same amount of volume of water used to produce the electrolyte. This is because while adding salt raises conductivity, oxygen in the solution slows down the rate of reaction. The same amount of water used to produce 20 grams of salt produced more voltage than 30 grams of salt electrolyte, as in the current study. A study on the Correlation of Salinity and Electric Voltage demonstrated that the generated voltage is linearly correlated with the salt density in the water and will reach a saturation point at some level of salinity, which is another explanation for the result. This could happen, and other studies have talked about how the formation of ion pairs and ion aggregation caused electrolyte conductivity to gradually decrease in concentration, preventing ion migration and blocking ion channels. In these scenarios, the free ion pairs are even higher than those of 20 grams of salt in 350 milliliters of water once the concentration reaches 30 grams. The ion movement in 30g of salt in electrolytes hinders and slows down the movement of free ions. Eventually, this will reduce the performance of the fuel cell in terms of slowing down the charging and discharging rates of ions in the cell.

4.5 Current and Power Density of Saltwater Lamp Analysis.

4.5.1 Current Density of Saltwater Lamp Analysis.

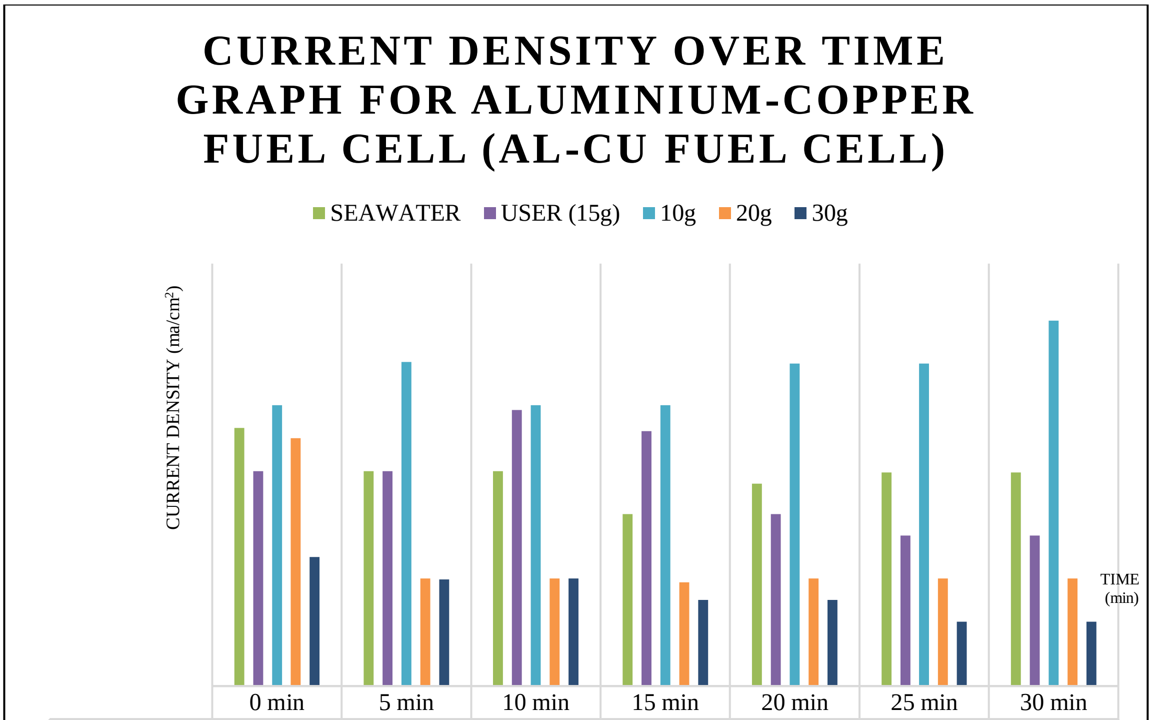
To shift the focus toward practical application, conventionally, the performance of a fuel cell is characterized in terms of output variable values like electric power density and coulombic efficiency. Additionally, other variables like current density, electrical energy, normalized energy recovery, and energy generation efficiency have been used. Despite reports that the operational, these values are typically independently determined by averaging measurements taken under various operational conditions. The parameters that were focused on in this project were the power density and current density of both Al-Cu Fuel Cells and Al-Cu Fuel Cells over a different concentration of electrolyte during the same thirty minutes. All data were gathered over five-minute intervals.

