FINAL YEAR PROJECT II: DISSERTATION REPORT

TITLE: ENHANCEMENT OF SOLAR STILL DISTILLATION BY EXTERNAL LENS CONCENTRATOR COLLECTOR

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CERTIFICATION OF APPROVAL

ENHANCEMENT OF SOLAR STILL DISTILLATION BY EXTERNAL LENS CONCENTRATOR COLLECTOR

by

WAN NOR FADHLIN WAN HUSAIN

A project dissertation submitted to the

Civil Engineering Programme

Universiti Teknologi PETRONAS

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BACHELOR OF ENGINERING (Hons)

(CIVIL ENGINEERING)

Approved by,

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sourced or persons.

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WAN NOR FADHLIN WAN HUSAIN

ABSTRACT

In many parts of the world, fresh water is unavailable to people. The worldwide rapid growth in industry has greatly increased the demand for fresh water. Early advancements in providing such solutions have come up with desalination plants to convert sea water into drinking water through distillation system. However, the operational and maintenance costs are high and energy demanding which is a practical option only in rich countries. Solar distillation is an expanding alternative to desalination that is distilling water using solar energy. Solar distillation is environmentally safe and uses solar radiation to evaporate saline water into potable water. This project aims to develop a solar desalination device that will produce fresh water using direct solar energy and to enhance the production of fresh water trough solar distillation by using external energy concentrator using lens under local condition. The solar still was operated in two modes of operation; basic solar still alone and basic solar still with external energy concentrator using lens. The experiment was taken in the month of July start on 9am to 5pm. The condensing tank efficiency increased 4% by using the enhancement of external concentration collector.

ACKNOWLEDGEMENTS

Alhamdulillah, with the will and the permission from Allah SWT, I successfully completed this Final Year Project. From this project, not only the knowledge that I gain but through this project I also gain the experience to become more responsible and appreciate on people contribution for me on this project.

Therefore, my highest appreciation I give to my supervisor of my Final Year Project, Dr. Naiman Sapari for his support, ideas and guidance towards the completion of this project. His guidance helps me to makes continuous progress in every week throughout the completion of this project.

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CHAPTER 1: INTRODUCTION

1.1. PROJECT BACKGROUND

Fresh water is most essential from all of natural resources. It is a fundamental to all development of the human living such as domestic, industrial and agriculture purposes. The supply of fresh water is now lesser than the demand of the population. Although more than two-third of the earth's surface is covered with water, there is still arisen crisis of water scarcity. Water scarcity mostly occurred due to the lack of sufficient available water resources to meet the demands of water usage within a region.

Today, the major health issue is related to the unclean drinking water. The pollution of water resources is increasing day by day around the world due to rapid growth of human population and increase of industrial developments. This pollution cause more than 2 million people die each year from diseases such as cholera, typhoid, and dysentery that are spread by contaminated water or by a lack of water for hygiene (Zheng, Chen, Wang, & Zhang, 2014). As the demands of the fresh water increase day by day, the death of people due to illness caused by water pollutant also increase.

WWF-Malaysia, with the assistance from Water Watch Penang (WWP) studied the state of water resources management in Malaysia and founded that there are 11 major issues that affect the sustainability of Malaysia's water resources. The Water Sustainability Index (WSI) that measures the sustainability of water resources both in terms of availability and usage showed that a decrease from 64% in 1992 to 33% in 2002 is a reflection that Malaysia's water resources are rapidly depleting and have been managed unsustainably. These situation will effect's the Malaysia water supply and definitely will cause water shortage in future.

1.2. PROBLEM STATEMENT

The demand on fresh water is growing increasingly and this issue is becoming one of the worldwide challenges. According to the United Nations, water use has grown at more than twice the rate of population increase in the last century. By 2025, an estimated 1.8 billion people will live in areas plagued by water scarcity, with two-thirds of the world's population living in water-stressed regions as a result of use, growth, and climate change.

The challenge we face now is how to effectively conserve, manage, and distribute the drinkable water we have by using solar still distillation. Since water is portable only when it contains less than 500 ppm of salt, much research has gone into finding efficient methods of removing salt from seawater. These are called desalination processes. Desalination of seawater is an alternative to compensate for the shortage of drinking water.

The current desalination technology is expensive and the rural pupil can't afford to buy it. The cost distribution of Solar Desalination is dramatically different compared to of Reverse Osmosis and Multi Stage Flash. The main cost in solar distillation is in the initial investment. However, once the system is operational it is extremely cheap to maintain and the energy has little or even no cost. This system can have a "no cost" energy supply because the sun's energy is completely free and if the situation allows it, the system can run completely using solar radiation in an ideal environment.

Figure 1 below showed the cost of Reverse Osmosis (RO), Multi Stage Flash (MSF) and Multi Effect Distillation (MED) cost. From the figured, we can see cost of all processes contained electrical energy but by using Solar

Desalination process, we can cut the cost of electrical energy thus this will make it cheaper than others.

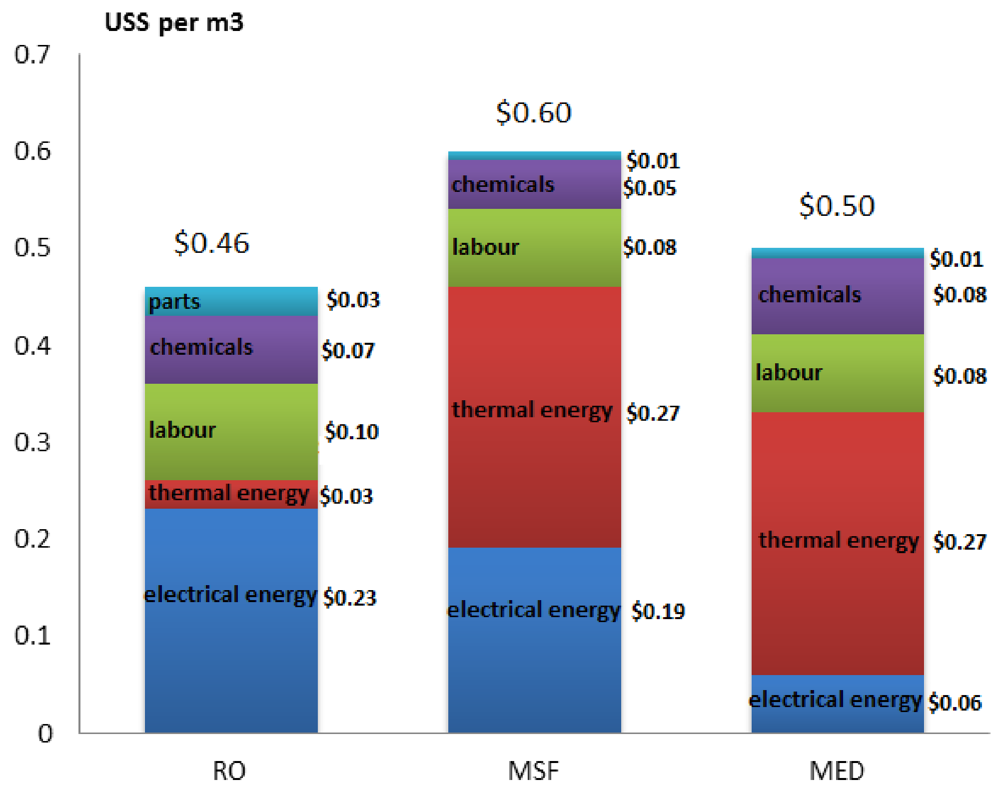

Figure 1: Typical cost of different desalination processes (Tiwari, Singh, & Tripathi, 2003).

1.3. OBJECTIVES

On this proposed project, the author will strive to overcome the problem that has been discussed in the previous section. As been clarified earlier, there are two main objective of this project which is:

a) To develop a solar desalination device that will produce fresh water using direct solar energy.

b) To enhance the production of fresh water trough solar distillation by using external energy concentrator using lens.

The combination of these two objectives will overcome the main to water scarcity crisis. The final outcome of this device is should be able to produced fresh water with optimum production for daily use.

The feasibility of this project to be carried out within two semester period are promising because the technology for both of the objective stated above are existed, and the author will improvised and integrate into a smatter system for better application in real world.

1.4. SCOPE OF STUDY

Basically, in order to achieve the objectives in the previous section, the scope of study in this project is to utilize energy from the sun for desalination process to produce drinking water using lab scale models.

The solar distillation device will be constructed based on double effect active solar still coupled with a compound lens concentration (CLC) collector due to the feasibility of this method which clearly draw an extra solar radiation onto solar still. It can help to increase the evaporation rate.

In this paper the author also will study the rate of drinking water produced per day by using the CLC collector. The experiment will be conducted to collect the data and to improve the design until the optimum production is achieved.

1.5. RELEVANCY OF THE PROJECT

This project is relevant to human, health and the environment. Desalination is believed to be an effective way to satisfy the increasing demand of the fresh water. Solar still presents some specific advantages such as environmental friendly, clean and free energy and using locally available materials.

1.6. FEASIBILITY PROJECT WITHIN SCOPE AND TIME FRAME

For this project, the first semester focuses on literature review for solar still, formulation of methodology and identifying the ideal design and system of solar still. The second semester was mainly on fabrication of solar still, experiments, collecting data and analyzing the result.

CHAPTER 2: LITERATURE REVIEW

2.1 DESALINATION

More than two-third of the earth's surface is covered with water. But, about 97.5% of the Earth's water is salt water in the oceans: 2.5% only is fresh water which included ground water, lakes and river water. This is the water that is needed by humans and animal (Kalogirou, 1998). Since the supply of seawater is very big, it has a large potential to produce drinking water of acceptable quality. Desalination process is to overcome the water scarcity crisis around the world.

