DESIGN OF SOLAR DESALINATION SYSTEM FOR SALT AND GREY WATER

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BACHELOR OF MECHANICAL AND MANUFACTURING ENGINEERING TECHNOLOGY WITH HONOURS

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Faculty of Mechanical and Manufacturing Engineering Technology

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A thesis submitted
in fulfillment of the requirements for the degree of
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2022

DECLARATION

I declare that this entitled “Design of solar desalination system for salt and grey water ” is the result of my own research except as cited. The Design of solar desalination system for salt and grey water has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : *Nur Afrina*

Name : NUR AFRINA BALQIS BINTI ZAIDY

Date : 18/01/2022

APPROVAL

I declare that this entitled "Design of solar desalination system for salt and grey water " is the result of my own research except as cited. The Design of solar desalination system for salt and grey water has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : PROF. TS. JUHARI BIN ABD RAZAK

Date : 18/01/2022

DEDICATION

Thank you to my beloved grandparents, Puan Halimah Binti Salleh and Mohd Fadil Bin Ismail.

ABSTRACT

People in many regions of the globe lack access to clean water. The demand for fresh water has risen dramatically as a result of the fast expansion of industry throughout the world. Desalination facilities, which use a distillation method to turn sea water into drinking water, were among the first innovations in offering such solution. The problem statement of this study, rural area or remote area can't afford to buy the current desalination technology it is because of it so expensive for them. However, the cost distribution of solar desalination is drastically unalike and initial cost is the most expensive part of solar distillation. Although, at one time the system is up and running, it's very expensive to maintain and the very cheap of energy. However, the maintenance and operational cost are high and energy demanding. Besides, objective of this project is to develop desalination process that produces freshwater while using energy efficiently and to compare the system performance for salt water and grey water systems. After that, the scope of this project is the quality of the project which is solar still come out with some specific advantage such as environmentally friendly, free energy and using locally available materials. Next scope is solar still is highly dependent on the solar irradiation by water productivity because sun is the only source of heat to solar still. In other hand, methodology of this project is using solar still through by one phases. From this project use wrapping plastic to drip the water from a process condensation to the water storage. The function of the wrapping plastic that can help the concentration of sunlight. Second phase is using condensing tank which use aluminum sheet and make it into cuboid shape for condensing tank. After that, the condensing tank will be put under sunlight to get the hight temperature. From the result experiment, could develop desalination process that produces large amount of fresh water and get comparison the system performance for salt and grey water. From the data analysis and condensing tank efficiency has 4.41 percent grey water and for salt water 2.70 percent.

ABSTRAK

Penduduk di banyak wilayah di dunia ini kekurangan akses ke air bersih. Permintaan untuk air tawar telah meningkat secara dramatis sebagai hasill pengembangan industri yang pesat di seluruh dunia. Kemudahan penyahgaraman yang menggunakan kaedah penyulingan untuk mengubah air laut menjadi air minuman merupakan salah satu inovasi pertama dalam menawarkan penyelesaian tersebut. Pernyataan masalah kajian ini, kawasan luar bandar atau kawasan pedalaman tidak mampu membeli teknologi penyahgaraman semasa kerana ia sangat mahal untuk mereka. Walau bagaimanapun, pengagihan kos penyahgaraman selar secara drastik tidak sama dan kos awal adalah bahagian penyulingan solar yang paling mahal. Walaupun, pada satu masa sistem ini beroperasi, ia sangat mahal untuk dijaga dan tenaga yang sangat murah. Dengan menggunakan sinaran suria sistem dapat berjalan sepenuhnya di persekitaran yang ideal. Walaubagimanapun, kos penyelenggaran dan operasi adalah tinggi dan memerlukan tenaga. Selain itu, objektif utama projek ini adalah mengembangkan proses penyahgaraman yang menghasilakn air tawar sambil menggunakan tenaga dengan cekap dan membandingkan prestasi sistem untuk air masin dan air kelabu. Selepas itu, skop projek ini adalah kualiti projek yang solar masih keluar dengan beberapa kelebihan tertentu seperti mesra alam, tenaga bebas dan menggunakan bahan-bahan yang ada di tempatan. Skop seterusnya ialah solar masih sangat bergantung pada penyinaran solar oleh produktiviti air kerana matahari adalah satu-satunya sumber haba untuk solar. Sebaliknya, metodologi projek ini menggunakan pegun solar melalui satu fasa. Daripada projek ini gunakan plastik pambalut untuk menitiskan air daripada proses pemeluwapan ke tempat simpanan air. Fungsi plastik pembalut yang dapat membantu kepekatan cahaya matahari. Fasa kedua menggunakan tangki pemeluwapan yang menggunakan kepingan aluminum dan menjadikannya bentuk kuboid untuk tangki pemeluwapan. Selepas itu, tangki pemeluwapan akan diletakkan di bawah cahay matahari untuk mendapatkan suhu yang tinggi. Daripada eksperimen ini yang dihasilkan, dapat membangunkan proses penyahgaraman yang menghasilkan sejumlah besar air tawae yang mendapatkan perbandingan prestasi sistem untuk air masin dan air kelabu. Daripada analisis data dan kecekapan tangki pemeluwapan mempunyai 4.41 peratus air kelabu dan untuk air masin 2.70 peratus.

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Last but not least, from the bottom of my heart a gratitude to my beloved grandparents, Puan Halimah Binti Salleh and Mohd Fadil Bin Ismail. Not to forget my parents Puan Faizah Binti Abd Razak and Zaidy Bin Mohd Fadil for their encouragements and who have been the pillar of strength in all my endeavors. Also for their endless support, love and prayers. My eternal love also to all my friends, for supporting and motivation. Finally, thank you to all the individual(s) who had provided me the assistance, supported and inspiration to embark on my study.

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LIST OF SYMBOLS AND ABBREVIATIONS

MSF	-	Multi-Stage Flash Distillation
MED	-	Multi-Effect Distillation
VCD	-	Vapor Compression Distillation
TVC	-	Thermal Vapor Compression
MVC	-	Mechanical Vapor C ompression
EDR	-	Electrodialysis Reversal
RO	-	Reverse Osmosis
ED	-	Electrodialysis
m_{ew}	-	Mass of water production
η_d	-	Condensing tank efficiency
h_{fg}	-	Latent heat vaporization
$I(t)$	-	Monthly solar radiation (December)

A	-	Compartment area of condensing tank

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

Desalination using solar energy is a known and reliable method. The oldest known use of still dates back to 1551, when Arab alchemists utilized it (Biswas, 2012).

Any procedure that removes salts from water is known as desalination. Desalination can be utilized for municipal, industrial or commercial purposes. Desalination technologies are becoming cost-competitive with alternative means of providing useable water their expanding requirements as technology improves. During World War II, it was though that desalination technology or ‘desalting’ should be created to transform saline water into useable water in areas where fresh water resources were enough. Reason, congress created ‘The Saline Water Act’ in 1952 to offer governmental funding for desalination (Esmaeilion, 2020).

Solar water desalination works on a simple yet effective basis. Water vapor and others rises when the water evaporates. This treatment eliminates microbiological organisms as well as contaminants (Ruano et al., 2016). Besides, by using solar also can use for distillation process that can produce fresh water in our basic daily used.

1.2 Problem Statement

Public health necessitates the availability of safe daily water. Cooking, drinking, cleaning, personal hygiene, irrigation, recreational and industrial uses are just a few of the ways drinking water may utilized. The global effort to find efficient, cost-effective and technologically sound techniques for producing clean daily water for underdeveloped nations has intensified. Water shortage will affect an estimated a few billion people by 2025, with population of the world was living in water stressed areas of usage and expansion.

A piece of work today is to use solar still distillation to successfully save, the drinking water we have to manage and distribute. Because water is only transportable if it contains less than 500 parts per million of salt, a lot of study has gone into developing effective ways to remove salt from sea water (Kalogirou, 1998). Desalination process what they're termed. Desalination of sea water is an option for making up for a lack of drinking water.

Moreover, rural area or remote area can't afford to buy the current desalination technology it is because of it so expensive for them (Esmaeilion, 2020). When compared to multi-stage flash and reverse osmosis, the cost distribution of solar desalination is drastically unalike. The initial cost is the most expensive part of solar distillation. Although, at one time the system is up and running, it's very inexpensive to maintain and the very cheap of energy, if not free.

1.3 Research Objective

The main research is to Design of Solar Desalination System for Salt and Grey Water. Specifically, the objectives are as follows:

a) To develop desalination process that produces of freshwater while using solar energy.

b) To compare the system performance for salt water and grey water systems by using solar energy.

1.4 Scope of Research

The scope of this research were:

- Develeop quality water and quality of the project which is solar still come out with some specific advantage such as the living world friendly, free energy and using local available materials.
- The most limitation in this experiment is cost, which has limitation in the selection of phase change materials since the phase change materials utilized must be inexpensive while still possessing the necessary properties for usage as thermal energy storage.
- A scale model of the proposed design.