The amount of charge flowing through a specific conductor cross-sectional area is referred to as the current density. When there is a constant flow of charge, the amount tends to stay the same. In this instance, the volume of the electrolyte and the Al and Cu plates that were used in them was the same plates. A measure of power output per unit volume is referred to as power density. Even though it is not as commonly used as energy density, it is still useful in discussions about energy systems, especially when used in portable applications like this one. In the context of electronics power management, power density measures the amount of energy that can be processed in each area. A system's mass or volume determines how much energy it can produce if it has a high-power density.



	0 min	5 min	10 min	15 min	20 min	25 min	30 min
SEAWATER	119.59	147.58	150.13	155.22	157.76	157.76	160.31
USER 15(g)	106.87	132.32	129.77	134.86	142.49	142.49	142.49
10(g)	71.25	83.97	91.60	91.60	109.41	106.87	111.96
20(g)	188.30	201.02	216.28	216.28	216.28	216.28	218.83
30(g)	152.67	165.39	173.03	180.66	183.21	185.75	190.84

Figure 4.4: Average Electrical Conductivity and Average Voltage of Aluminium-Air Fuel Cell (Al-Air Fuel Cell)



	0 min	5 min	10 min	15 min	20 min	25 min	30 min
SEAWATER	30.53	25.45	25.45	20.36	23.94	25.27	25.27
USER (15g)	25.45	25.45	32.67	30.18	20.36	17.81	17.81
10g	33.26	38.35	33.26	33.26	38.17	38.17	43.26
20g	29.36	12.72	12.72	12.27	12.72	12.72	12.72
30g	15.27	12.63	12.72	10.18	10.18	7.63	7.63

Figure 4.5: Current Density Over Time Graph For Al-Cu Plate (Al-Cu Fuel Cell)

Based on the result gathered current density over time and power density over time graph has been plotted for both Al-Air Fuel Cell and Al-Cu Fuel Cells to study the significant stability function of operating conditions. In a fuel cell system, electrochemical stability is very essential to determine excellent operation time over different concentrations. Figure 4.4 shows the trend of the current density of the Al-Air Fuel Cell over 30 min while Figure 4.5 shows the trend of the current density of the Al-Cu Fuel Cell. As referred to figure 4.4 can observe that the lowest current density is at the beginning of the experiment and 10g of saltwater concentration has the lowest current density with 71.25mA/cm^2 while the highest current density obtained was from 20g of saltwater at the 30th minute of operation of salt water lamp. The trend of overall shows the current density gradually increases as the time operation increases. This shows the electrolytes need to be stable to produce a better current supply for the operation of the saltwater lamp. It is difficult to assess the electrolyte's stability under more realistic circumstances. The electrolyte is subjected to strongly reducing or oxidizing conditions for a much shorter period per cycle when a cell is operated at high rates than when the cell is operated at low rates(Ruben-Simon Kühnel, 2020). As a result, the rate of current has a significant impact on the electrolyte's rate of decomposition per cycle. In this test, the saltwater with 20g is the showcase more stable version of Al-Air Fuel Cell. From the tenth minute to 25^{th} minute it has a very stable current density level than on the 30th minute, it increases slightly. Compare with seawater, seawater has a very constant increment in the flow of charge, which kept its current density to be the tendency to increase steadily. Lastly, when comparing this with user 15g the standard user amount it took almost 20 minutes to be stable enough to produce the stable current density.

For figure 4.5, AL-Cu Fuel Cell the trend is similar 20g of saltwater has a more stable current charge flow, whereby from the minute of 5 towards to 30^{th} minute the electrolyte was very stable with 12.72 mA/cm^2. However, the Al-Cu Fuel Cell's highest current density, the 10g, is 43.26 mA/cm2. This is due to the plating time, concentration, and collision theory, an important idea that is a significant concept regarding reaction rates. At the beginning of the reaction, the ions in the electrolyte will proceed more slowly than they will begin to react actively as time goes on. Because the formation of the coating must consume the metal, it is evident that the concentration of reactants gradually decreases as the plating time increases. In contrast to other concentrations of salt water, where the current density gradually decreases over time, 10 grams of saltwater, on the other hand, has low concentrations of ions that take longer to react with the electroplate. Figure 4.6 depicts a graph of the average current density to provide a comprehensive overview of the performance of the two fuel cells. The Al-Air Fuel Cell outperforms the Al-Cu Fuel Cell in terms of the amount of charge that flows through the cell for 30min with different concentrations as shown in Figure 4.6. Figure 4.6 also shows that Al-Air Fuel Cell operates efficiently when it has a concentration of saltwater of 20g because it produces the highest average current density.