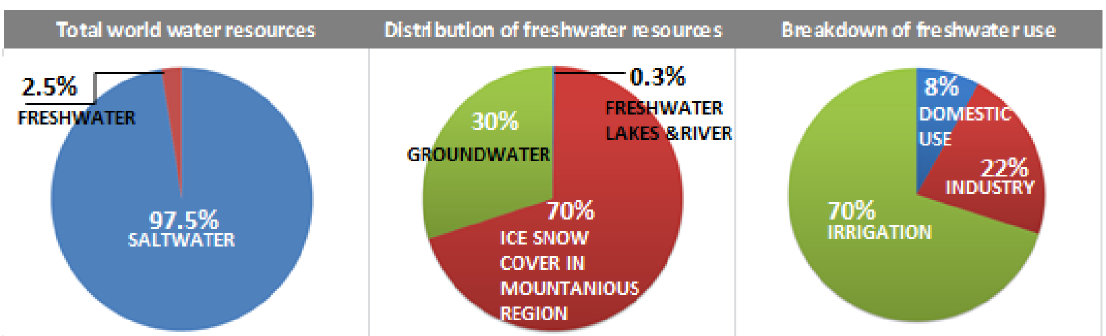

Figure 2; ; Distribution of world water resources (Lattemann, Kennedy, Schippers, & Amy, 2010).

Desalination is a process in which saline water is separated into two parts using different forms of energy, one that has a low concentration of dissolved salts (fresh water), and the other which has a much higher concentration of dissolved salts than the original feed water (brine concentrate) (Shatat, Worall, & Riffat, 2013). Saline water can be classified as either brackish water or seawater depending on the salinity and water source.

Recently, the rapid growth of human population has led to the rapid growth of the world economic as well. Consequently, water scarcity has become the greatest fear for human population now and in the future. Desalination of sea (or saline) water in many parts of the world is the best alternative and has been practiced regularly for over the past 50 years and is a well-established means of water supply in many countries (El-Sadek, 2010).

The desalination of water has been practiced since ancient times but was not widely used due to technological limitations, the prohibitive high capital costs, high-energy consumption and finally very high unit cost when compared to conventional water (Tsiourtis, 2001). Technology of desalination around the world has grown rapidly as the water scarcity increased day by day. Seawater desalination became a kind of ‘‘strategic reserve technology’’(Zheng et al., 2014).

In the light of water scarcity and limited available freshwater resources, the growth of the desalination market in the world is rapidly developing to meet the increasing water demand utilizing seawater, brackish water, river water, and brine (Shatat et al., 2013). The installed capacity was 60 Mm3/day in 2010 and is expected to be doubled by 2015. 38 Mm3/day of these plants are planned to be installed in the Gulf region and 59 Mm3/day in the rest of the world as shown in Figure 3 (Lattemann et al., 2010).

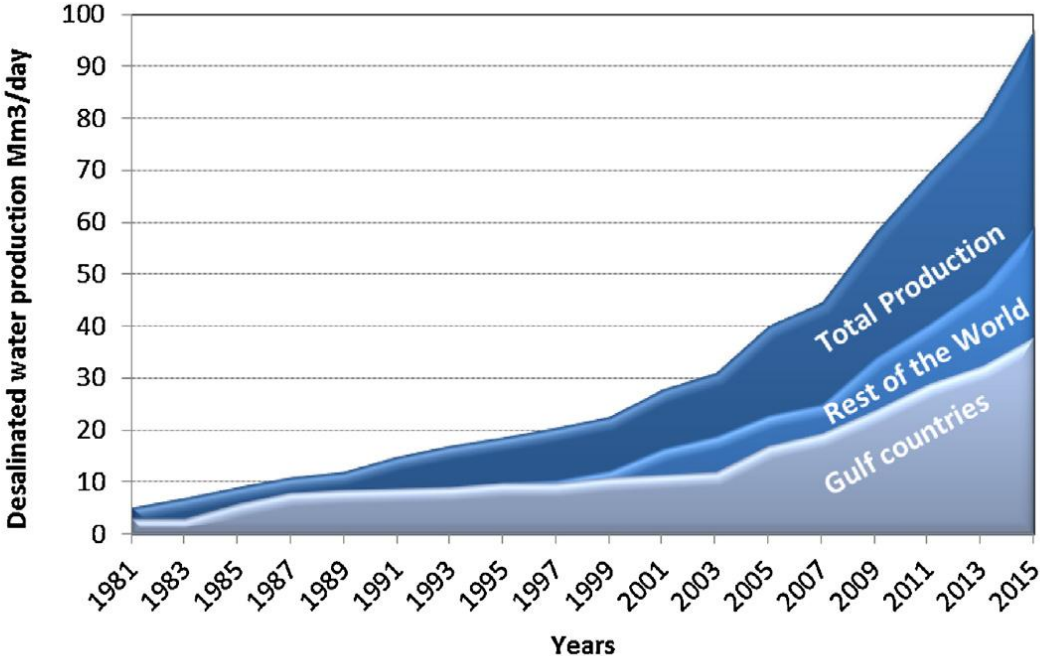

Figure 3 ;The desalination water production per day (Lattemann et al., 2010).

Currently, most of the desalination projects focused on developing cost-effective ways of providing fresh water for human use in regions where the availability of fresh water is, or is becoming, limited. Although seawater desalination projects often face some environmental and economical challenges, these challenges can be successfully addressed by carefully selecting the project site, by combining energy-efficient and environmentally equipment and systems.

2.2 WATER DESALINATION TECHNOLOGIES

A number of seawater desalination technologies have been developed during the last several decades to augment the supply of water in arid regions of the world (Khawaji, Kutubkhanah, & Wie, 2008). Previously, the cost of desalination process is quite high and many of develop country can't afford to buy these technologies. However, desalination has been growing rapidly as an industry and as a field of research that combines engineering and science to develop innovative and economical means for water desalting (El-Naas, 2011).

The desalination process can be based on thermal and membrane separation method (El-Dessouky & Ettouney, 2002). As shown in Figugre 4, both methods encompass a number of different processes. An alternative process can be done by using freezing and ion exchange process.

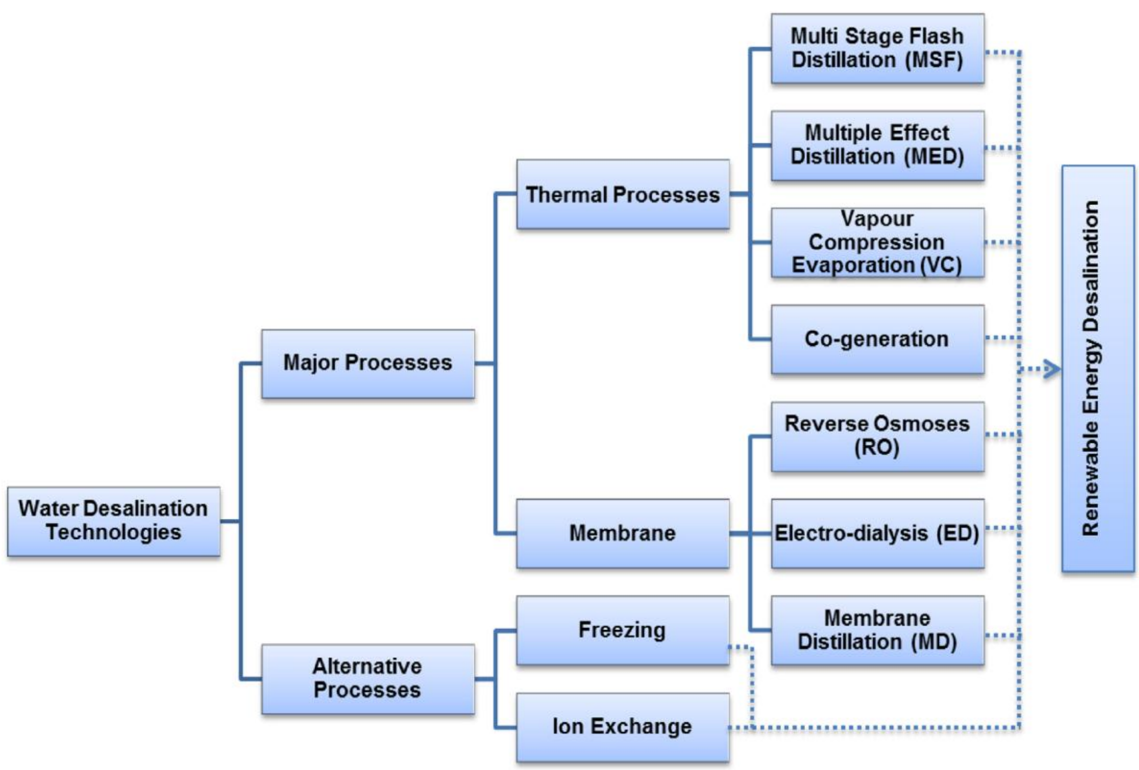

Figure 4; Water desalination technologies (Shatat et al., 2013).

Today, reverse osmosis (RO) is the leading technology for new desalination installations, with a 44% share in world desalting production capacity and an 80% share in the over 15,000 desalination plants installed worldwide (Morillo et al., 2014). The Middle East has forged ahead as the leader in large-scale seawater desalination. With only 2.9% of the world's population, it holds approximately 50% of the world's production capacity. Figure 5 showed a comparison of different desalination process done by 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 produc	90-567	108-432	-	-	-	-
Electricity consumption (kJ/kg of product)	7.2-18	5.4-10	-	28-40		43
Prime energy consumption (kJ/kg of product)	110-653	110-369	-	80-110	65-120	144
Energy recovery	Sensible to latent	Latent to latent	Recovery low temperature vapor	Recovery low temperature vapor	Pressure recovery	-
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, sacrifie power plant performance	Limited to smaller size plant, need skillfull operator	Membrane replace every 5-7 years, cannot treat high salinity water	Almost all brackish water application

Figure 5; A comparison of different desalination process (Li, Goswami, & Stefanakos, 2013)

2.3 SOLAR STILL

Solar still distillation is a process of distillation that used solar energy to produce fresh water. Solar desalination would permit obtaining fresh water by means of an environmentally friendly process even in remote areas with no access to electricity or other conventional energy sources. Solar desalination can be classified as most economic device that used renewable energy sources (Blanco Gálvez, García-Rodríguez, & Martín-Mateos, 2009). Comparatively this technology has no skilled workers needed and low maintenance due to which it can be used anywhere with lesser number of problems.