1.5 Gant chart and milestone

Figure 1.1 and table 1.1 below is showed the project for the design and development of the design of solar desalination for salt and grey water.

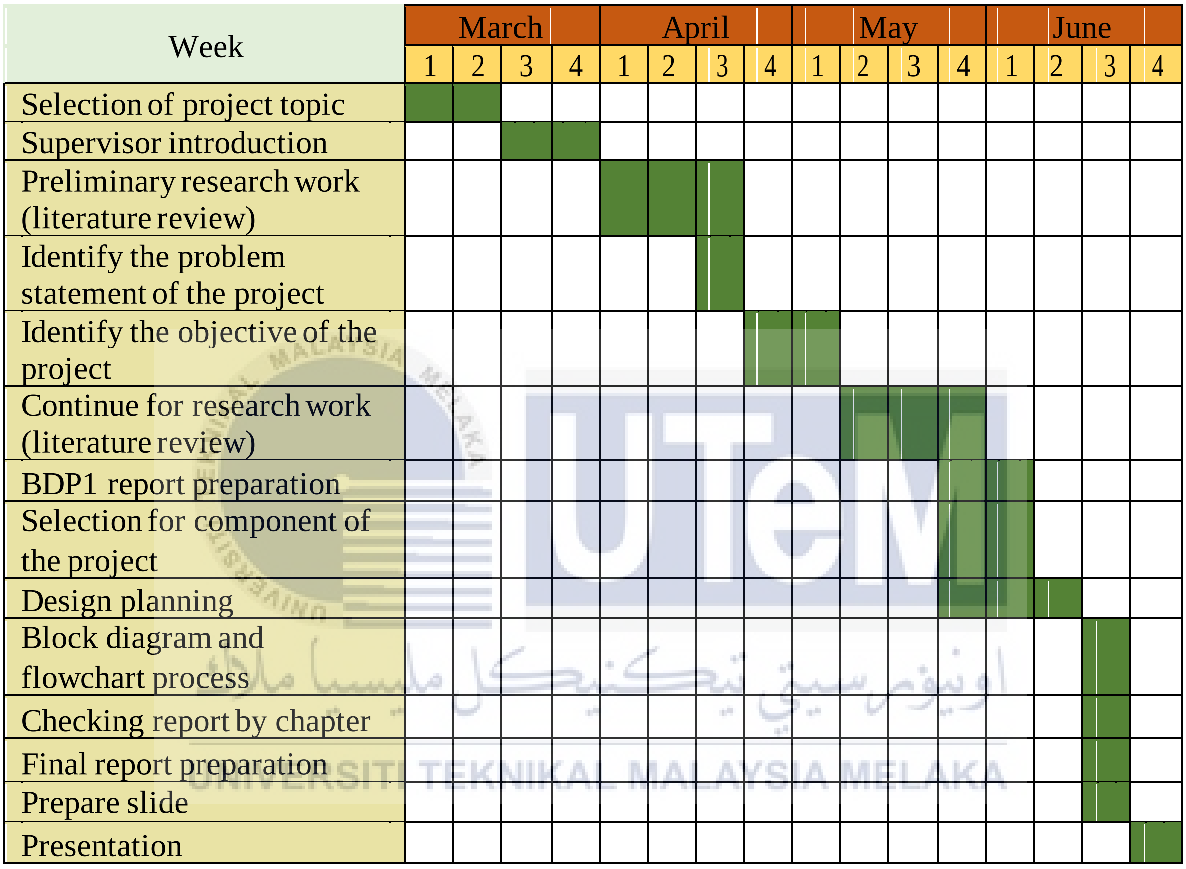


Figure 1. 1 Gant chart PSM 1

Week	October				September				December				January			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Redo and make correction report for chapter 1 & 2	■	■	■	■												
Survey the components and materials				■												
Fabrication of solar still					■	■	■	■								
Experiment preparation and setup									■	■						
Experiment run											■	■				
Analysis of result and modification												■	■			
PSM2 report preparation												■	■	■		
Draft slides and video for PSM2														■		
Submission report to supervisor and panels															■	
Final year project presentation															■	

Figure 1. 2 Gant chart PSM 2

Table 1. 1 Project Milestone

Week	Activity
1	PSM 1 briefing
1	Selection of supervisor and title
2	Module implementation (Report writing)
3-15	Meeting and discussion with supervisor
5	Progress work evaluation
5-7	Verification of PSM 1 tittle and synopsis
8-10	Drafting chapter 2 and chapter 3
11-12	Checking for chapter 2 and chapter 3
12-13	Perform correction and improvement on report
14	Submission of PSM 1 report
13-14	Slide presentation process
14	PSM 1 slide presentation

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The current chapter focuses on the research conducted on design solar desalination of salt and grey water and it is performance on solar still to produce fresh water. A summary of the research from various type of sources had been highlighted in this chapter.

2.2 Desalination

About 97% of the earth's water is salt water in seas, whereas just 3% of all fresh water is found in ground water, lakes and rivers which provide the majority of what humans and animals require. Although, increased industrialization and global population expansion have resulted in a significant increase in the need for fresh water (Patel & Patel, 2021).

Desalination is a system that the saline water was separates into two parts which one with a low salt concentration meaning the water was treated and the other with a significantly greater concentration than the original input water, known as brined concentrate or simply 'concentrate'(Esmaeilion, 2020). Besides, desalination of saltwater is the oldest water treatment processes in human history, and it has shown to be one of the most dependable backup options for satisfying the fresh water demands of both humans and enterprises . Desalination of saltwater and brackish water had the ability to resolve humanity's growing fresh water demands (Matos et al., 2012). However, it is unsustainable since it used a large amount of energy, primarily from fossil fuels, which can be difficult to get in distant places and whose price are very variable (Akhter et al., 2018).

When traditional resources, recycling or demand control measures fail to enhance water supply, desalination of sea or brackish water provides an option. However, desalination of water has been done since antiquity, but it has not been generally adopted because to technological restrictions, prohibitively high costs, excessive energy used and when compared to ordinary water it very high unit cost. Project of desalination may not be regarded as alternative water development options created by technological advancements in the previous 30 years that drastically decreased capital costs and energy usage (James et al., 2016).

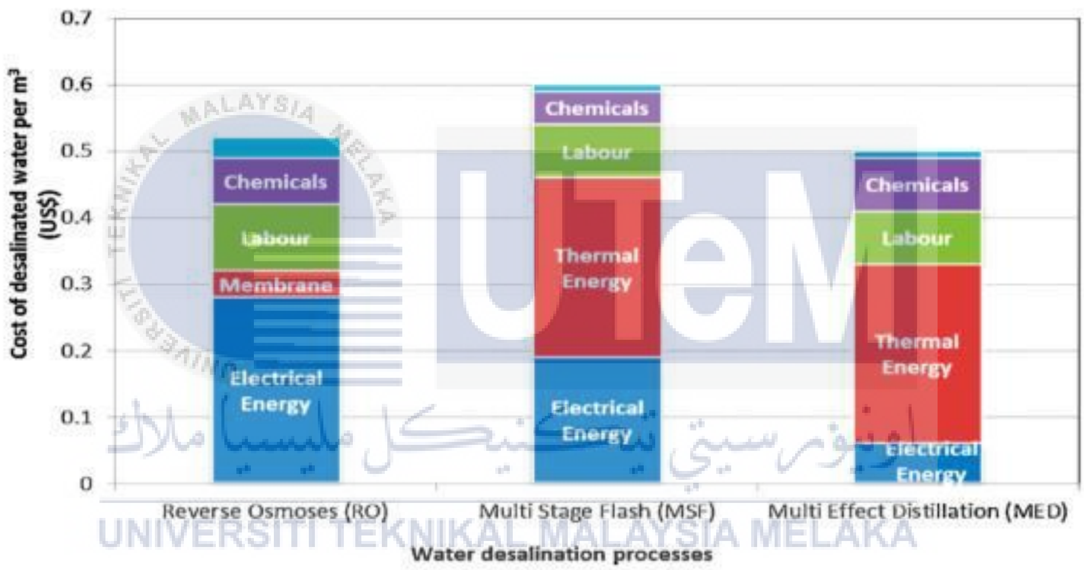


Figure 2. 1 Figure Cost of Reverse Osmosis and thermal desalination processes (Ullah & Rasul, 2019)

The costs of Reverse Osmosis (RO), Multi-Stage Flash (MSF) and Multi-Effect Distillation (MED) are shown in Figure 2.1. The cost of all methods comprised electrical energy as shown in the graph, but by applying the solar desalination method, it can reduce the cost of electrical energy, making a cheaper than others (Akhter et al., 2018).

2.3 Water desalination technologies

Thermal and membrane separation methods can be used in the desalination process (Daniel Buschert, 2014). Futhermore, the desalination system may be divided into two types which is with membranes and without membrane. Reverse Osmosis (RO) and Electrodialysis (ED) are two good examples of with membranes of desalination technologies.