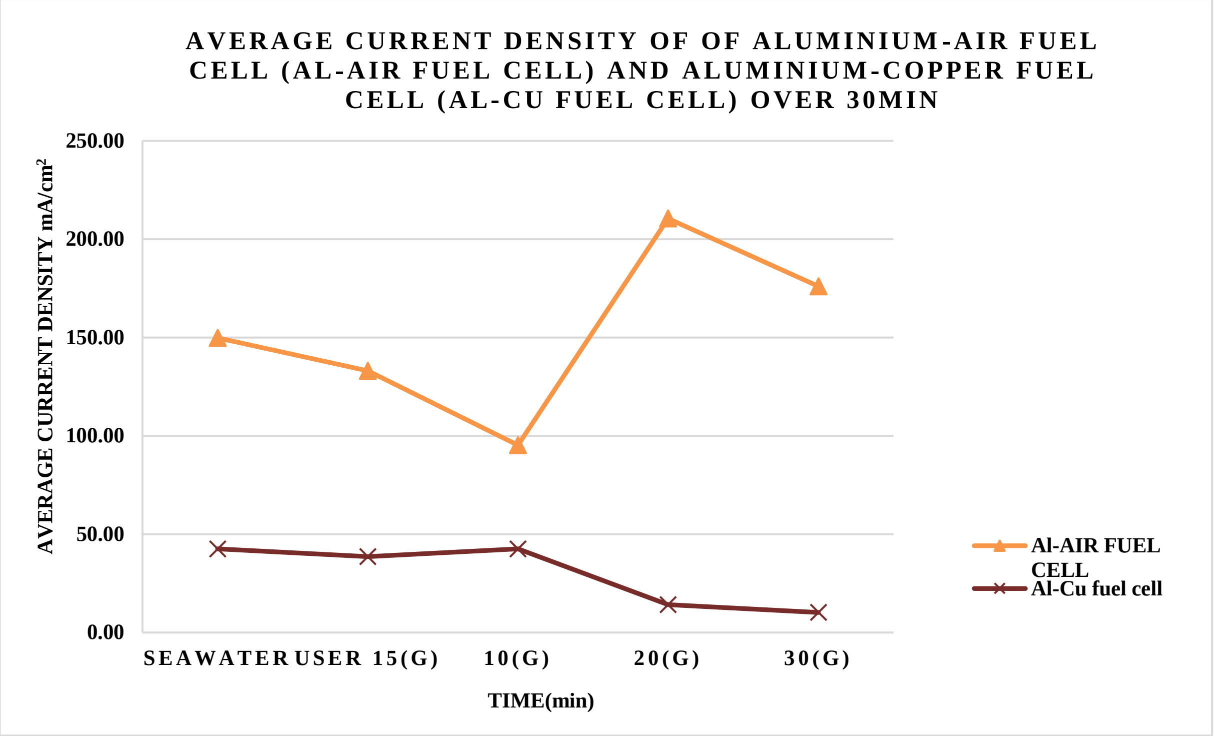


Figure 4.6: Average Current Density of Aluminium-Air Fuel Cell (Al-Air Fuel Cell) And Aluminium-Copper Fuel Cell (Al-Cu Fuel Cell) Over 30min

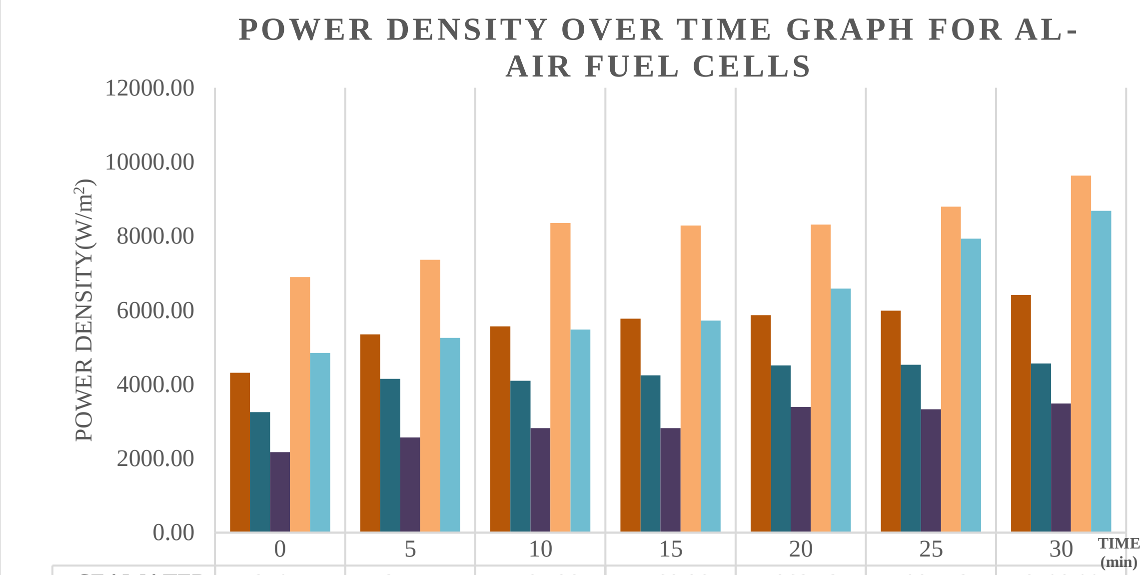
4.5.2 Power Density of Saltwater Lamp Analysis.