A solar distillation device or solar still can alleviate the need of clean drinking water for a majority of population, which has an abundance of solar energy available. A solar still operates similar to the natural hydrologic cycle of evaporation and condensation.

The principle of solar desalination was explained as shown in the figure 6 (Bhardwaj et al., 2013). A schematic of a typical solar still showed the incoming solar radiation heats upwater, resulting in subsequent evaporation and condensation of vapors. Then, next figure showed the thermal resistance diagram for heat transfer at the surface. R and h represent the thermal resistance and heat transfer coefficient respectively. Subscripts I, S and E represent internal, surface and external properties. The phenomena associated with the condensation surface in a solar still.

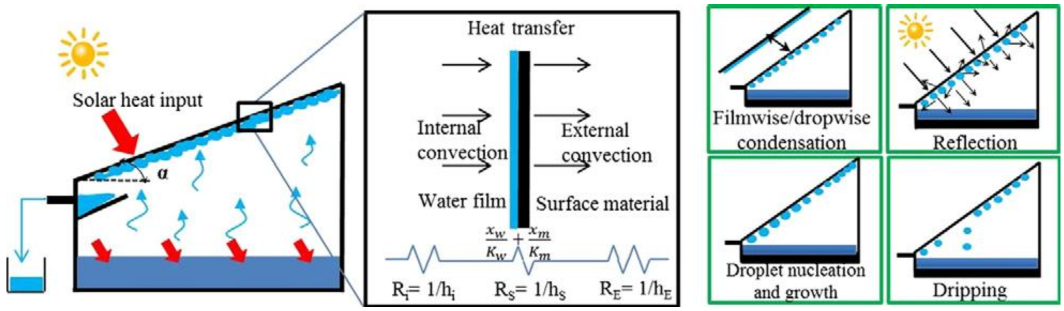

Figure 6; Principle of solar distillation (Bhardwaj, ten Kortenaar, & Mudde, 2013)

Solar stills are categorized into two distinct types; active and passive (Muftah, Alghoul, Fudholi, Abdul-Majeed, & Sopian, 2014). In a passive solar still, the solar radiation is received directly by the basin water and is the only source of energy for raising the water temperature and consequently, the evaporation leading to a lower productivity (Sampathkumar, Arjunan, Pitchandi, & Senthilkumar, 2010). Passive solar stills are divided into conventional and efficient designs. In the active distillation process, hot water from the collector panel is fed into the basin of solar still in order to achieve a faster rate of water evaporation (Tiwari, Shukla, & Singh, 2003).

Kaushal and Varun (2010) had reviewed on comparison of different types of solar still used. The summary of their studied was shown in Figure 8. The laboratory test was done by using apparatus of two effects having 500 mm x 500 mm heat penetrating area that was designed and made mainly from polyethylene film.

Types of solar stills	Geometry	Properties	Results	Advantages	Disadvantages
Simple solar still	Area = 500 mm × 500 mm, insulation = 1.5 mm, glass thickness = 5 mm	Intensity of insulation. Productivity steady state efficiency	Results obtained with the no insulation condition are more realistic since the presences 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 × 500 mm, bags = 500 mm^2, tube = 15 mm, fibrous sheet = 1.3 mm, side angle = 14.6°, inclination angle = 9.7°	Photocell temperature. Productivity solar intensity	Water to power ratio for such a hybrid system may be a key factor to determine the optimum condition. Main aim is to increase production.	Portable. Used in caravans recourse survey and military front. In laboratory.	Low performance. Used for small purposes.
Water film cooling over a glass cover of a still	Area = 500 mm × 500 mm, insulation = 1.5 mm, glass thickness = 5 mm	Steady state efficiency. Ambient temperature. Wind speed. Humid ratio.	For a conventional still, efficiency increases at low V_a and then decreases. A high value of $h_{c,f}$ 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 × 500 mm, insulation = 1.5 mm, glass thickness = 5 mm, pump. l_w = 1 m	Annual yield. Water depth. Inclination of flat plate collector	The performance of passive solar still in terms of hourly yield for different water depth.	Passive stills are more economical to provide potable water.	High capital cost. Depth increases efficiency decreases.
Multi-effect diffusion type solar still	Height of the still = 1 m. Length of the flat plate reflector = 1 m. Width of the still and flat plate reflector = 1 m. Diffusion gap between partition = 5 mm. Number of partitions = 10. Emissivity of glass cover = 0.9. Air gap between the glass cover and first partition = 10 mm. Reflectivity of the flat plate reflector = 0.95. Emissivity of the front surface of the first partition = 0.3	Solar radiation. Solar absorption. Time. Daily amount of distillate. Partitions. Overall productivity. Thickness of diffusion gaps between partitions. Feed rate of saline water. Reflectivity of flat plate reflector. Angle of flat plate reflector	The overall daily productivity is 1/5 of scale. The daily amount of distillate is largest on second partition and decreases from second to last partition. The overall daily productivity is larger on the winter solstice 39.7 kg/m^2 day than on spring equinox 34.2 kg/m^2 day since the sun rays are more inclined on the winter solstice than on the spring equinox, and this causes solar absorption.	Suitable for small purposes. More efficient when gap is very small. Mainly used in military fronts. Easy to operate. User friendly.	Diffusion gap between the partitions is the main problem. Air gap between the glass cover should be optimal.
Tilted wick solar still	Width of the still = 1 m. Length of the still = 1 m. Height of reflector = 0.5 m. Angle of the still = 30°. Azimuth angle of still = 0°. Diffusion gap between wick and glass cover = 10 mm. Absorptivity of wick = 0.9. Absorptivity of glass cover = 0.08. Reflectivity of reflector = 0.85	(1) Distillate production rate. (2) Solar radiation absorbed on wick. (3) Daily amount of distillate. (4) Angle of still. (5) Time	Distillate production rate as well as the solar radiation absorbed on the wick is greater for the still with reflector more than the still without a reflector during the time from 8 a.m. to 4 p.m. because the evaporating wick could not receive radiation from the reflector during the period.	Daily productivity of the still with reflector increases by 9% as compared to simple solar still. Productivity of water is more and used for economical purposes.	With out reflector productivity decreases. Wick is the main problem. Continuous feed of water is required for wick. Contamination due to wick always occur.
Solar still made up of tubes for sea water desalting	Table area = 1 m^2. Width = 0.5 m. Length = 2.0 m. Horizontal transparent tubes = 0.10–0.25 m, i.e. inner diameter. Horizontal tube = 0.01 m, i.e. inner diameter. Thin transparent plastic foil = 0.01 m	Daily energy efficiency of the still. The latent heat of vaporization. Temperature	Enhanced fresh water productivity is obtained with respect to conventional solar still in which sea water evaporation and water vapour condensation occur in one confined space.	Used for costal area. Easy to manufacture. Efficiency is higher than simple still. Fibrous material used. Due to tube contamination is much less.	Capital cost is high. Very sensitive apparatus. Due to fibrous material cost increases.

Figure 7; Comparison of different types of solar still used (Kaushal & Varun, 2010).

2.4 DESIGN OF SOLAR STILL

The desalination process can be enhanced by using various design of solar still. Currently, there are two type of design that has been used in various experiment; compound parabolic concentration (CPC) or flat plate collectors.

A studied that had been done proposed a double effect active solar still coupled with a CPC collector (Prasad & Tiwari, 1996). Water was heated and evaporated in the still with the aid of solar collector heating the water as it entered the still. The still consisted of two glass covers - the lower glass cover with flowing water on the upper side, and another above the lower glass cover and exposed directly to the sun. Vapor condensed on the inner side of the lower glass cover where the latent heat was transferred to flowing water, whereas the secondary vapor condensed on the inner side of the upper glass cover. The basic design used in the studied is shown in figure 9.

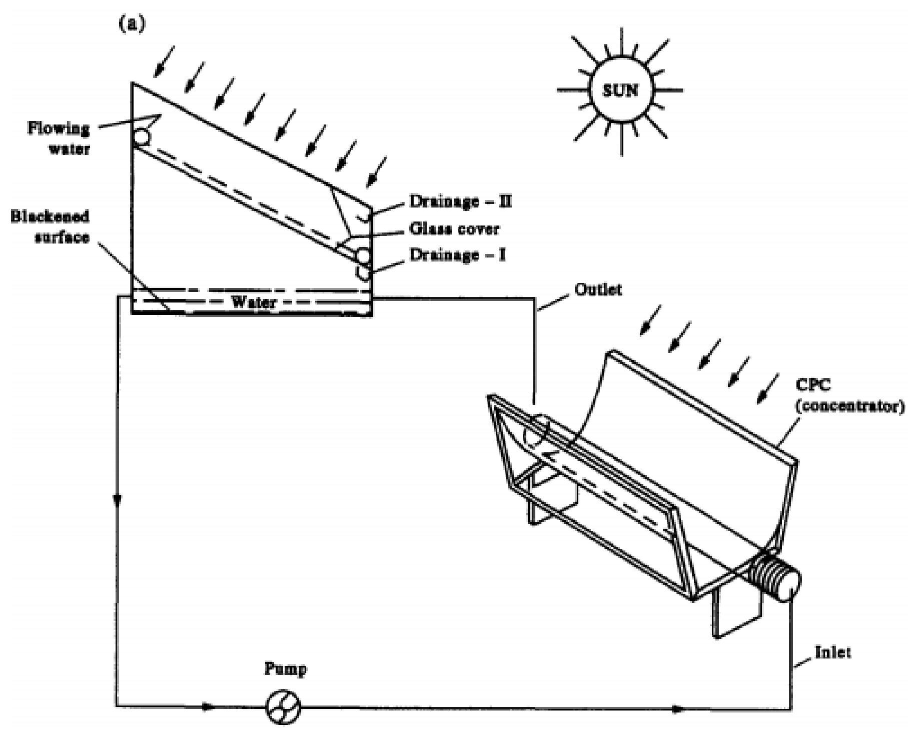

Figure 8; Active solar with CPC (Prasad & Tiwari, 1996).