Thermal desalination is highly essential right now. The temperature is increased to a certain level in all thermal desalination systems. To increase the vaporization of the salt water,the pressure is decreased or elevated in various systems (Kingsbury et al., 2020). This is done, for example in Multi-Stage Flash (MSF) and Multi-Effect Distillation (MED). The temperature of the saltwater is increased to or above the boiling point at ambient pressure in Multi-Stage Flash (MSF) and Multi-Effect Distillation (MED), which consumes more energy than evaporation systems. However, as identified in table 2.1, there are procedures that use diverse approaches within those two main kinds.

Table 2. 1 Water desalination technologies and processes (Kucera, 2014)

THERMAL TECHNOLOGY	MEMBRANE TECHNOLOGY
Multi- Stage Flash Distillation (MSF)	Electrodialysis (ED)
Multi-Effect Distillation (MED)	Electrodialysis Reversal (EDR)
Vapor Compression Distillation (VCD)	Reverse Osmosis (RO)

The method of RO was first commercialized in the 1970s. In the United States, RO is now the most frequently utilized desalination technique (Akhter et al., 2018). On the other hand, RO is the most popular techcnique for new desalination installations, providing for 44% of global desalination capacity and 80% percent of the over 15,000 desalination units constructed globally. The Middle East has surged forward as the world leader in large. Scale desalination of salt water. Despite having 2.9% of the world's population, it has about half of the world's manufacturing capacity (Reif, n.d.).

Table 2. 2 Figure A comparison of a different desalination processes (Li et al., 2013)

	MSF	MED	TVC	MVC	RO	ED
Operation temperature ('C)	35 - 120	35 - 100	>120	30 - 60	20 - 40	20 - 40
Pretreatment requirement	Low	Low	Low	Low	High	High
Scale problem	High	Medium	Medium	Medium	Low	Medium
Freshwater quality (ppm TDS)	<10	<10	<10	<10	350 - 500	350 - 500
Heat consumption (Kj/kg of product)	90 - 567	108 - 432	None	None	None	None
Electricity consumption (kJ/kg of product)	7.2 - 18	5.4 - 10	None	28 - 40	None	43
Prime energy consumption (kJ/kg of product)	110 - 653	110 - 369	None	80 - 110	65 - 120	144
Energy recovery	Sensible to latent	Latent to latent	Recovery low temperature vapor	Recovery low temperature vapor	Pressure recovery	None
Sensible to feed in seawater temperature	Yes	No	No	No	No	No
others	Proven technology for large scale plant	Proven technology	Steam temperature >120'C, sacrifice power plant performance	Limited to smaller size plant, need skillfull opearor	Membrane replace every 5-7 years, cannot treat high salinity	Almost all brackish water application

2.4 Solar still

Solar energy is used to convert from solar still to the humidity in the air into fresh water (Reif, n.d.). one of the simple and old methods of water desalination are called as a solar still. A solar still is made up of a basin and a transparent material that allows to coming sun radiation to pass through to the salt water in the basin for heat absorption and evaporation. However, a solar still has solar energy absorption, salt water evaporation and fresh water condensation all in one container. Solar stills are direct collecting systems by definition.

Solar distillation with solar stills is a good established technique. It is utilized to create fresh water all over the world due to its low maintenance requirements (Wiltshire, 2005). This process is repeated in a double effect solar still, where the heat of condensation is utilized to fuel a further process of evaporation. The use of numerous effects tends to improve the performance but it comes at 'no cost' (Chen et al., 2020). To increase the solar flux absorption, the basin is normally painted dark or black the sun rays received by the basin heat the water, increasing the water vapor pressure until art of the salt water evaporates such as the water vapor rises (Zhu et al., 2021).

Figure 2.2 shows the phenomena required with the condesation surface of a solar still. Incoming solar still showed that sun was warms the water, causing evaporation and condesation of vapors, according to a schematic of a conventional solar still. The thermal resistance diagram for heat transmission at the surface was then shown in the following figure. The thermal resistance and heat transfer coefficient are present by R and H. Next, inner and outer surface characteristics are represented by the labelling I, S and E. In a solar still, the phenomena connected with the condesations surface.

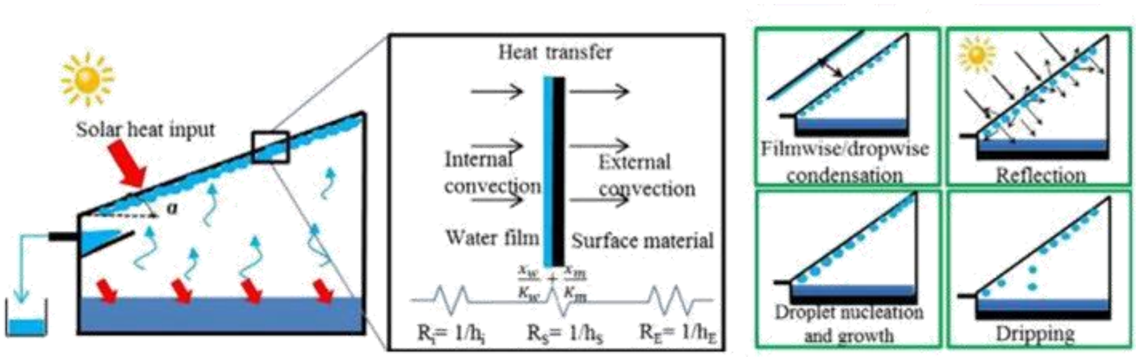


Figure 2. 2 Figure Principle of solar still (Bhardwaj et al., 2013)

There are two types of solar still which is active and passive. Between with both types of solar still can compare which is water depth in the basin, basin material, wind velocity, solar radiation, ambient temperature and inclination angle are all factors hat influence the still performance. Other than that, for this system can compare with the temperature between the water in the basin and the inner surface glass cover will influence the productivity of any form of solar still (Of, 1990). Moreover, solar energy is put together by structural elements (basin liner) for evaporation of saline water in a passive solar still. For quicker evaporation in the case of an active solar still, an external source of heat energy is necessary. A flat plat solar collector with circulating pump, additional condenser and other components can provide additional energy for an active system (Oteng-Peprah et al., 2018). Between both two types is conventional and efficient. To produce a quicker rate of water evaporation, heated water from the collector of panel is supplied into the basin of the solar still in the active distillation process (News, 2021)

As shown table 2.3 below, there is a few review comparison of different types of solar still used. By using a simple apparatus of effects that having 500 mm x 500 mm heat penetrating area that was made and design from polythylene film.

Table 2. 3 Comparison of different types of solar still used (Kaushal & Varun, 2010)

Types of solar stills	Geometry	Properties	Results	Advantages	Disadvantages
simple solar still	Area = 500 mm x 500 mm, insulation = 1.5 mm, glass thickness = 5 mm	intensity of insulation, productivity , steady state efficiency	Results obtained with the number insulation condition are more realistic since the presence of wind increase the energy losses from system.	Easy to install. Easy to operate. Less capital cost. Simple construction.	Efficiency is low. Productivity of water is low. Used in small area.
A roof type solar still	Base = 500 mm x 500 mm, bags = 500m2, tube = 15mm, fibrous sheet = 1.3 mm,	Photocell temperature, productivity solar intensity	Water to power ratio for such a hybrid system may be a key factor to determine the	Portable. Used in caravans resources survey and military	low performance. Used for small purposes.

	side angle = 14.6°, inclination angle = 9.7°		optimum condition. Main aim is to increase production.	front. In laboratory.	
water film cooling over a glass cover of a still	Area = 500 mm x 500 mm, insulation = 1.5 mm, glass thickness = 5 mm	Steady state efficiency. Ambient temperature. Wind speed. Humid ratio	For a conventional still, efficiency increase at low Va and decreases. A high value of hcf results E loss	more efficient than simple still productivity of water is higher.	very sensitive. Glass temperature is main problem.
passive active solar still	Area = 500 mm x 500 mm, insulation = 1.5 mm, glass thickness = 5 mm, pump = 1m	Annual yield, water depth, inclination offlat plat collector	The performance of passive solar still in terms of hourly yield for different water depth.	Passive stills are more economical to provided potable water.	- High capital cost.

Solar still made up of tubes for sea water desalting	- Table area = 1m2, - width = 0.5 m - length = 2.0 m - horizontal transparent, tubes = 0.10 - 0.25 m, I.e. inner diamter, - horizontal tube = 0.01 m, i.e inner diameter. thin transparent plastic foil = 0.01 m.	Daily energy efficiency of the still.	Enhanced fresh water productivity is obtained with respect to conventional solar still in which sea water evaporation and water vapour condesation occur in one confined space.	Easy to manufacture..	- Capital cost is high..

2.5 Solar collector using convex lens

Distillation is a low-tech, low-cost method of purifying water that can be simply applied everywhere on the planet. On the other hand, the sun is a plentiful and limitless energy source that can be found virtually anywhere on the globe and might be utilized to purify water through distillation (Kingsbury et al., 2020). In this experiment, the carrying out of a solar still with convex lenses on the glass cover and radiating surfaces below the lens to boost solar radiation within the solar still is investigated in this experiment. From figure 2.3 below, the findings of this study showed that adding convex lens and radiating surfaces to a single basin solar still may considerably boost daily output and efficiency.