A system can store a lot of energy in a small amount of mass if it has a high energy density. A high-power density is not always accompanied by a high energy density. A mobile phone is one example of this kind of energy storage because it has a high energy density but a low power density and can-do work for a long time. It can run for most of the day, but to charge it, it needs to be connected to another power source for at least an hour.

According to the result gathered power density over time graph has been plotted for both Al-Air Fuel Cell and Al-Cu Fuel Cells performance of a fuel cell device that can supply. Figure 4.7 shows the trend of the current density of the Al-Air Fuel Cell over 30 min while Figure 4.8 shows the trend of the current density of the Al-Cu Fuel Cell. As referred to figure 4.7 can observe that the lowest power density is at the beginning of the experiment and 10g of saltwater concentration has the lowest current density with 2168 W/m^3 while 9623.0 W/m^3 highest current density obtained was from 20g of saltwater at the 30^{th} minute of operation of the saltwater lamp. As like current density the trend overall shows the current density gradually increasing as the time operation increases.

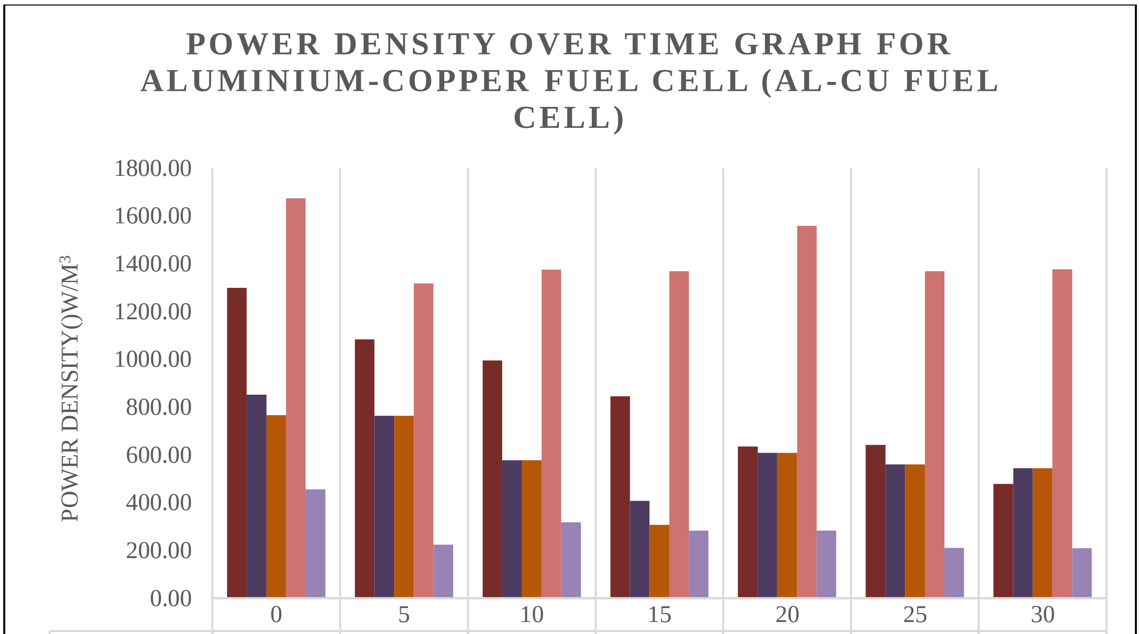
In this test, the Al-Air Fuel Cell with the saltwater of 20g is the showcase more effective version. For figure 4.7, AL-Cu Fuel Cell the trend is similar to 20g of saltwater has a more stable power delivered by a fuel cell. However, the power it supplied is very compared to Al-Air Fuel Cell. It shows almost 85.68% different rates of power delivered. This is because initially the current and voltage influence. AL-Cu Fuel Cell has very low voltage and current produced compared to Al-Air Fuel Cell. The ideal fuel cell would maintain a constant voltage that is determined by thermodynamics and supply any amount of current if it has sufficient fuel. However, in practice, the actual fuel cell voltage output is lower than the ideal thermodynamically predicted voltage. Additionally, a real fuel cell's voltage output decreases as more current are drawn from it, limiting the amount of power that can be produced. To put it another way, a fuel cell's current is directly proportional to how much fuel it uses each mole of fuel yields and moles of electrons. As a result, the electric power produced per unit of fuel also decreases as fuel cell voltage decreases. Thus, fuel cell voltage can be interpreted as a measure of efficiency. To put it another way, the fuel cell voltage axis can be thought of as an "efficiency axis." Therefore, maintaining a high fuel cell voltage even under high current loads is essential to the technology's successful implementation.(O’hayre, 2016)