A design involves using solar collectors, which makes use of compound parabolic concentration (CPC) or flat plate collectors draw extra solar radiation into the solar still. This method aims to increase the heat generated in the still for evaporation to take place. A studied by using active solar still has been done (Badran, Al-Hallaq, Eyal Salman, & Odat, 2005) . They made use of a design where a conventional solar still is assisted by another heat source. In this case the source is a fiat-plate collector. The set-up was assembled from existing, locally made components: a basin-type still with a double-slope glass roof, a conventional fin-tube flat-plate collector, a constant head tank and a feeding tank. It produced ~2.3 kg/m2/d with a solar collector and ~1.5 kg/m2/d without a solar collector. The efficiency for both trials is 22.26% and 28.56% respectively.

In addition, there is also a design with a concentric tubular solar still whereby CPCs are used to reflect concentrated beam radiation to the focal line of the tube. The experiment used an innovative design of tubular solar still with a rectangular basin for water desalination with flowing water and air over the cover (Arunkumar, Jayaprakash, Ahsan, Denkenberger, & Okundamiya, 2013). The inner and outer circle tubers are positioned with a 5mm gap for flowing water and air to cool the outer surface of the inner tube. Water was flowed at 10 ml/min while air was blown at a constant rate of 4.5 m/s. Under average solar radiation of ~905 W/m2 and average ambient temperature of 30°C, productivity with air flow was 3.95 kg/m2/d while with water cooling was up to 5 kg/m2/d, without any cooling aids the production was 2.05 kg/m2/d. It is mentioned that the current tubular solar desalination system has a low warm up time compared to basin type. However, it is able to operate at high temperatures due to the focusing of the CPC.

CHAPTER 3: METHODOLOGY

3.1 PROJECT ACTIVITIES

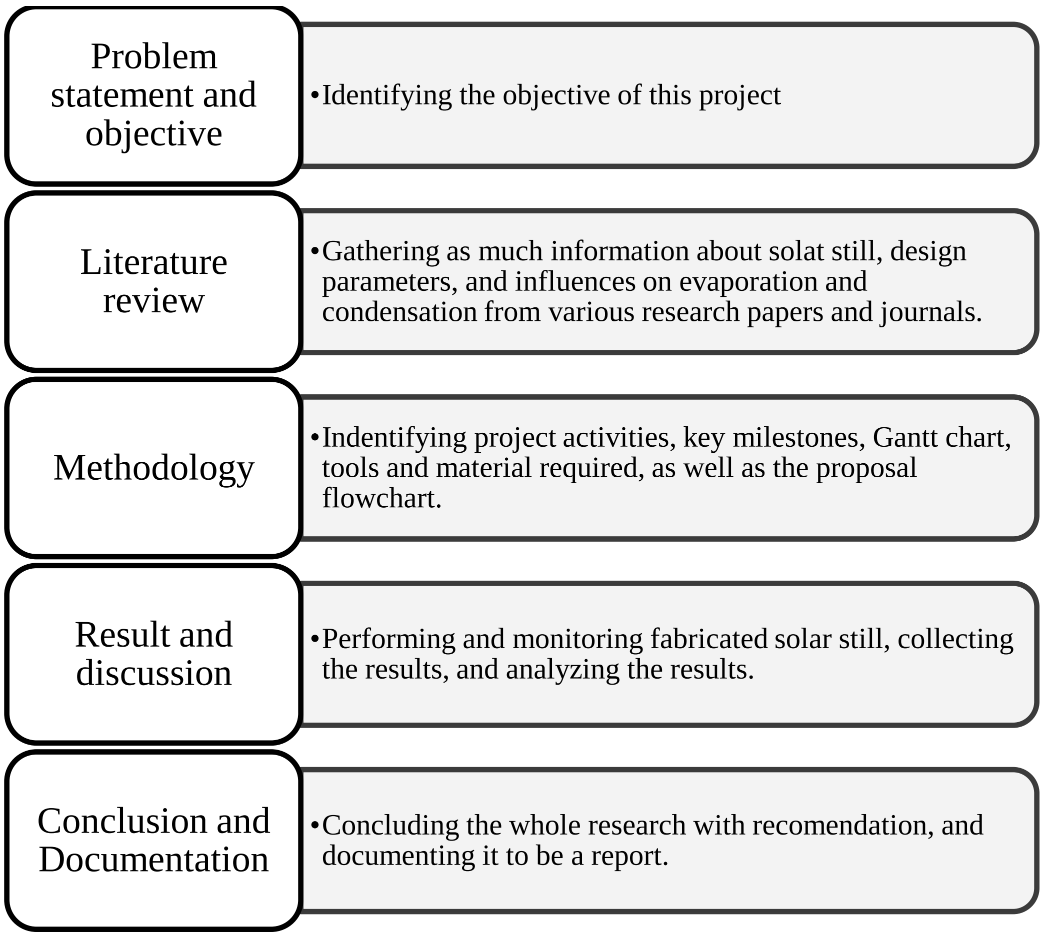

Figure 9; Project activities for Final Year Project

The method of study opted for this research is to gather suitable data on designing a solar still. Preliminary research on the solar still was carried out through literature study and obtaining preliminary data. Through literature study, various solar stills designs have been studied along with their methodology, results, efficiency and productivity levels. With the information gathered, a solar still design was based upon their research results and improvements can be made to further optimize the design.

The preliminary data obtained and the collections of data are based on secondary information sources. The design of a solar still derived from the basin solar still which consist of an inclined glass roof, basin, and a compartment to collect distilled water and also lens as external collector.

Materials required for a basic solar still is inexpensive but may increase if additional components are added, such as the use of external collectors. Several changing variables including solar radiation, ambient temperature and wind velocity were considered in this study. The solar radiation per square meter is measured using a compact digital solarimeter whereas the various temperatures are measured using a digital thermometer.

Sample collections of water involved using lake water to measure the quantity of production. The assessment of performance of solar distillation system involved monitoring of the solar still daily as well as the ambient conditions; i.e. amount of solar radiation per square meter, checking the temperature of water in the solar still and temperature of inner and outer glass cover, ambient temperature efficiency of evaporation and condensation rate, and amount of distilled water collected daily.

Results and discussions are obtained further as the project progresses after monitoring and testing of the fabricated solar still. The results obtained will be compared with previous works and will be discussed based on the findings. Conclusions are made after thorough checking and referencing of works and data to finalize the results.

3.2 EXPERIMENTAL SETUP

The process of the solar still distillation by external lens concentrator collector:

Figure 10; solar still distillation by external lens concentrator collector flow process.

Figure 11;Feeding tank used in the experiment

The flow process of still distillation is shown in the figure 10. The lake water sample first will be put in the feeding tank with upside down bottle to control the water flow pressure in the condensing tank. Next, the lake water sample will flow in to the external lens concentrator lens that filled up with oil in the tank to assist the increase temperature of the lake water sample. The external lens functions as concentrator of the sunlight. The sunlight will be concentrate to the oil inside the tank and then the oil will heat up. Since the sunlight will be concentrate to one point, the oil help to spread the temperature to all areas in the tank. Then, the lake water sample flow in to the condensing tank. From this experiment, the author target to prove that the efficiency of using water lens is higher than without using water lens.

The experiment was conducted from 9.00am to 5.00pm during the period of July 2014. The solar still was operated in two modes; one solar still alone and one solar still with external lens concentrator collector. The reading of solar radiation, production of water, oil and glass temperature was measured every one hour. The daily efficiency, $\boldsymbol{n_d}$ of the solar still is obtained by the summation of the hourly condense production, $\boldsymbol{m_{ew}}$ is multiplied by latent heat, $\boldsymbol{h_{fg}}$ and divided by daily average solar radiation, $\boldsymbol{I(t)}$ and the whole area $\boldsymbol{A}$ of the condensing tank (Abdullah, 2013).

3.3 DESIGN PROPOSAL

There are three stages of design in this project. Firstly, w the designing of the external water lens stand which is used to concentrate the sun energy to the concentrator collector. Secondly, the designing of the concentrator collector on the type of suitable material to maximise the absorption of sun energy concentrate by water lens. Lastly the designing of condensing tank also on type of suitable material and also the suitable size to maximise the production of water collected.

3.3.1 External Water Lens Stand

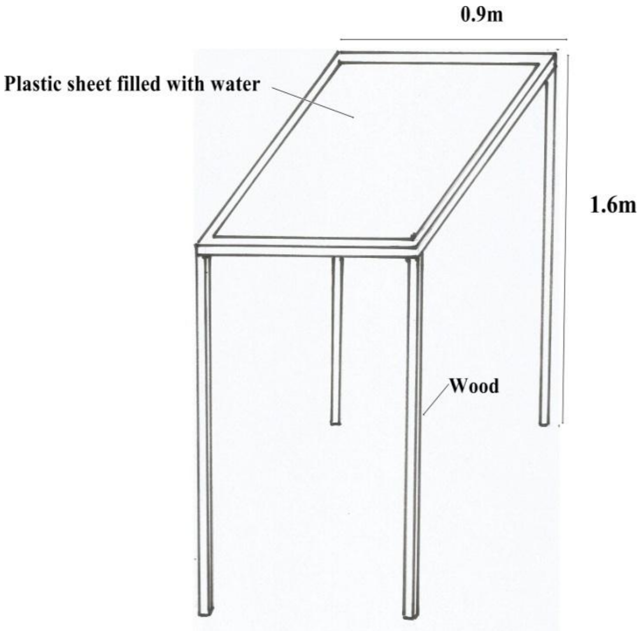

Figure 12;External lens stand

The original design is to use lens but since lens of larger size is hard to find, the author design the lens using water. The wood stand size of 0.9m x 0.9m x 1.6m is covered with 1.5m x 1.5 m plastic sheet at the top of the stand. 5 litre of tap water is filled on the plastic to act as a lens. From the water filled at the topside of the stand, the lens naturally form of 0.4m diameter with depth of 0.3m.