Figure 2. 3 Figure Solar still with radiating surfaces inside the basin and solar still with radiating surface and convex lenses on the cover glass (Ahmed et al., 2017).

High the radiation intensity and as a result, the temperature within the solar still is another possible aprroach for increasing the productivity of the single basin solar. This accomplished through the use of fresnel lens focused on solar power technology or convex lens built into the solar still's glass cover. All entering rays that are parallel to the lens's major axis coverage to a single point on the other side of the lens termed the focal point of the lens in a convex lens. The focal length of the lens is the distance between it and the lens(Chen et al., 2020). This experiment method used 12 of convex lenses on the glass cover and radiating surfaces at the lens foci to capture solar energy and enhance the temperature differential between the glass cover and the surface of the basin water.

To increase solar energy absorption, the basin are coated with black stone and black rubber. Distillate of the glass cover on the inner side flows down the glass cover into the condensate collecting channel because eat is please at 50 degrees inclination angle. Silicon rubber is used to seal any gaps between the glass cover and the solar still box for preventing leaking. To prevent rust and reduce heat lost from the wall of the basin sides and bottom, the solar still box is made of fiberglass. A picture of the glass cover's testing set up, which includes convex lenses and radiating surfaces.

Every 15 minutes, the temperatures of the input and outflow seawater, the inner and outer glass cover, radiating surfaces and the interior spaces and ambient are recorded and the sun irradiation is measured by manually. Using a calibrated flask provided below the basin, the distilled water is collected and measured hourly. An anemometer is used to measure wind velocity. The ambient temperature varies between 26°C and 29°C, while the solar radiation received during the research ranges from 708 to 998 W/m^2. Based on the experiment to the testing results, the productivity of the modified still with a convex lens and radiating surface at a water mass of 20 kg is 2.248 liter per day, which is 15 percent greater than the traditional still under the same operating circumstance. The changed of still with a convex lens and radiation surface has a maximum efficiency of 63.63%.

2.6 Design of Solar still

Using a variety of designs of solar stills can improve the desalination process. From the basin of a passive solar connected to a flat plate collector to the basin through an insulated pipe external thermal energy is supplied into the basin of a basin of a passive solar still (Biswas, 2012). Besides, solar energy is gathered by structural elements itself for evaporation of saline water in a passive system. For quicker evaporation in an active solar still, extra heat energy from an external source is necessary. A flat plate solar collector with circulating pump, additional condenser and other components can provide additional energy for an active system.

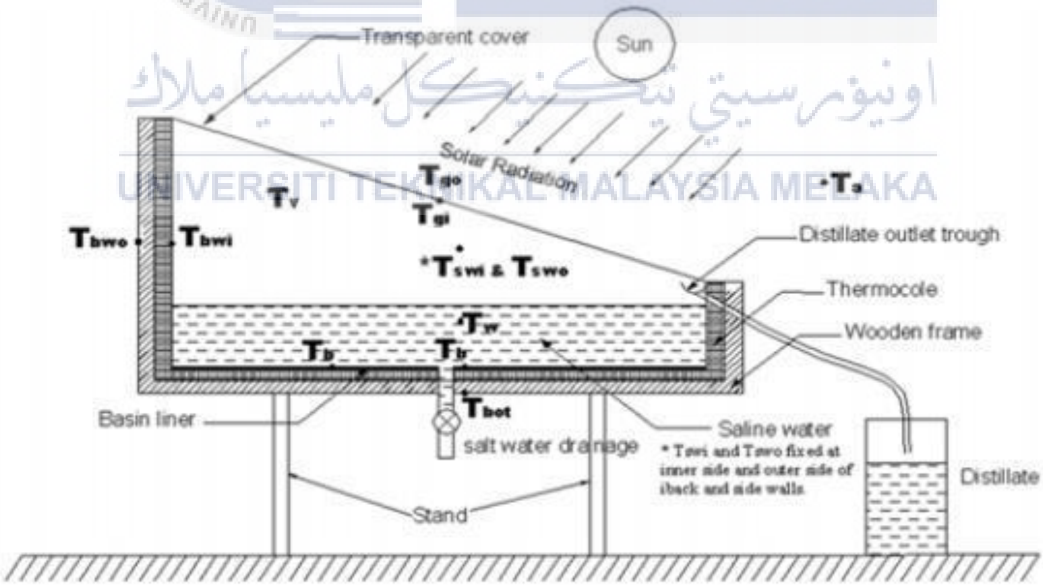


Figure 2. 4 Figure Schematic diagram of the experiment set up (Varun Raj & Muthu Manokar, 2017)

The purpose of this study is to get the impact of water capacity on internal and exterior heat transfer in a solar distillation system (Chen et al., 2020) . It is well knowledge that as the the water depth in the solar still's basin increases, the distillate production falls substantially. The method that this experiment used the interior dimensions of a single slope basin type solar still are 1000 mm x 500 mm and the glass cover are slanted at 10° with regarded to the horizontal. The purpose of this research is to investigate the impact of water capacity on the distillation system's cumulative energy balance. In the other hand, inner and outer heat transmission are thought to be strongly influenced by the water capacity of the basin. The evaporative, radiative and convective heat transfer from water to glass is also shown to have a significant impact on the distillation system's performance. This experiment was conducted under the same environmental circumstances from January to March 2009. The experiments have been managed from 9.00 am to 6.00 pm.

To ensure the optimum still design, the solar still efficiency is regarded the most significant metric to asses. Based on the figure 2.4, between 9.00 am until 13.00 pm, 10 mm and 20 mm water levels are thought to be more efficient than others, although this efficiency diminishes until the evening. For higher water levels, efficiency increases gradually from morning to evening, peaking in the late evening. Due to the production of distillate water energy being significantly larger than solar radiation input during this period, 50 mm and 60 mm water levels are given more than 100 percent efficiency between 17.00 pm until 18.00 hours.

Summary

This literature review was conducted in order to have a better understanding on process solar still of desalination. Moreover, it provides explanation on how desalination enhances the water productivity of solar still. Based on this literature review, the required things for material, design and component for this project using warpping plasting on top to triggered the radiation on the top glass of the basin. Besides, the system of type solar still which passive process can use for this project and experiment. It is solar radiation that collected by structure elements (basin liner) itself for evaporation of saline water. Other than that, it also helps in providing knowledge on how to enhance design the solar still by using all the experiment in journals.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The research strategy chosen for this project is to collect the relevant data on how to develop a solar still. From the literature review, have a better understanding on process solar still of desalination. Moreover, from literature review know how to design and what component and material that required on this project. So, decided to choose the process of wrapping plastic as a solar collector. Next, the system of type solar still which passive process can use for this project.

3.2 Flowchart

From phases of the process, it begins with a literature review in order to gather knowledge and an overview of the topic. The flowchart process begins with the identification of the system's objective and problem statement, as shown in Figure 3.1. After that, perform some literature review research from a variety of periodicals and the internet before moving on to the overall system project evaluation.