On the contrary, as we investigate the average power density for both fuel cells still the Al-Air Fuel Cell performed better than Al-Cu Fuel Cell in terms of power delivering for 30min with different concentrations as shown in Figure 4.9. Figure 4.9 also shows that Al-Air Fuel Cell operates efficiently when it has a concentration of saltwater of 20g because it produces the highest average power density.



	0	5	10	15	20	25	30
SEAWATER	4310.57	5352.57	5562.86	5768.86	5863.43	5987.43	6408.00
USER (15g)	3252.00	4145.14	4094.57	4240.00	4512.00	4528.00	4560.00
10(g)	2168.00	2564.57	2818.29	2818.29	3390.86	3324.00	3482.29
20(g)	6892.57	7358.29	8354.29	8281.43	8305.71	8791.43	9632.00
30(g)	4851.43	5255.71	5478.86	5720.57	6582.86	7925.71	8678.57

Figure 4.7: Power Density Over Time Graph For Aluminium-Air Fuel Cell (Al-Air Fuel Cell)



	0	5	10	15	20	25	30
SEAWATER	1299.43	1082.86	995.14	845.71	634.29	641.14	478.29
USER (15g)	851.43	762.86	577.14	407.43	608.00	560.00	544.00
10 g	765.71	762.86	577.14	307.43	608.00	560.00	544.00
20 g	1673.71	1317.14	1375.71	1368.57	1558.86	1368.57	1377.14
30 g	456.00	224.57	317.14	283.43	283.43	210.00	209.14

Figure 4.8: Current Density Over Time Graph For Aluminium-Copper Fuel Cell (Al-Cu Fuel Cell)

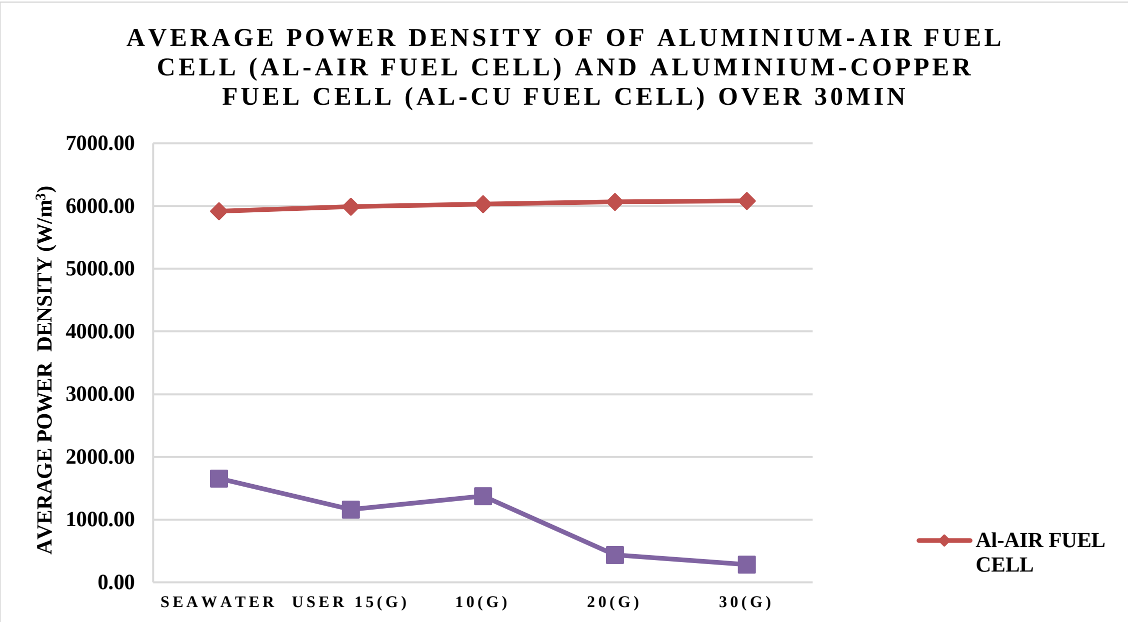


Figure 4.9: Average Power Density Of Aluminium-Air Fuel Cell (Al-Air Fuel Cell) And Aluminium-Copper Fuel Cell (Al-Cu Fuel Cell) Over 30min