3.3.2 Concentrator Collector

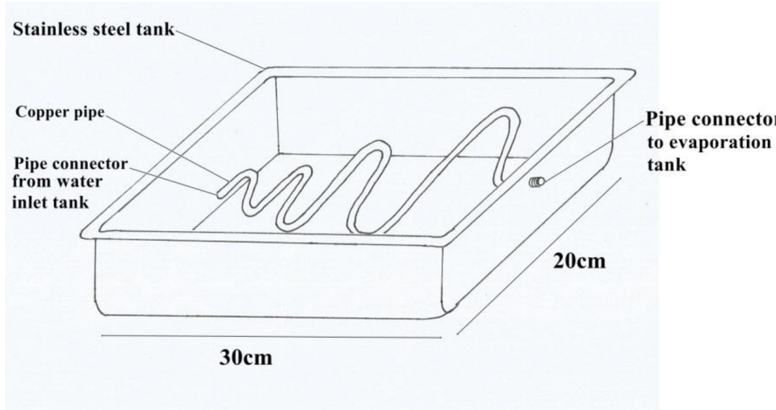

Figure 13;Concentrator collector tank

The concentrator collector tank design in the size of 0.3m x 0.2 m. Inside of the concentrator collector tank is the copper pipe. The diameter of copper pipe was 0.5 cm. The copper pipe in the tank was installed in increasing line from the pipe connector from water inlet to the pipe connector to evaporation tank. This is to avoid steam happen in the pipe during the process. The copper pipe was used because it has high resistance toward high temperature. The black paint stainless steel basin was made by spraying flat black paint with non-reflective surface to reduce lost of solar energy and increase absorption of heat.

3.2.3 Condensing Tank

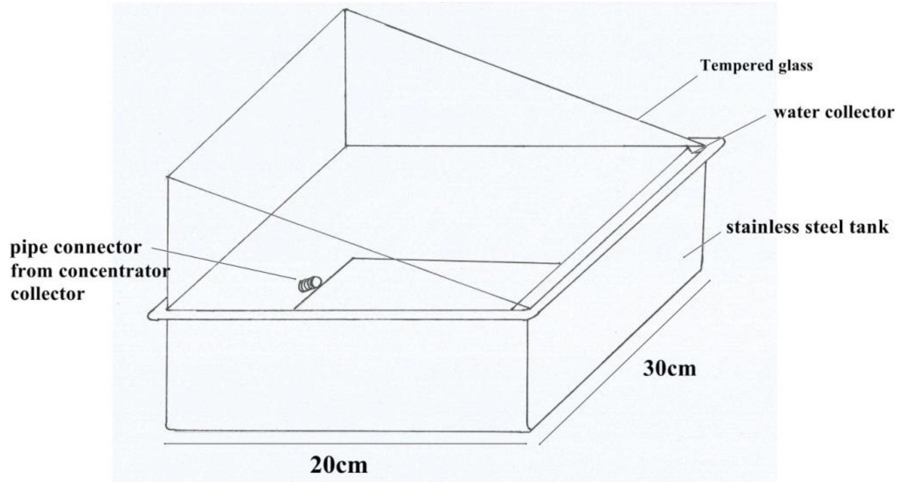

Figure 14; Condensing tank

The condensing tank size is 20x30cm. The half part of the tank was made form stainless steel. The upper part of evaporation tank is made up from 4mm thick of tempered glass. It was made from tempered glass and stainless steel to avoid the loss in heat energy to maintain the temperature of the distilled water. The black paint stainless steel basin at the bottom was made by spraying flat black paint with non-reflective surface to reduce lost of solar energy and increase absorption of heat.

3.3 MATERIALS AND EQUIPMENT REQUIRED

Materials and equipment to be used also has been identified as below;

Materials

- Plastic sheet
- PVC pipes
- Steel tank
- Tempered Glass
- Copper pipe
- Connecting pipes
- Wood frame for water lens

Equipment

- Digital Thermometer - Ambient temperature, Glass cover, Water in basin
- Solarimeter - Daily solar radiation
- Feeding tank
- Water bottles - Water storage
- Lab equipment for water analysis.
- Beaker

3.4 GANTT CHART & KEY PROJECT MILESTONE

The following flow chart is showing methodology part of this project and the Gantt Chart used as works guideline through this eight months.

The Gantt chart for entire project of FYP I is planned and shown in figure below;

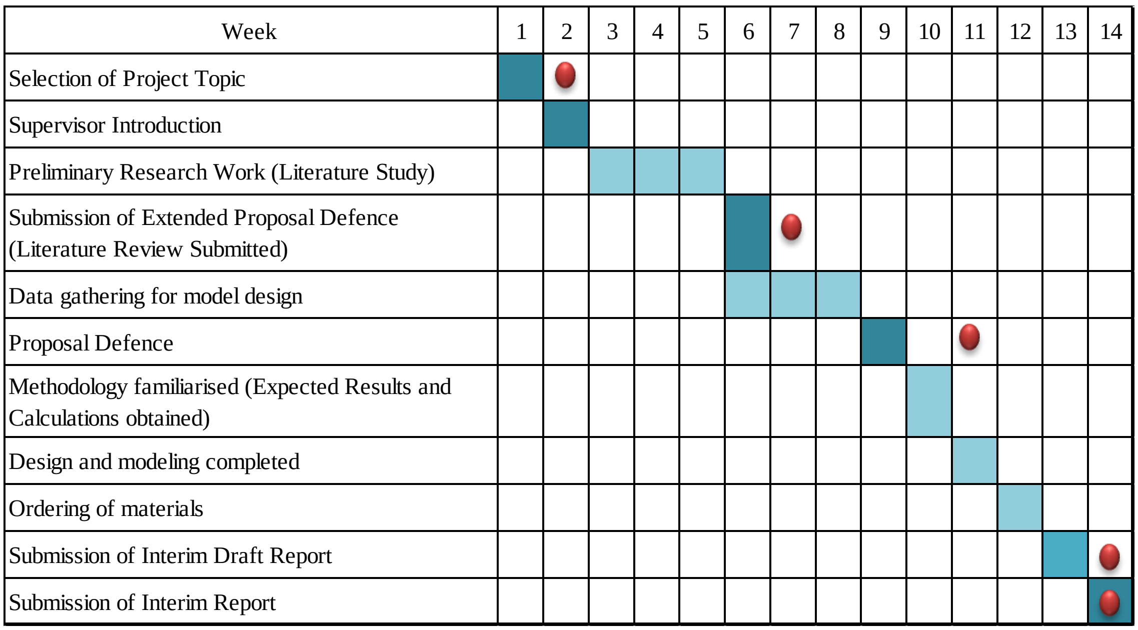

Figure 15;Project Gantt chart FYP I

FYP I Key Mile Stones

Title selection	: Week 2
Extended proposal submitted	: Week 7
Proposal defense	: Week 11
Materials & Equipment Identification	: Week 14
Interim report submitted	: Week 14

The Gantt chart for entire project of FYP II is planned and shown in figure below;

Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Fabrication of solar still	■	■												
Experimental preparerațion		■	■											
Experimental run				■	■	■								
Submission of Progress Report							●							
Analysis of result and modification						■	■	■	■					
Pre- SEDEX										●				
Submission of Draft Final Report											●			
Submission of Dissertation (soft bound)												●		
Submission of Technical Paper												●		
Viva													●	
Submission of Dissertation (hard bound)														●

Figure 16;Project Gantt chart FYP II

FYP II Key Mile Stones

Submission of Progress Report	: Week 7
Pre- SEDEX	: Week 10
Submission of Dissertation (soft bound)	: Week 12
Submission of Technical Paper	: Week 12
Viva	: Week 13
Submission of Dissertation (hard bound)	: Week 14

CHAPTER 4: RESULTS AND DISCUSSION

4.1 EXPERIMENT STAGE 1 – Without External Concentrator Collector

4.1.1 RESULT - Without External Concentrator Collector

The results for the three basin experiment are obtained after 1 day experiment duration on July 15th, 2014 and are presented as follows.

	Is(W/m2)	Tw	Tig	Tog	Wh_{exp} (ml)	Wd_{exp} (ml)
9.00 AM	204	27	33	27	0	0
10.00 AM	270	27	36	28	6	6
11.00 AM	290	28	40	30	7	13
12.00 PM	283	28	40	30	7	20
1.00 PM	464	30	41	35	7	27
2.00 PM	784	33	44	35	10	37
3.00 PM	496	27	42	27	7	44
4.00 PM	430	31	42	31	8	52
5.00 PM	334	28	38	29	8	60

Table 1;Result for without external concentrator collector (July 15th, 2014)