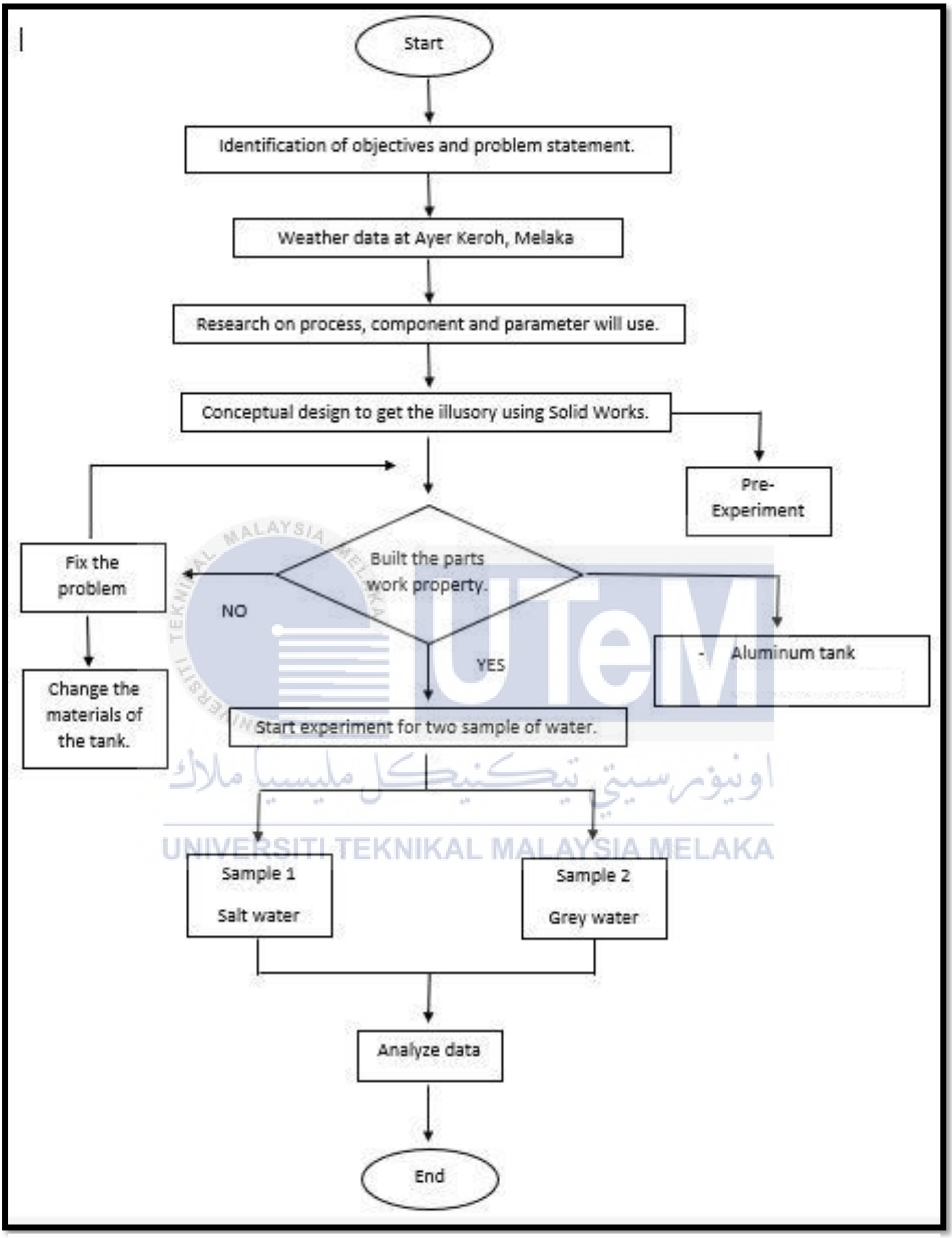


Figure 3. 1 Flow chart

3.3 Pre-experiment

The process of desalination is shown in the figure 3.1. This process need two transparent glass bottle, pipe and sample of salt water. One transparent bottle paint it with black spray colour and spray the whole body of glass bottle. It function that sunlight is absorbed by the black glass bottle speed the rate of evaporation. After that, the salt water sample will be put in the clear glass bottle. Then, just connect through of the both of glass bottle. After this, the two of glass bottle will be put under the sunlight. The sunlight will be concentrate to the black glass bottle then the black glass bottle will heat up the salt water. After salt water are heat up, from black gl ass bottle will produced water vapour through pipe into clear glass bottle. Means, the evaporation is then trapped by the clear glass bottle and funneled away.

From this experiment, the experiment main to proved that the efficiency of using that two glass bottle is not higher because the duration of doing this experiment only one month while with erratic weather. However, this experiment was conducted during 18th May until 18th June. It takes one month to produce water vapour. The bottle was left under the sun for a month.

This experiment doing for the project that will run in this chapter 3. It is because to know how it works on the process of solar still as desalination which used salt water that put in the black bottle glass under the sunlight that is it really work for evaporation and condensation process. However, turning salt water into water vapor required a certain amount of energy to produce fresh water with temperature at 30°C to 40°C. But, on this process takes time to obtain fresh water.

3.4 Design of solar still

In this project, there one design stages. To begin, the design will be the aluminum tank, which have two compartments for two sample which is saltwater and grey water and wrapping plastic on top of the tank utilized to concentrate the solar energy into the solar collector that will produce the water vapor.

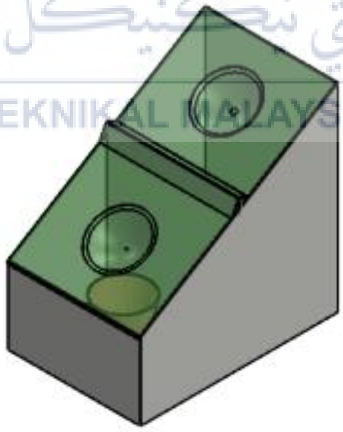
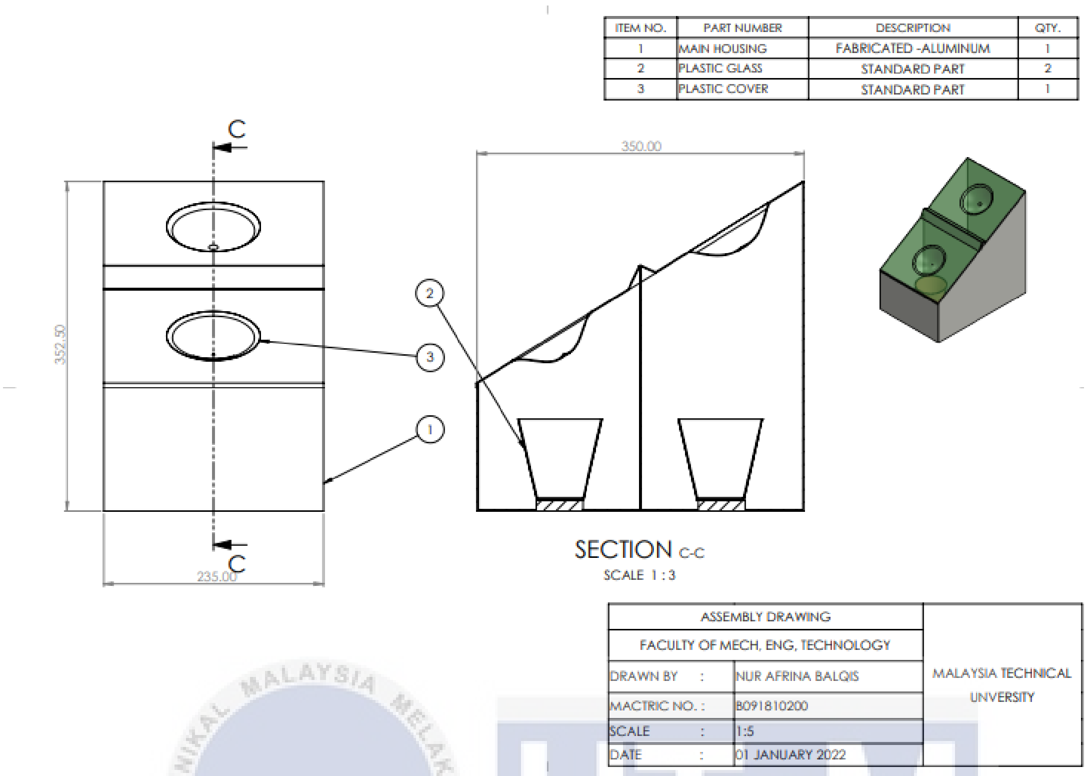


Figure 3. 2 Design of solar still



From this figure 3.2, process solar still is important to used solar or other words is sun. from this experiment, materials involve for a basic solar still is low-priced but may increase if supplementary components are added, which is the wrapping plastic on top of the condensing tank. First planning in this experiment is supposedly use convex lens but it’s hard to get and it also high cost. Besides, after doing a few research it only has a few different of the benefit. So that, by doing this experiment in low cost it just uses wrapping plastic and aluminum tank and divide by two compartments.

After that, wrapping plastic also have same function with convex lens such as primary concentrator for multi-junction solar cells. It is normally designed to increase the taking on angle, increase the light intercepting efficient, make similar the energy distribution.

Next, the wrapping plastic also can enhance the intercepting of light to the top of the condensing tank to speed up absorbed of sunlight. As people know, aluminum material has good thermal resistance conductivity.it is also helping to heat up faster water sample to get a lot of water vapor and fast. From the top of the wrapping plastic will produce water vapor it will dripped to the water collector.

For data analysis, to check the quality and quantity of water sample, the author will use the turbidity test, water quality test which nitrate, phosphate, carbon dioxide, litmus paper and dissolve oxygen. For quantity of water, the author use measuring cylinder to calibrate the water. However, the evaluation of showing of solar distillation system require to monitor the solar still daily as well as the ambient conditions. Example, to check the temperature of water and inner and outer tank cover will. All the examples will check by suing digital thermometer. For solar radiation, will check using the software which is homer optimization. So that, by using all the appropriate will get all the results.

3.4.1 Design parameter

The conductivity of solar still is the amount of water distilled collected per day. The production of solar still rely on solar radiation intensity, the inner and outer of the temperature, ambient temperature, quality and quantity of water. Form table 3.1 below are the raw design value of parameter from journal (Husain, 2014) and (Bhagwatrao Barve et al., 2017).

Table 3. 1 Design parameter

Parameter	Value
Aluminium condensing tank	0.235 m x 0.35 m Front high = 0.135 m Back high = 0.35 m Aluminium thickness = 0.001 m
Solar radiation (per month)	498.7 W/m2
Ambient temperature	52.7°C
Maximum temperature of inner aluminum	46°C
Maximum temperature of outer aluminum	50°C

Figure 3. 3 Solar radiation monthly in Ayer Keroh, Melaka

3.4.2 Components and materials

The design of solar still full assembly which is condensing tank, wrapping plastic and water storage. The condensing tank will make from aluminum sheet to shaped as a cubic that is 0.001 m thick. It is made of aluminum sheet to prevent heat loss and keep the temperature of the distilled water constant. The condensing tank for width and length 0.235 m x 0.35 m, for front high is 0.135 m and back high is 0.35 m in size. Then, from the design of solar still above has explain that the aluminum sheet has a good thermal resistance conductivity. The condensing tank has design to have an angle about 60 degrees because easy to drip the water vapor into the water storage.

