Evaluation of Polythene Film Cover Double-Slope Solar Still with Different Materials on Distill Water Production.

MARDIANA MARZUKI

CIVIL ENGINEERING

UNIVERSITI TEKNOLOGI PETRONAS

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By

Mardiana Bt. Marzuki
15172

Dissertation submitted in partial fulfilment of the requirements for the Bachelor of Engineering (Hons) (Civil)

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Universiti Teknologi PETRONAS,
Bandar Seri Iskandar,
31750 Tronoh,
Perak Darul Ridzuan.

CERTIFICATION OF APPROVAL

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MARDIANA MARZUKI (15172)

A Project Dissertation submitted to the Civil Engineering Programme Universiti Teknologi PETRONAS in partial fulfillment of the requirement for the BACHELOR OF ENGINEERING (Hons) (CIVIL ENGINEERING)

Approved by,

_________________________ (DR. HJ. KHAMARUZAMAN B. WAN YUSOF)

UNIVERSITI TEKNOLOGI PETRONAS TRONOH, PERAK
JANUARY 2014

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 sources or persons.

MARDIANA MARZUKI (15172)

ABSTRACT

Water is crucial for human to continue life. But, in many part of the world, fresh water resources are unreachable or unavailable to people especially those lives in rural area. This problem become more serious when the industry in worldwide is growth rapidly and increased the demand for fresh water supply. For the solution, some engineers and researcher come up with desalination plants to produced potable water from saline or brackish water. However, the operational and maintenance cost are high and energy used are non-renewable sources which the rate are increase by the time. Instead of desalination, the solar distillation is an alternative to overcome this problem. Solar distillation is environmentally safe, economically in cost and uses solar radiation to evaporate saline or brackish water to potable water. The aim of this project is to investigate the effect of several variables in production rate of potable water. The design of this project is double-sloped solar still with polythene film cover. The variables are the type of basin's material; black paint and black soil, with lake water basin as control. The experiment is conducted for three days and the distillate are collected for every 30 minutes from 0800 hours till 1800 hours daily. For the results, the solar still with black paint basin produced the highest volume of distill water which is 701 ml. The volume of distillate produced from solar still with black soil basin and conventional basin are 546 ml and 374 ml respectively. Further research need to done so that the solar still can perform better to serve human better.

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CHAPTER 1: INTRODUCTION

1.1 Background of study

Water is very crucial in human being life especially for drinking. Human beings need at least two to three liters water daily. On this earth, the water covers most of the part but only 1% of total water on surface is fresh water. The fresh water found in lakes, rivers or underground and this limited quantities needs to be treated for drinking. In Malaysia, there still a lot of underground water sources that supply mineral or drinking water compared to others 26 countries that do not have inadequate water supply even to maintain agricultures. Today, the populations of human beings are rapidly increasing and approximately 1.1 billion people in this world have limited access to safe drinking water thus; supplying drinkable water is one of the major problems in developing countries and to the people those live in rural area.

The desalination from ocean or saline water is the most suitable solution for the shortage for drinkable water supply. There many methods of desalination developed over years including reverse osmosis (RO), multi-stage flash (MSF), multi-effect distillation (MEF), and electrodyalysis. It is viewed that three process RO, MSF and MEF will be dominant and competitive in future (Rautenbach, 1992; Rautenbach et al., 1995). These methods require fossils or electric energy source and the cost for the energies are raised over the years. When electrical and fossils are get involved, the maintenance also needed. Thus these methods are not particularly inadequate due to high cost for energies and maintenance. For people have limited access for safe drinking water and the countries are not developed well, it is desirable to provide them with drinking water distilled by solar energy from sea water or brackish water.