Where,

Is = Hourly solar radiation

Tw = Temperature of water in condensing tank

Tig = Temperature of inner glass of condensing tank

Tog = Temperature of outter glass of condensing tank

Whexp = Hourly water production of solar still

Wdexp = Daily water production of solar still

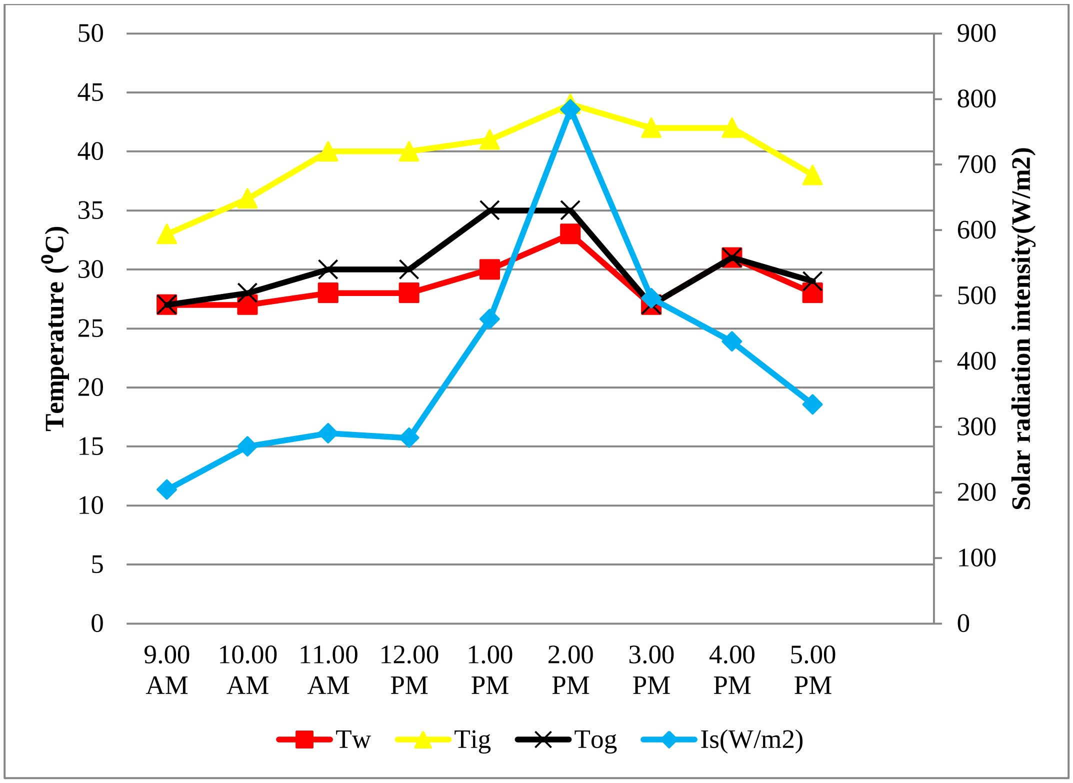

Figure 17;Temperature vs Solar radiation intensity with Time (without external concentrator collector July 15th, 2014)

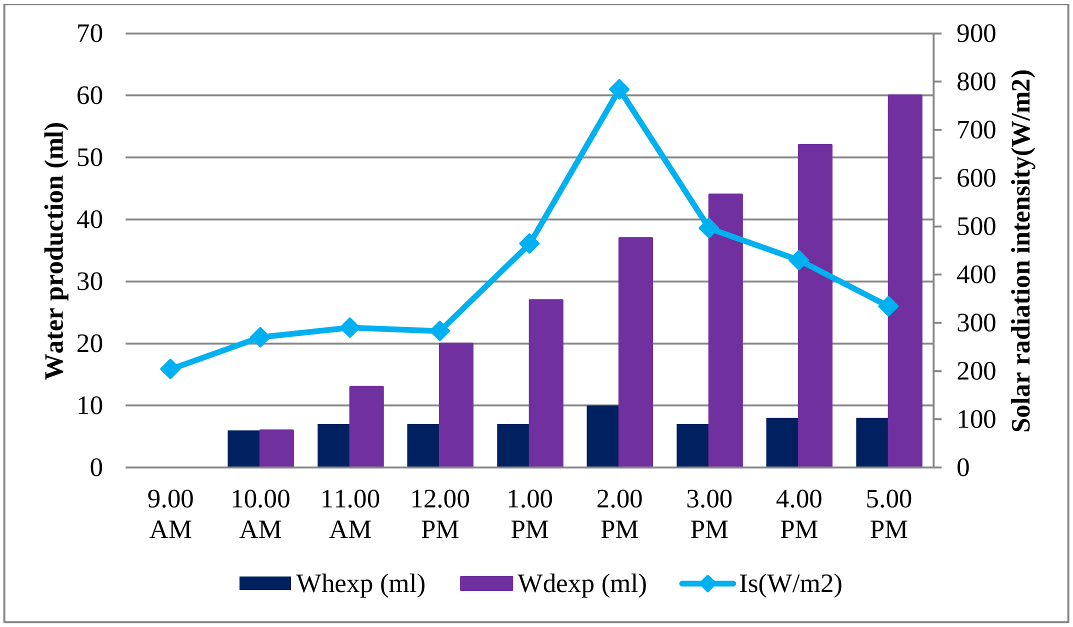

Figure 18;Cumulative and daily production (without external concentrator collector July 15th, 2014)

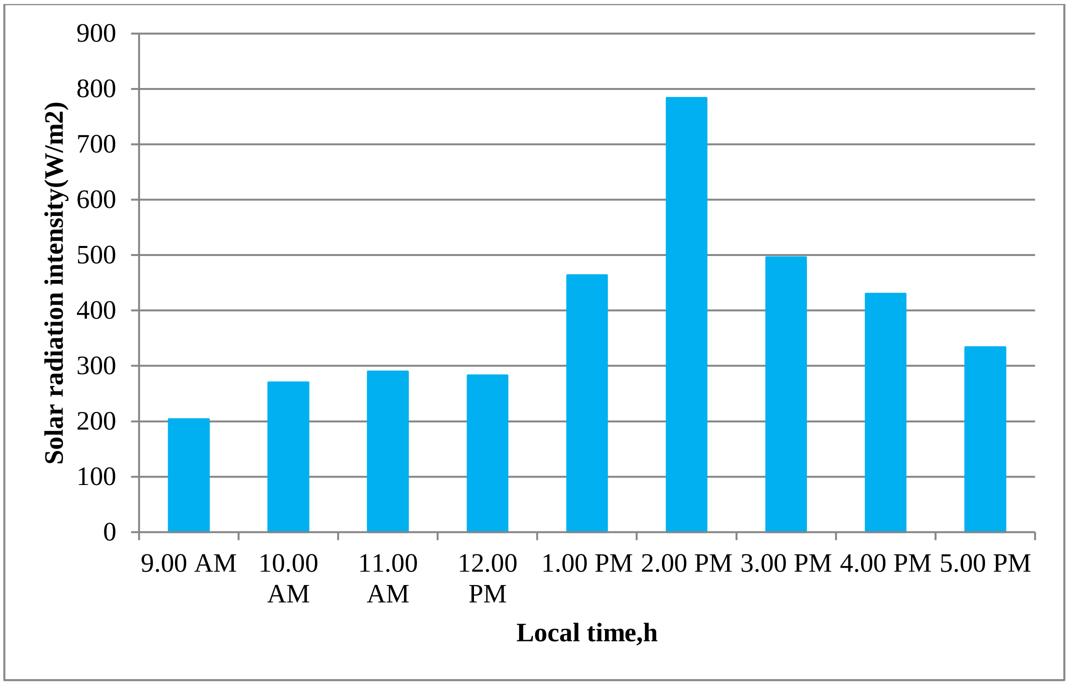

Figure 19;Maximum and minimum solar radiation (without external concentrator collector July 15th, 2014)

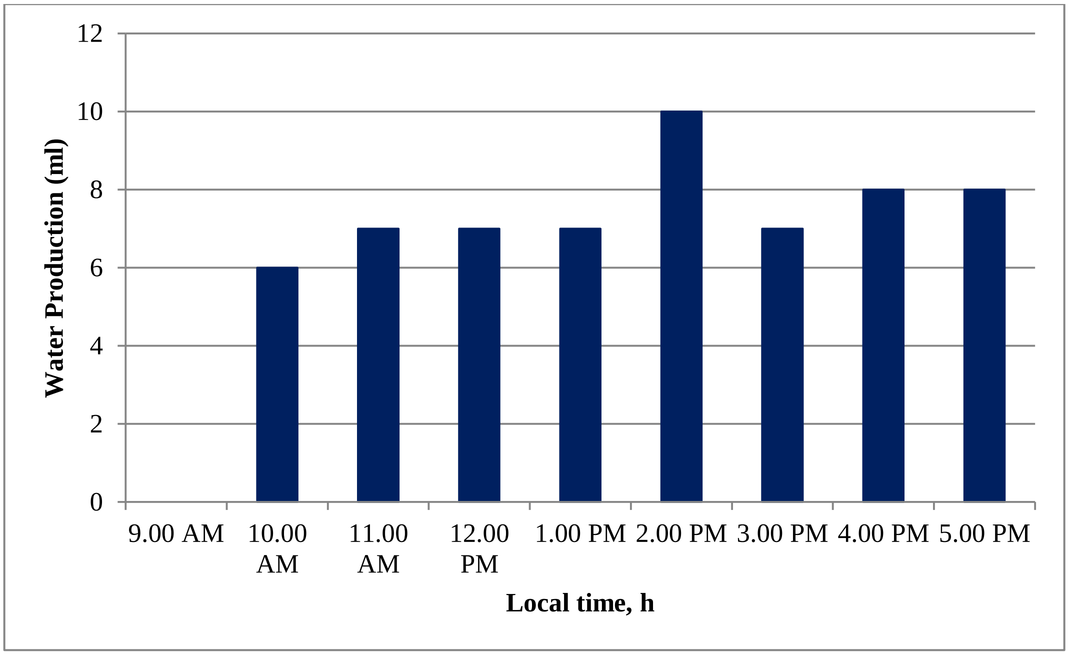

Figure 20;Maximum and minimum water production (without external concentrator collector July 15th, 2014)

4.1.2 DISCUSSION- Without External Concentrator Collector

Table 4.1 showed the data from the experiment without external concentrator collector. The graph in figure 4.1 until figure 4.4 was plotted based on data collected in the experiment. The weather recorded on 15th July 2014 is sunny day and the experiment was recorded for 8-hours from 8.00am to 5.00pm.

Figure 4.1 showed the graph of various temperature vs solar radiation intensity with time. The water temperature reaches highest reading on 2.00 pm. It showed that the most efficient solar radiation received is on 2pm. The maximum temperature of inner glass reaches 44˚C. The highest temperature difference between inner glass and outer glass for this experiment is 11˚C. It was higher than the experiment with external concentrator collector. The temperature of outer glass is always higher than the temperature or inner glass which is indicates that the condensing tank is producing a heat.