Next, the condensing tank is design into two compartments for two sample which is saltwater and grey water. The measurement of two compartment is compartment A, 0.235 m x 0.175m, for front high of the condensing tank is 0.26m and back high is 0.35m. For compartment B, the width and length is same with compartment A, the different of the condensing tank only at their front and back high. The front high is 0.135 m and the back high is 0.26m.

The wrapping plastic is place at the top of the condensing tank. The measurement of the wrapping plastic is 0.30 m x 0.25 m for the width and length. Besides, the wrapping plastic also can enhance the intercepting of light to the top of the condensing tank to speed up absorbed of sunlight.

3.5 Experiment setup

Figure 3. 4 Condensing tank

The flow process of still distillation is shown in figure 3.4. The saltwater and grey water sample will be put in the condensing tank that has two compartments. For compartment A it will be put the grey water and compartment B will be put the saltwater.

Next, the water storage will put at the center of both condensing tank compartments to save the water vapor of two sample. Then, the condensing tank has be place under sunlight and will be concentrate to the water sample in condensing tank. The wrapping plastic also help the concentrate the point of sunlight and heat up faster the water sample. So, there will have a process of evaporation and condensation. Then, the wrapping plastic will drip the water vapor to the water storage.

The experiment was conduct from 10:00 pm to 18:00 pm during period of December 2021. The solar still was operated two sample in two compartments. The first one grey water sample and second one is saltwater in one condensing tank. The reading of production of water, and aluminum temperature was measured every two hours.

The daily efficiency η_d of the solar still is obtain by summation of the hourly condense production, m_{ew} is multiplied by latent heat, h_{fg} and divided by monthly solar radiation, I(t) and the whole area A of the condensing tank.

3.6 Cost

Table 3. 2 Cost of material and equipment

No.	Material and equipment	Quantity	Cost(pieces)	Total Cost
1.	Aluminium sheet	1	RM 98.00	RM 98.00
2.	Silicon glue	1	RM 8.00	RM 8.00
4.	Silicon glue gun	1	RM 15.00	RM 15.00
5.	Wrapping plastic	2	RM 7.80	RM 7.80
6.	Water storage	1	RM 2.00	RM 2.00
			TOTAL	RM 130.80

Summary

This chapter 3 explain that the most details on how Design of Solar Desalination for Salt and Grey Water was planned methodologically. This chapter also includes the design 2D and development phase in selscting component and dimension of the proposed design and assembled the correct design and selecting design parameters. Besides, data collection that taken from the experiment setup which is two sample of water. This chapter also is related to the problem statement, objective and scope that have been presented in chapter 1.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

The water quality and performance of both water sample has been done to make sure the quality analysis was achieved the objective of this experiment. The water was checked by all the equipment which is pH meter, turbidity test, nitrate test and many more of water quality test kit. The result has showed that all the water quality and performance requirements is pass and the procedure is safe to be use in our daily.

4.2 Results and discussion of grey water

The results for grey water sample of this experiment are obtained after one day experiment duration on 28th Dis 2021 are showed below.

Table 4. 1 Result of grey water

t	T_A (°C)	T_{AT} (Inner) (°C)	T_{AT} (Outer) (°C)	T_W (°C)	W_{hexp} (ml)	W_{dexp} (ml)
10:00 AM	37.7	34.2	36.2	32	0	0
12:00 PM	51.4	44.3	46.4	48	4.5	4.6
2:00 PM	52.7	45.6	46.9	46	4.6	9.3
4:00 PM	47.8	42.7	44.1	43	3.3	12.6
6:00 PM	38.2	33.5	35.8	40	1.4	13.8

Where,

t – Time

T_A - Temperature of ambient

T_{AT} (Inner) – Temperature of inner of aluminium tank (inner)

T_{AT} (Outer) – Temperature of outer of aluminium tank (outer)

T_W – Temperature of water

W_{hexp} – Weight of water hourly production

W_{dexp} - Weight of daily hourly production

So, from table 4.1, result that recorded from experiment sample one which is grey water that conducted at time 10:00 am to 6:00 pm with monthly solar radiation on December was 498.7 W/m2. Next, from table 4.1 had six data that be taken which is ambient temperature, aluminum tank temperature inner and outer, temperature of water, hourly water production and daily water production. It has been taken for every two hour.

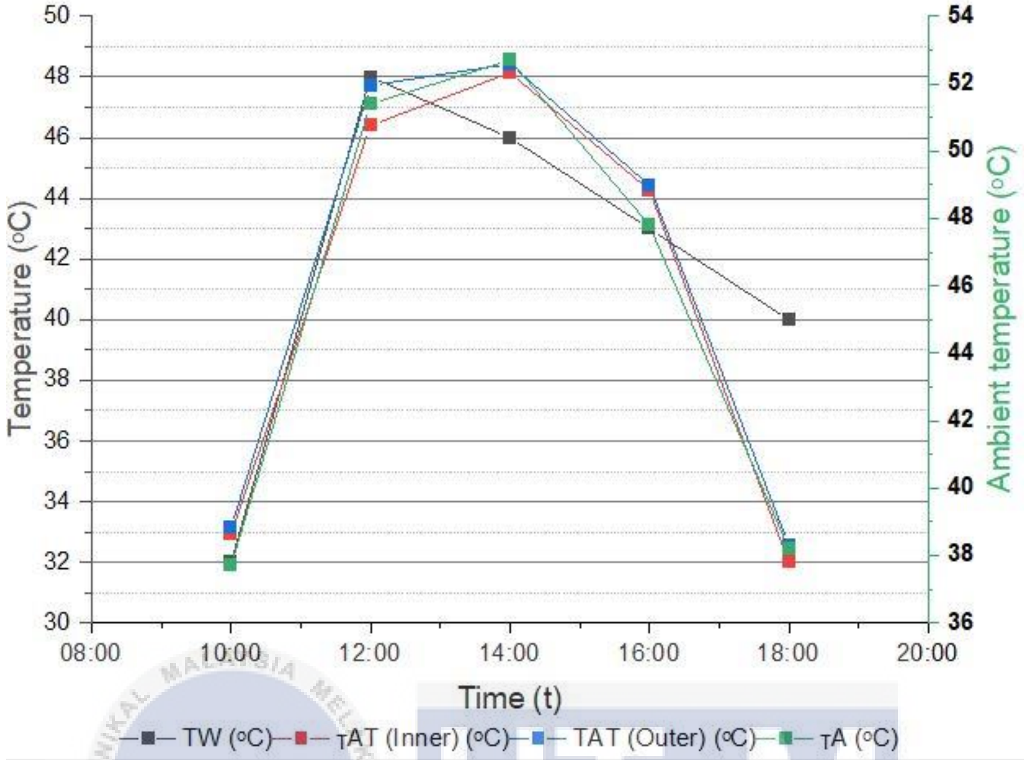


Figure 4. 1 Temperature vs ambient temperature with time (grey water)

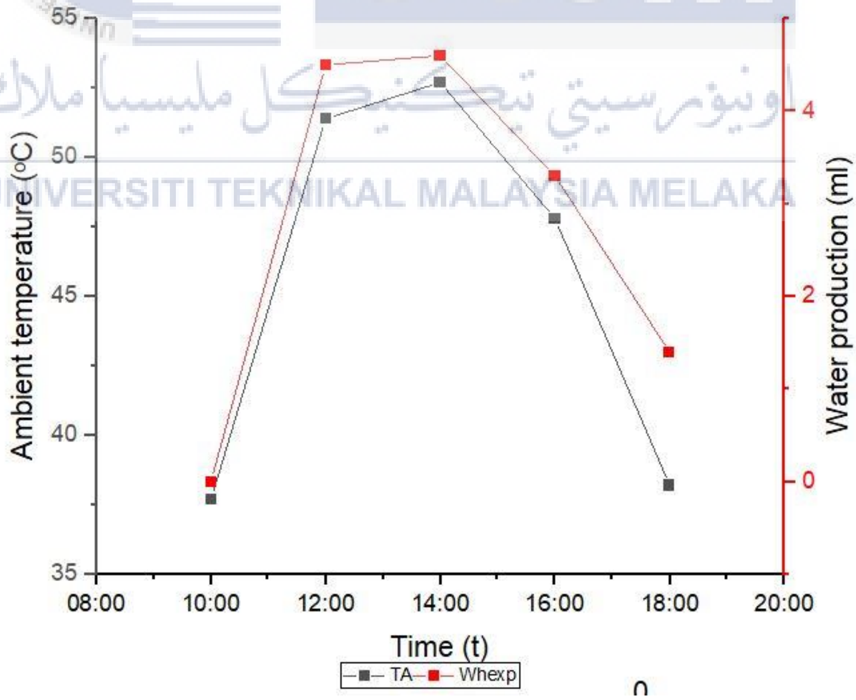


Figure 4. 2 Cumulative and daily water production (grey water)