4.6 Salinity Concentration and Electrical Conductivity of Saltwater Lamp Over Time Analysis

Table 4.3 shows the weight of Aluminium (Al), and Copper (Cu) electrodes before and after being immersed and run the test in the 350 ml of saltwater and seawater for overall total testing 101.5 hours hours. It can be observed that even, Al electrodes experienced the highest reduction in weight, and copper (Cu) has the smallest reduction in weight. In the Al-Air Fuel Cell the Al act as the anode which undergoes reduction while the air act as the cathode, while in the Al-Cu Fuel Cell, Al still as the anode which can easily take part in a chemical reaction in saltwater solution as compared to copper. In an electrolysis reaction Cu electrode does not really take participate in the reaction, it just aids the electron flows. The anode that consists of an Al electrode undergoes an oxidization process by giving up electrons. This reaction causes white gelatinous precipitate around the cell which is called Aluminium Hydroxide $Al(OH)_3$ as shown in figure 4.10. Therefore, it causes the corrosion on Al plate and makes the weight of Al to kept reduce. This explains the high differences in the before and after weight of the Al plate. The differences of the weight reduction and appearance of the Al electroplate demonstrate in figure 4.11.

The electroplate is predicted to have a lifetime to last up to 150 hours before it needs to be replaced if it is turned on continuously. Therefore, it is safe to conclude that the electrodes can produce electricity for at least 6 days. Due to the deterioration of the electroplate, particularly the Al plate in this experiment, saltwater lamp performance can eventually decrease over time, based on our testing with other previous studies, resulting in a shorter life span. The electroplates lifespan will be greatly reduced as a result of its prolonged submersion in the salt solution. (S.Ramakanth, 2012) says that to avoid speeding up the corrosion of the electrodes, a protective paint or powder coating is typically applied. However, because it may alter the rate of reaction and reduce the voltage output, this may not be suitable for use with any saltwater-powered devices. On the other hand, it will also increase the total cost of producing electricity because Al does not hold paint well and must be coated with powder coating or a primer for base paint. Therefore, the proposed design with a mechanism that can automatically remove the electrodes from the salt solution whenever the lamp is not in use is one less expensive way to extend the electrodes' lifespan. the other way is to switch off the saltwater lamp and remove the saltwater when it is not in use would sustain the lifetime of the electroplate.

Table 4.4 : The weight of Al, and Cu electrodes before and after being immersed in a saltwater lamp

Electrode	**Weight before (g)**	**Weight after (g)**	**Difference (g)**
Al	29.1	22.89	**6.21**
Cu	**80.30**	**80.36**	**0.06**

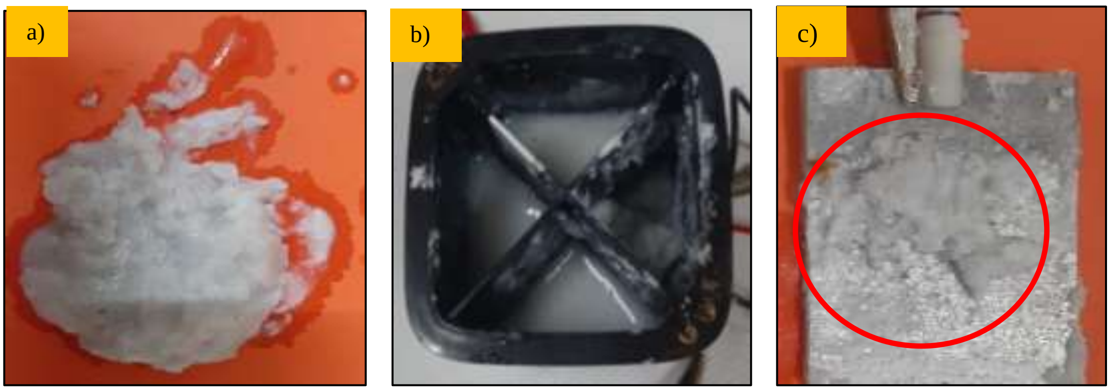


Figure 4.10: The white gelatinous precipitate, Aluminium Hydroxide Al(OH) (a) the removed Aluminium Hydroxide Al(OH), (b) the formation of Aluminium Hydroxide Al(OH) after run for 48 hours and (c) the formation of Aluminium Hydroxide Al(OH) that sticking.