Figure 4.2 showed the graph of cumulative and daily production for the experiment without external concentrator collector. The graph showed that production of water increase with the increase of the solar radiation intensity. Besides that, it also showed that the water production reaches the maximum on 2.00 pm which is 10ml/h with solar radiation intensity of 784 W/m2. The cumulative production of the day is 60ml/d. Average solar radiation was 395 W/m2 during the 8-hour experiment on July 15th.

Figure 4.3 and 4.4 showed the graph of maximum and minimum solar radiation and the maximum and minimum water production. From the figure 4.3, the solar radiation intensity reading increase until it reaches the maximum point at 2.00 pm and then gradually decreases. The maximum point showed that the most effective solar energy received by the condensing tank is on 2.00pm. The maximum water production is also on the maximum solar radiation intensity.

From the data collected, the efficiency, $\boldsymbol{n_d}$ of the solar still is obtained by the summation of the hourly condense production, $\boldsymbol{m_{ew}}$ is multiplied by latent heat, $\boldsymbol{h_{fg}}$ and divided by daily average solar radiation, $\boldsymbol{I}(\boldsymbol{t})$ and the whole area $\boldsymbol{A}$ of the condensing tank (Abdullah, 2013). The calculation is showed below. The average of solar efficiency of basic condensing tank is between 19% to 39% (Abdullah, 2013). In the experiment the efficiency obtained is 20.48% which is in the average range.

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

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;

$$\boldsymbol{n_{d=}} \frac{\mathbf{0.060}\boldsymbol{kg} \times \mathbf{237200}\boldsymbol{J/kg}}{\mathbf{395}\boldsymbol{W/m^2} \times \mathbf{3600}\boldsymbol{s} \times \mathbf{8} \times \mathbf{0.06}\boldsymbol{m^2}} \times \mathbf{100}\%$$

$\boldsymbol{n_{d=}}$**20.85%**

4.2 EXPERIMENT STAGE 2– With External Concentrator Collector

4.2.1 RESULT - With External Concentrator Collector

The results for the three basin experiment are obtained after 1 day experiment duration on July 20th, 2014 and are presented as follows.

	Is(W/m2)	Tw	Tig	Tog	Whexp (ml)	Wdexp (ml)
9.00	198	27	33	26	0	0
10.00	273	27	36	27	6	6
11.00	286	27	36	28	6	12
12.00	364	27	37	28	8	20
1.00	412	27	38	28	8	28
2.00	636	28	40	31	12	40
3.00	354	27	38	29	8	48
4.00	321	27	36	27	8	56
5.00	284	27	36	27	6	62

Table 2;Result for without external concentrator collector (July 20th, 2014)

Where,

Is = Hourly solar radiation

Tw = Temperature of water in condensing tank

Tig = Temperature of inner glass of condensing tank

Tog = Temperature of outter glass of condensing tank

Whexp = Hourly water production of solar still

Wdexp = Daily water production of solar still

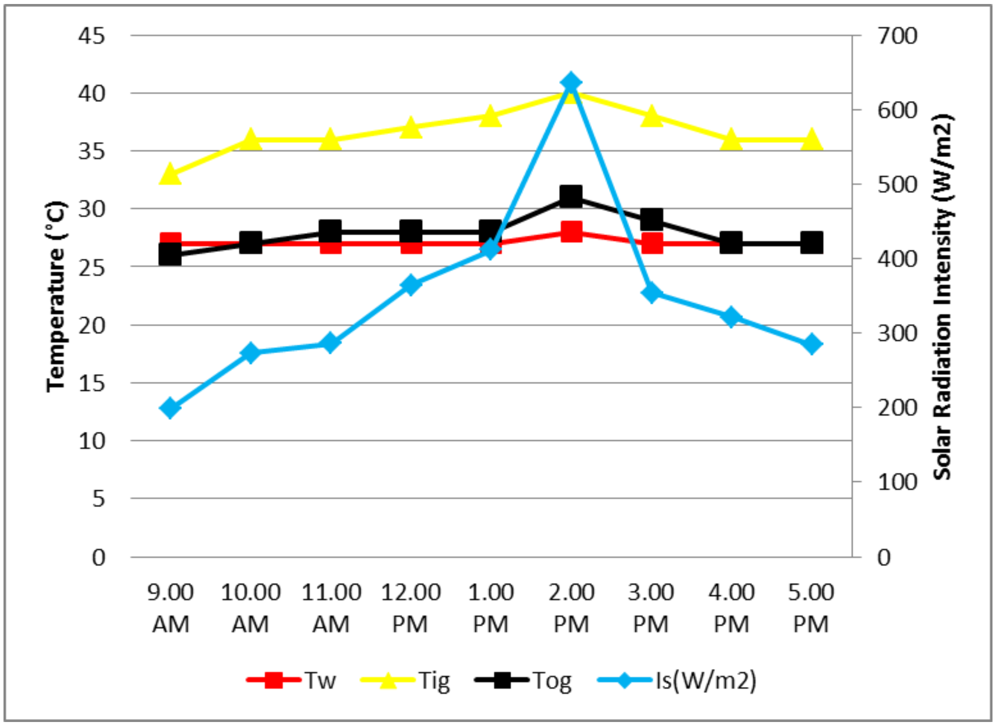

Figure 21;Temperature vs Solar radiation intensity with Time (with external concentrator collector July 20th, 2014)

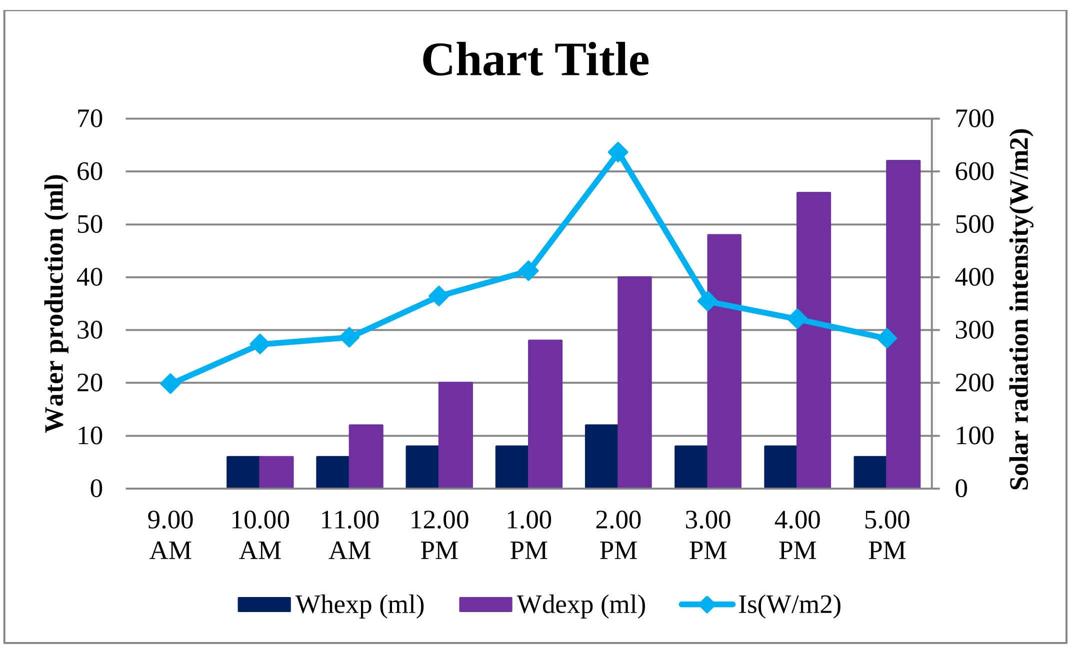

Figure 22;Cumulative and daily production (with external concentrator collector July 20th, 2014)

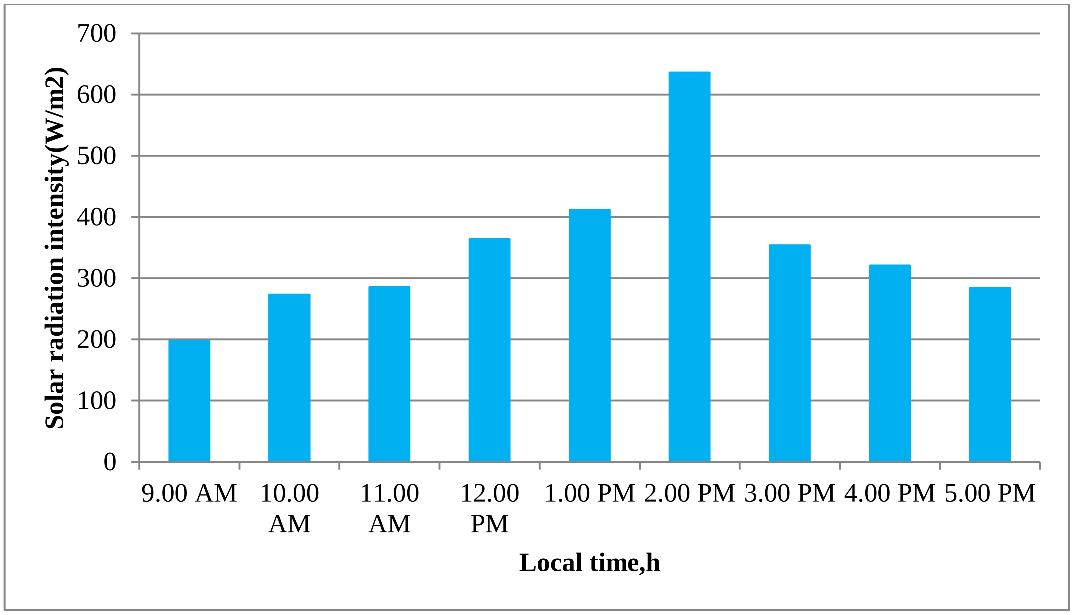

Figure 23;Maximum and minimum solar radiation (with external concentrator collector July 20th, 2014)