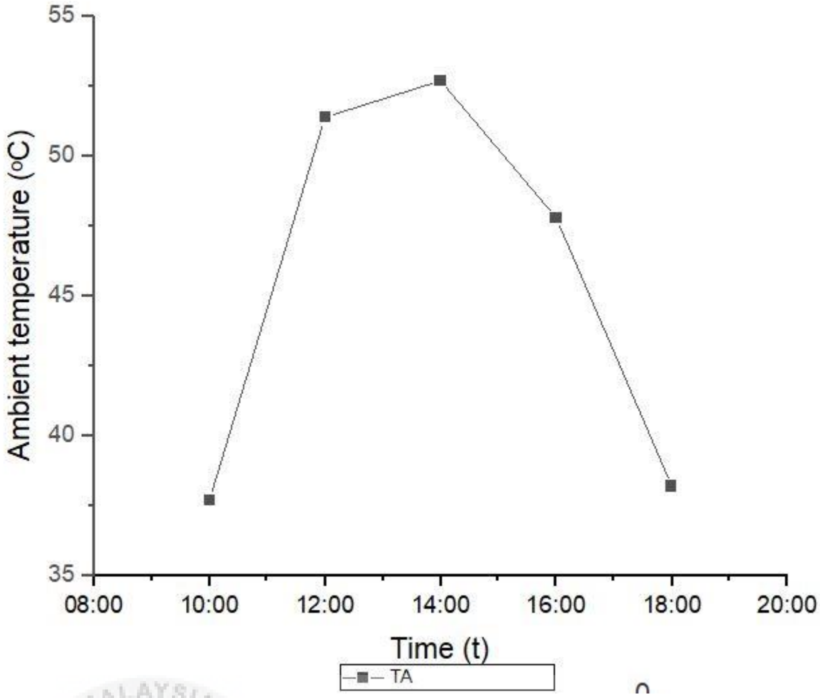


Figure 4. 3 Maximum and minimum ambient temperature (grey water)

The results from the grey water experiment sample were shown in Table 4.1. The graphs in figures 4.1 through 4.3 were created using data acquired throughout the experiment. The weather on December 28, 2021, was sunny, and the experiment lasted 8 hours, from 10 a.m. until 6 p.m.

The graph of different temperatures vs. ambient temperature over time is shown in Figure 4.1 at 2:00 p.m., the water temperature reaches its greatest point. The most efficient ambient temperature received is at 2 p.m., according to the data. Inner glass achieves a maximum temperature of 45.6°C. For this experiment, the largest temperature differential between the inner and outer glass is 1.3 C. It was less than the saltwater sample trial. The outer glass temperature is always greater than the inner glass temperature, indicating that the condensing tank is creating heat.

The graph of cumulative and daily output for the experiment grey water was shown in Figure 4.2. The graph revealed that as the ambient temperature rises, so does the amount of water produce. Furthermore, it was discovered that the water production peaks at 4.6 ml/h around 2.00 p.m., with an ambient temperature of 52.7°C. The total production for the day is 13.8 ml/d. On December 28th, solar radiation was 498.7 W/m2 for the month of December experiment.

The graphs of maximum and lowest ambient temperature, as well as maximum and minimum water production, were shown in Figures 4.2. The ambient temperature value increases from figure 4.3 until it reaches its greatest point at 2.00 pm, after which it progressively falls. The greatest point indicated that the condensing tank receives the most effective ambient temperature at 2:00 p.m. The greatest amount of water produced is also dependent on the ambient temperature.

The efficiency of the solar still is calculated using the data gathered by adding the hourly condensate output, multiplying by latent heat, and dividing by monthly solar radiation, and the total area A of the condensing tank (Abdullah, 2013). The results of the computation are shown below. The efficiency gained in the experiment was 4.41%.

$$n_{d} = \frac{\sum m_{ew} \times h_{fg}}{\sum A \times I(t)} \times 100\%$$

Where, m_{ew} = Mass of water production

h_{fg} = Latent heat vaporization

$I(t)$ = Daily average solar radiation

A = Whole area of condensing tank

Condensing tank efficiency

$$n_{d=} \frac{0.014kg \times 2260000J/kg}{498.7W/m^2 \times 3600s \times 8 \times 0.05m^2} \times 100\%$$

$$n_{d=}\ 4.41\ \%$$

4.2.1 Quality water of grey water

Table 4. 2 Result of quality water (grey water)

	Grey water	Distillate	Standard
pH	7.15	8.07	6.5 - 9
Turbidity (NTU)	4.77	0.84	0 - 5
Phosphate (mg/l)	5	0.5	0 - 10
Nitrate (mg/l)	20	5	0 - 10
Carbon dioxide (mg/l)	40	30	>10
Dissolve oxygen (mg/l)	6	7	15 - 8
Colour	Greenish	Colourless	Colourless
Odour	Have Odour	Odourless	Odourless

For quality water was check by a few intruments. So from table 4.2 was taken by the test kit which is pH meter, turbidity test, phosphate test, nitrate test, carbon dioxide test and dissolve oxygen test. So, all the result in the table 4.2 was taken by all that instruments.

Figure 4. 5 pH meter

Figure 4. 6 Turbididty meter

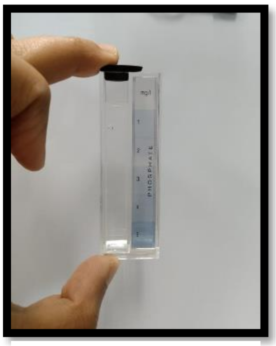


Figure 4. 4 Phosphate

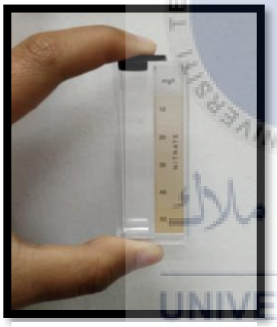


Figure 4. 8 Nitrate

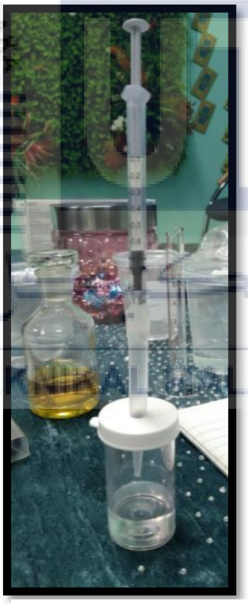


Figure 4. 9 Dissolve oxygen


Figure 4. 7 Carbon dioxide

So, this is the test that used for the testing of water. Firstly, I used pH meter, then, turbidity test as can see that is the result that shown in table which the result is 8.07 that use turbidity meter. then, by phosphate testing just mix the one packet of phosphate reagent and sample of water shake until dissolve. Then, wait for one minute and transfer to the comparator cube then see the result. For nitrate testing, same goes to phosphate testing that just mix the sample and nitrate reagent then shake until dissolve and wait for one minute. But different for oxygen dissolve and carbon dioxide testing.

Dissolve oxygen testing just add sample until full bottle, add five drops of manganous sulfate solution and five drops alkali-azide reagent into bottle sample then shake bottle after adding all the solution, then wait for one minute until the impurities in bottle going down. After that add ten drops of sulphuric acid solution then it turns to yellow and replace the solution in the bottle to the small plastic vessel and last drop one of starch indicator. The take the titration syringe and push plunger completely into the syringe then place syringe tip into cap port of the plastic vessel and slowly add the titration solution drop by drop, swirling to mix after each drop. Then continue adding titration solution until the solution in the plastic vessel turns pink.

For carbon dioxide, placed water sample into bottle until five ml, then add one drop of phenolphthalein indicator into sample water. Then shake until the solution are dissolve. After that, place the mix solution into small plastic vessel and take the titration syringe and push the plunger completely into the syringe. Insert tip into reagent two solution and pull plunger out until the lower edge of the plunger seal is on 0 ml mark of the syringe. Next, place syringe tip into the cap port of the plastic vessel and slowly added the titration solution drop by drop, swirling to mix after each drop. Continue adding titration solution until the solution in the plastic vessel turns pink.

By doing the testing the water quality examination was performed to ensure that the water produced by the condensing tank is safe to use in daily on a regular basis. In the Environment Laboratory, the water quality was tested. All the water quality requirements were met, and the water produced by the condensing tank is safe to drink on a regular basis.