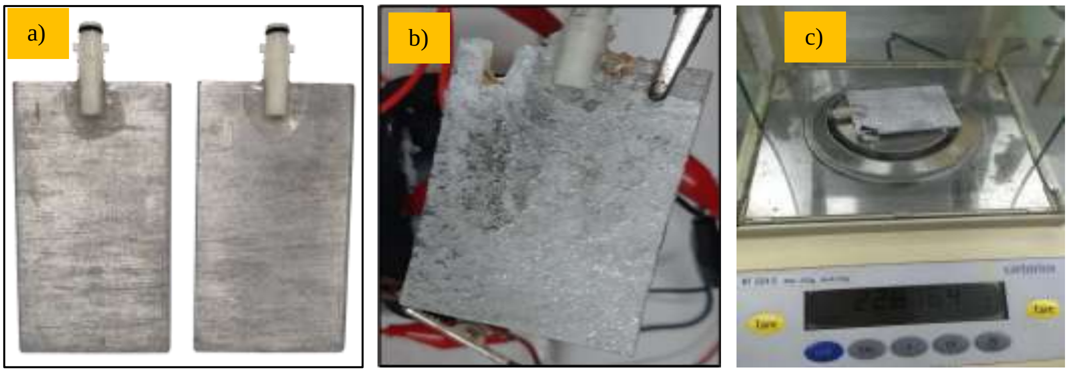


Figure 4.11: The Al plate appearance throughout the experiment (a) the Al plate before immersed in saltwater for 24 hours (b) the removed Al plate after immersed in saltwater for 24 bours (c) Final weight measurement of Al plate.

CHAPTER 5

CONCLUSION

5.1 Introduction

The conclusion of the research findings is highlighted in this chapter. It discusses the study's findings and recommendations. This chapter discusses all the study's objectives. This chapter wraps up all the information.

5.2 Conclusion

Al-Air Fuel Cell versus Al-Cu Fuel Cell comparison, Al-Air Fuel Cells can work together to make a stable saltwater lamp that can run for a long time. When it comes to concentration, the saltwater lamp's performance can be enhanced with a concentration of 20 grams. Because conductivity rises in direct proportion to concentration, the study found that saltwater concentration has a linear relationship with conductivity. Further examination of the saltwater lamp's efficiency reveals trends in both fuel cell output voltage (V) and electrical conductivity (EC). The formation of ion pairs and ion aggregation in electrolytes hinders and slows down the movement of free ions, so as the EC increases, the voltage production increases for all concentrations except 30g. By slowing down the ion charging and discharging rates in the fuel cell, will eventually reduce its performance. The Al-Air Fuel cell's output voltage, when compared to the results for power and current density, is sufficient to turn on the lamp with 20 grams of salt or 3 tablespoonfuls. Al is an extremely active electrode that readily reacts with saltwater, as demonstrated by the durability test. The testing revealed that the electrodes made of aluminum (Al) and copper (Cu) both before and after being submerged continued to reduce, resulting in the formation of aluminum hydroxide ($Al(OH)3$). It is anticipated that the electroplate will last for up to 150 hours before it needs to be replaced. As a result, we can confidently draw the conclusion that the electrodes can continue to generate electricity for at least six days..

5.3 Recommendation

There are also some recommendations which may help improve research on this topic for future researchers. It is recommended for this study that; the study can be conducted using various types of electrodes to observe more wide opportunities that could reduce the cost intern of electroplates. It is also recommended to try a variety of temperatures for the saltwater higher the temperature and the performance of ion movement can be increased. In terms of improving the current density, in a fuel cell, and electrical device applications like point-of-load voltage regulators, the figure of merit (FoM) for current density is frequently a more suitable one to use. These designs scale in size according to output current, and typically, the output voltage levels are modest, at or below 1 V. Power density figures can be artificially inflated by assuming an unreasonably high output voltage, hence current density is a more useful metric because it disregards the output voltage. Several engineers conducted research to improve power density, with the primary focus on reducing the size of energy conversion passive components. The majority of the power solution's size is typically taken up by inductors, capacitors, transformers, and heat sinks. The control circuitry and semiconductor switches are significantly smaller and more integrated. Innovation in any one of these areas of the overall power design can be implemented to increase power density. As last recommendation to produce more effective saltwater lamps can produce a hybrid version lamp integrated with solar cells would be great and helps the needed community to improve people’s quality of life.