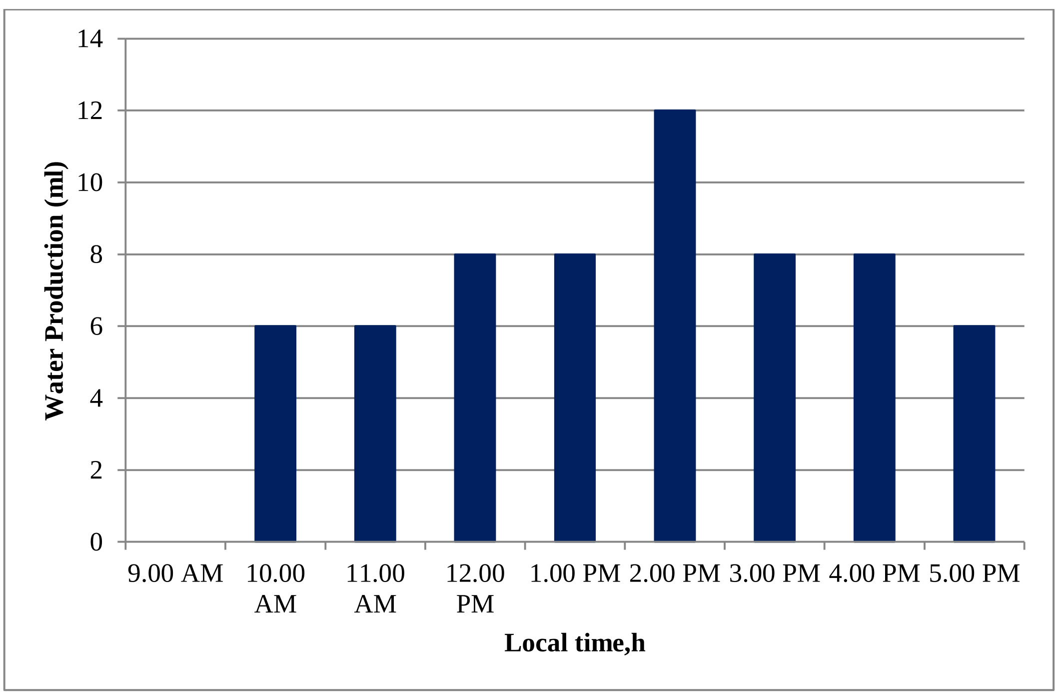

Figure 24;Maximum and minimum solar radiation (with external concentrator collector July 20th, 2014)

4.2.2 DISCUSSION - With External Concentrator Collector

Table 4.5 showed the data from the experiment with external concentrator collector. The graph in figure 4.5 until figure 4.8 was plotted based on data collected in the experiment. The weather recorded on 20th July 2014 is sunny and cloudy day and the experiment was recorded for 8-hours from 8.00am to 5.00pm.

Figure 4.5 showed the graph of various temperature vs solar radiation intensity with time. The water temperature reaches highest reading on 2.00 pm. It showed that the most efficient solar radiation received is on 2pm. The maximum temperature of inner glass reaches 40˚C due to the cloudy weather. The highest temperature difference between inner glass and outer glass for this experiment is 10˚C. It was lower than the experiment with external concentrator collector. The temperature of outer glass is always higher than the temperature or inner glass which is indicates that the condensing tank is producing a heat.

Figure 4.6 showed the graph of cumulative and daily production for the experiment without external concentrator collector. The graph showed that production of water increase with the increase of the solar radiation intensity. Besides that, it also showed that the water production reaches the maximum on 2.00 pm which is 10ml/h with solar radiation intensity of 636 W/m2. The cumulative production of the day is 62ml/d. Average solar radiation was 347.6 W/m2 during the 8-hour experiment on July 20th.

Figure 4.7 and 4.8 showed the graph of maximum and minimum solar radiation and the maximum and minimum water production. From the figure 4.3, the solar radiation intensity reading increase until it reaches the maximum point at 2.00 pm and then gradually decreases. The maximum point showed that the most effective solar energy received by the condensing tank is on 2.00pm. The maximum water production is also on the maximum solar radiation intensity.

From the data collected, the efficiency, $\boldsymbol{n_d}$ of the solar still is obtained by the summation of the hourly condense production, $\boldsymbol{m_{ew}}$ is multiplied by latent heat, $\boldsymbol{h_{fg}}$ and divided by daily average solar radiation, $\boldsymbol{I}(\boldsymbol{t})$ and the whole area $\boldsymbol{A}$ of the condensing tank (Abdullah, 2013). The calculation is showed below. The average of solar efficiency of basic condensing tank is between 19% to 39% (Abdullah, 2013). In the experiment the efficiency obtained is 20.48% which is in the average range.

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

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;

$$\boldsymbol{n_{d=}}\frac{\mathbf{0.062}\boldsymbol{kg} \times \mathbf{237200}\boldsymbol{J/kg}}{\mathbf{347.6}\boldsymbol{W/m^2} \times \mathbf{3600}\boldsymbol{s} \times \mathbf{8} \times \mathbf{0.06}\boldsymbol{m^2}} \times \mathbf{100}\%$$

$\boldsymbol{n_{d=}}$**24.48%**

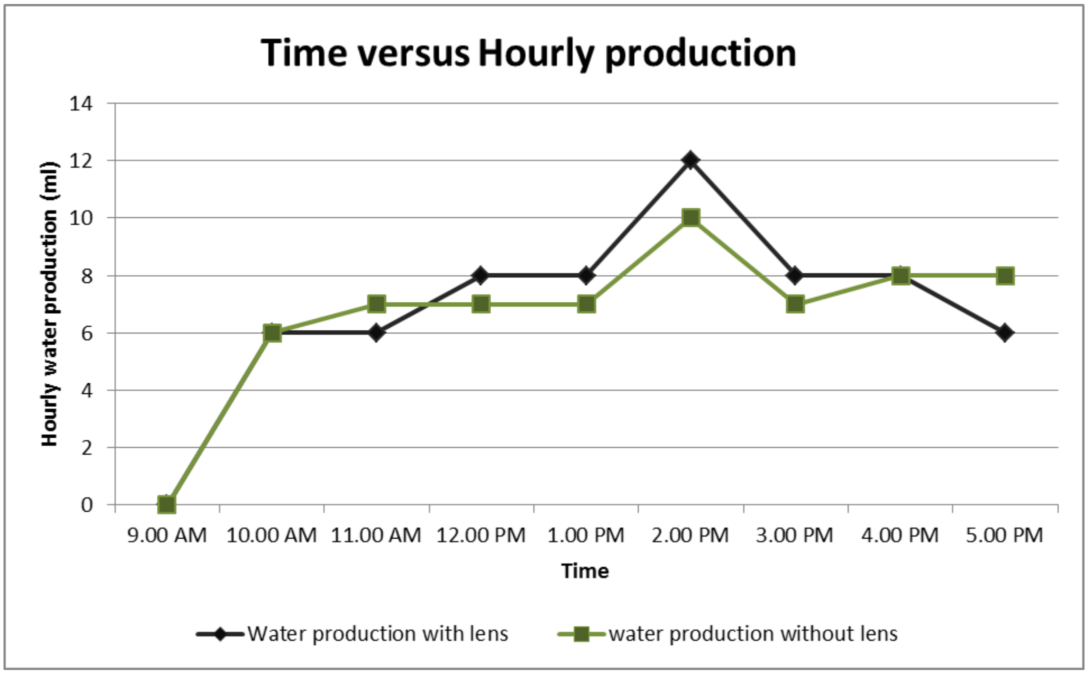

Figure 25;Productivity of condensing tank with and without external concentrator collector.

Figure 4.9 showed the comparison the water production of condensing tank with and without the external concentrator collector. The average solar intensity radiation reading for with and without the external concentrator collector is 347.6W/m2 and 395W/m2 respectively. Even though the average of solar radiation intensity reading of the experiment with the external concentrator collector is lower than without external concentrator collector, the water production with the external concentrator collector is higher than without external concentrator collector. From the calculation of the efficiency of condensing tank, the efficiency of using external concentrator collector is higher than not using external concentrator collector.

4.3 WATER QUALITY ANALYSIS

	Lake water	Distillate	Standard
pH	6.78	6.68	6.5 - 9
Turbidity (NTU)	33.57	0.5	0 - 5
Sulphate (mg/l)	18.67	0.45	0 - 250
Nitrate (mg/l)	2.37	0.73	0 - 10
Iron (mg/l)	0.98	0.14	0 - 0.3
Colour	greenish	colourless	colourless
Odour	have odour	odourless	odourless

Table 3; Water quality analysis result

The water quality analysis has been done to make sure the water production from the condensing tank is safe to drink. The water quality analysis was done in Environment Laboratory. The result showed that all the water quality requirement is pass and the water produce by the condensing tank is safe to drink.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

Solar distillation condensing tank in this study was designed by using steel tank with black paint and tempered glass. The condensing tank was design with the size of 0.3m x 0.2m. From the study, the condensing tank has produce water of 60ml per day with average solar radiation intensity without external concentrator collector of 395W/m2 for 8-hour duration. While for production with average solar radiation intensity with external concentrator collector of 347.6W/m2 is 62ml. The condensing system in this study converted the sun energy into water with efficiency of 20.85% and with the enhancement of external concentrator collector using lens in this study converted the sun energy into water with efficiency of 24.48%. The difference of efficiency shows that the focusing of sun energy using lens increases the efficiency of condensing tank (solar distillation) by 4%.

5.2 RECOMMENDATION

There are a lot of improvement can be done on this research, some of the recommendation that can be considered are as follows:

- It is recommended to use a motor and a sensor to track the sun and rotate the concentrator collector accordingly.
- The steel tube for the connector between concentrator collector and condensing tank should be ensure to be tight and free from leakage.
- The system should be kept closed and sealed from wind or external effects.
- The wind velocity should be monitored since it has affected the rate of productivity.

Overall, solar-still water production under Malaysian conditions has potential to grow and may become an energy harnessing asset in the near future. Thereby, it is with hope that the findings of this project can aid in future developments of solar still.

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