4.3 Results and Discussion of salt water

Table 4. 3 Result of saltwater

t	TA (°C)	TAT (Inner) (°C)	TAT (Outer) (°C)	TW (°C)	Whexp (ml)	Wdexp (ml)
10:00AM	37.7	32.3	35.6	33	0	0
12:00PM	51.4	42.9	44.7	43	3.8	3.8
2:00 PM	52.7	45.9	47.8	49	4.2	8
4:00 PM	47.8	43.4	45.6	46	2.9	10.9
6:00 PM	38.2	37.9	39.5	42	1.3	12.2

Where,

t – Time

TA - Temperature of ambient

TAT (Inner) – Temperature of inner of aluminium tank (inner)

TAT (Outer) – Temperature of outer of aluminium tank (outer)

TW – Temperature of water

Whexp – Weight of water hourly production

Wdexp - Weight of daily hourly production

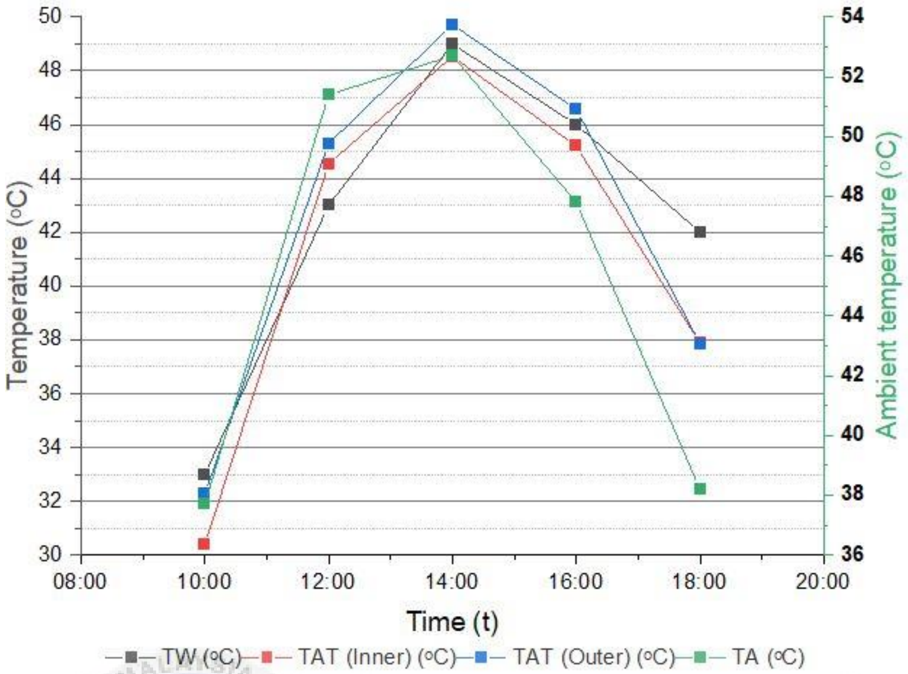


Figure 4. 10 Temperature vs ambient temperature with time (saltwater)

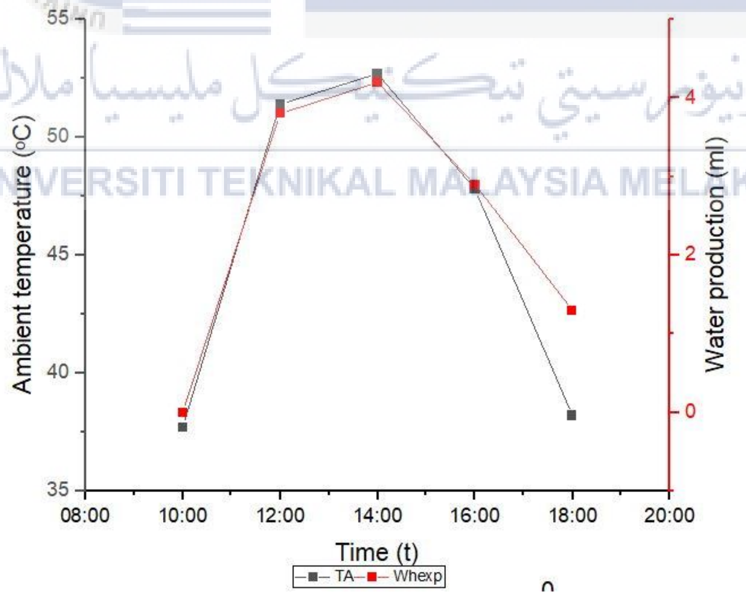


Figure 4. 11 Cumulative and daily water production

The results from the saltwater experiment sample were shown in Table 4.3. The graphs in figures 4.10 through 4.11 were created using data acquired throughout the experiment same goes with grey water. The weather and date also same with grey water which is on December 28, 2021, was bright, and the experiment lasted 8 hours, from 10 a.m. until 6 p.m.

The graph of different temperatures vs. ambient temperature over time is shown in Figure 4.10. At 2:00 p.m., the water temperature reaches its greatest point. The most efficient ambient temperature received is at 2 p.m., according to the data. Inner glass achieves a maximum temperature of 45.9 degrees Celsius. For this experiment, the largest temperature differential between the inner and outer glass is 1.9 °C. It was higher than the grey water sample trial. The outer glass temperature is always greater than the inner glass temperature, indicating that the condensing tank is creating heat.

The graph of cumulative and daily output for the experiment grey water was shown in Figure 4.11. The graph revealed that as the ambient temperature rises, so does the amount of water produce. Furthermore, it was discovered that the water production peaks at 4.2 ml/h around 2.00 p.m., with an ambient temperature of 52.7 °C. The total production for the day is 12.2 ml/d. On December 28th, solar radiation was 498.7 W/m2 for the month of December experiment.

The graphs of maximum and lowest ambient temperature, as well as maximum and minimum water production, were shown in Figures 4.10 and 4.11. The ambient temperature value increases from figure 4.10 until it reaches its greatest point at 2.00 pm, after which it progressively falls. The greatest point indicated that the condensing tank receives the most effective ambient temperature at 2:00 p.m. The greatest amount of water produced is also dependent on the ambient temperature.

The efficiency of the solar still is calculated using the data gathered by adding the hourly condensate output, multiplying by latent heat, and dividing by monthly solar radiation, and the total area A of the condensing tank (Abdullah, 2013). The results of the computation are shown below. The efficiency gained in the experiment was 2.7%.

$$n_{d=}\frac{\sum m_{ew} \times h_{fg}}{\sum A \times I(t)} \times 100\%$$

Where, m_{ew} = Mass of water production

h_{fg} = Latent heat vaporization

$I(t)$ = Daily average solar radiation

A = Whole area of condensing tank

Condensing tank efficiency

$$n_{d=}\frac{0.012kg \times 2260000J/kg}{498.7W/m^2 \times 3600s \times 8 \times 0.07m^2} \times 100\%$$

$$n_{d} = 2.70\ \%$$

4.4 Water quality analysis

Table 4. 4 Result of water quality (saltwater)

	Salt water	Distillate	Standard
pH	9.48	8.14	6.5 - 9
Turbidity (NTU)	10.28	1.51	0 - 5
Phosphate (mg/l)	5	0.5	0 - 10
Nitrate (mg/l)	10	5	0 - 10
Carbon dioxide (mg/l)	20	40	>10
Dissolve oxygen (mg/l)	1	1.4	15 - 8
Colour	Greenish	Colourless	Colourless
Odour	Have Odour	Odourless	Odourless

The water quality testing was same procedure and instrument with testing on grey water. So, the water quality examination was performed to ensure that the water produced by the condensing tank is safe to use on a regular basis. In the Environment Laboratory, the water quality was tested. All the water quality requirements were met, and the water produced by the condensing tank is safe to drink on a regular basis.

4.5 Summary

This chapter 4 was conducted to have a better explanation of data analysis on process solar still of desalination for saltwater and grey water. Moreover, this chapter also includes the discussion and calculation to achieve the objective of this report which to develop desalination process that produces of freshwater while using energy efficiently and to compare the system performance for saltwater and grey water systems.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In this work, an aluminum tank with wrapping plastic was used to create a solar distillation condensing tank. The condensing tank was designed to be 0.235m x 0.35m in size. According to the research, the condensing tank produced 13.8ml of water per day with an average solar radiation intensity of 498.7W/m2 over an 8-hour period. While the generation of saltwater with a solar radiation intensity of 498.7W/m2 is 12.2ml per day. In this research, the condensing system used solar energy to generate fresh water with a 4.41 percent efficiency for grey water. The efficiency difference demonstrates that concentrating solar energy utilizing wrapping plastic and aluminum condensing tank (solar distillation) by 63.33 percent.

5.2 Recommendations

There is a lot that can be done to enhance this study; some suggestions that may be explored are recommended to use a better solar collector such as convex lens or mirror to get the good concentratation of the sunlight. Besides, it is alos recommended to use heat sink or something that can give a good thermal conductivity to haet up faster. Next, use a different material for condensing tank such steel tank.

5.3 Project potential

This experiment had project potential because it low cost experiment and can be produced a large amount of fresh water for our daily use by using material properly.

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APPENDICES

APPENDIX A List of distribution netwok parameters.

Abbreviation	Definition
m_{ew}	Mass of water production
η_d	Condensing tank efficiency
h_{fg}	Latent heat vaporization
$I(t)$	Monthly solar radiation (December)
A	Compartment area of condensing tank
°C	Temperature
ml	Mililetre