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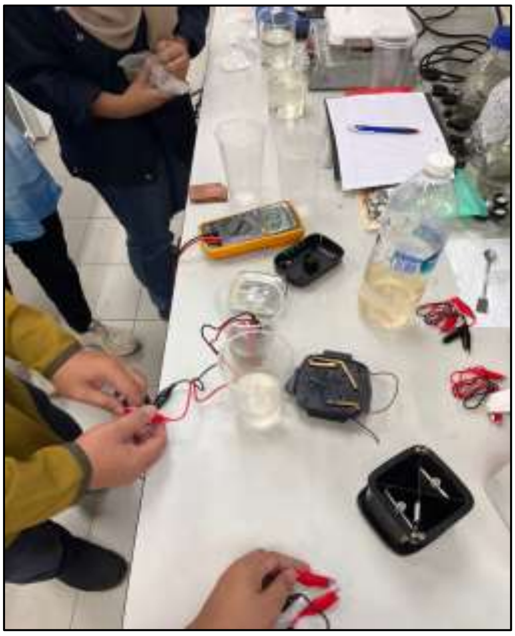
APPENDICES

Appendix A: Two type saltwater lamp

Al-Air Fuel Cell

Al-Cu Fuel Cell

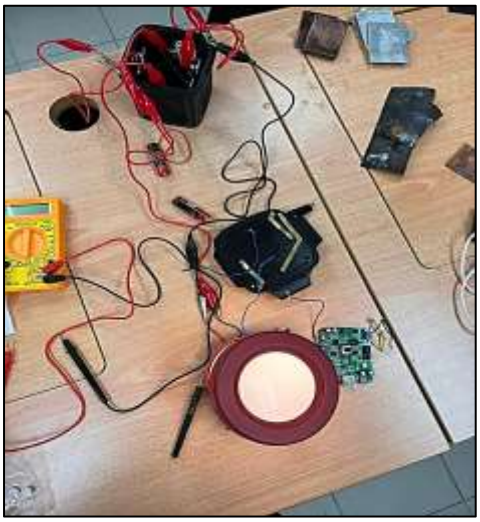
Appendix B: Preliminary Study at FTKKP laboratory



Appendix C: Electrolyte

Seawater collected at Teluk Cempedak   Prepared saltwater as electrolyte.

Appendix D: Measuring Current and Voltage using Digital Multi-Meter



Appendix E: Gant Chart

ACTIVITY	Week													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Briefing section	■													
Title discussion with supervisor and A1 Form submission	■	■												
Drafting outline of the project with supervisor.		■	■											
Related journal research - Consultation of the research paper that focuses on. - Approval of research paper that will be used.			■	■	■	■	■							
Generate/analyze the ideas and designs for saltwater lamp			■	■	■	■	■							
Material/costing listing for fuel cell components and LED light accessories.					■	■	■	■	■	■				
Select & finalize the practical design for the saltwater lamp.							■	■	■	■				
Verifying and finalizing methodology (testing method for each objective with the supervisor.					■	■	■	■	■					
Proposal's first draft preparation (Chapter 1 to Chapter					■	■	■	■	■	■	■			
Submission of the proposal's first draft										■	■			
Project advisor's approval of the proposal's first draft											■	■		
Prepare the presentation slides											■	■	■	
Present the proposal with panel													■	
Improvisation of the proposal													■	
Preparing the final proposal													■	■
Submission of the final proposal													■	■
Discussion with supervisor		■	■	■	■	■	■	■	■	■	■	■	■	■
Attending SDP Seminar			■	■	■	■	■	■	■	■	■			

The Gantt Chart for the SDP 1

The Gantt Chart for the SDP 2

Activity/ Week	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
SDP II briefing & Meeting with SV	■															
Planning on the progression and meeting the fabricator.		■	■													
Improvement and progression in lamp design			■													
Purchased electroplate and salinometer				■												
Meet again with fabricator on design concept. Get advice with supervisor on the design part.					■											
Begin preliminary study						■										
Went to UMP Pekan to meet Mr Senior Engineer, Ts. Mohd Nurulakla Mohd Azlan for better understanding on saltwater lamp mechanism.						■	■									
Meet again Mr Akla and Dr. Izan Izwan Misnon for trooublesshoot several issues in saltwater lamp								■								
Continue experimental Test in laboratory(Seawater, 10g, 15g, 20g, 30g)									■	■						
Result Analysis									■	■						
Chapter 4 writing								■	■	■	■	■				
Chapter 5 writing									■	■	■	■				

Submission of Form B1 Progress Report SDP																
Thesis writing																
Briefing on SDP2 Presentation Process																
Submission of thesis draft																
Preparation of presentation slide and Poster																
Submission of softcopy of draft thesis, poster and presentation slide																
Presentation																
Final editing of thesis																
Submission of Thesis, Technical paper and Logbook																