Solar distillation is a process where fresh water is produced from distillation of saline or brackish water by using solar energy for drinking, domestic and other purposes. As stated before, there are a lot more method to desalination, but the solar distillation appears as one of the best practical and the most economical, especially for mass production of fresh water from high saline water like sea water (Saidur et al., 2011). It is due to the energy used; solar energy which is free and the process involved are simple. Solar water distillation has been discovered over century ago. A solar plant with capacity around 4000 m2 has been built in Chile to feed mining workers and operated for many years successfully. Moreover, a small plastic solar still have been employed to provide potable water for life rafts floating in the ocean during World War II. As the time goes, there a lot of things to be improved so that more fresh water can be produced.

Solar still is probably the oldest method of desalination of water. The operation of this method same as the greenhouse effect where the water inside a closed glass covered chamber at temperature higher than the ambient evaporated due to the radiation from sun. Then, when the evaporated water reaches to the cooler transparent leaning surface made of glass or plastic, the evaporated water form purely distilled droplets. The droplets then slide down along the leaning surface; due to surface force, gravity and lastly collected through special channel located under the leaning surface.

The production of fresh water is depends on many factors. Cooper (1969) has been done a digital simulation for the productivity of a complicated still and the most common variables are water depth, wind velocity, still insulation, double glass cover, cover slope, and daily variability on productivity has been investigated. From the past researches, they did experiment on sand or soil but did not specified what type of soil or sand are used in the experiment. In that case, the further study should be done in this variables.

1.2 Problem statement

Fresh water resources are reducing a day to days. There are many methods to increase the drinkable water supply. Some countries implant Reserve Osmosis (RO) method and other some countries use multi-stage flash (MSF), multi-effect distillation (MEF), and electrodyalysis method. The simplest method and the most economical is by implanting solar still where the potable water can be produced by distillation process of saline or brackish water. The only energy sources used to generate the product (potable water) is the sun. In addition, the radiation of sun the one of the renewable energy sources so that the product can produced continuously without energy sources reduced. Over years, engineers have made several solar still with different configuration and done some experiments on efficiency of production rate with variables. The variables are water depth, wind velocity, still insulation, double glass cover, and cover slope. As the results, most of the entire researchers have the same result but the variable of sand or soil is not justifiable. As such, this variable have to be further explore and studied further. Theoretically, by using sand, the production rate of potable water would be increased.

1.3 Objective and scope of study

The main objective of this work is to test a specific design of solar still with several variables on production of distill water under Malaysia weather condition.

Other objectives include:

i- To compare which materials; black paint or black soil will produce more distill water by using double slope solar still.

ii- To obtain the maximum volume of product by evaluating several combination of variables.

This research comprises outdoor experiment where to collect data such as distill water production and laboratory experiment to analyze the distill water produced.

CHAPTER 2: LITERATURE REVIEW

Solar still is an environmental friendly and economically device capable of producing pure water through distillation process of saline or brackish water. The production rate of a solar still is affected by several variables. As such, design parameters and operational parameters. Designs parameters involve experimental on various design aspects of solar stills were conducted. Where else, operational parameters involve experimental on various materials used.

Garg and Mann (1976) conducted experiments to determine the effect of design parameters on the performance of single-sloped and double-sloped solar still in the arid zones of India. The result shows that single-sloped solar still are recipient to higher levels of solar radiation at both low and high latitude station compared to double-sloped solar still. Eduardo et al. (2000) built a double-sloped laboratory still setup, with controlled water at different glass cover temperature. Their model was compared with single-sloped still experimental data and there no significant differences between the production of the two. Rajaseenivasan and Murugavel (2013) worked on double-sloped single basin and double-basin solar still, for both theoretically and experimentally. In their work, an extra basin was added to the established single-basin for the purpose of increasing the performance of the double-sloped solar still. The result was significantly increased. The productivity increased by almost 85% as compared to single-basin which operating under similar circumferences.

Mamlook and Badran (2007) did a study on the major factors that affect the production rate by fuzzy sets implementation. They also mentioned other researchers that did a study focus on factors affecting the still productivity, using the experimental methods such as Naim and Abd El Kawi (2003), Nafey at el. (2001), Kumar and Tiwari (1996), etc. They proved that by using charcoal particle beds can improved productivity by almost 15% compared to wick-type material (Naim et al., 2003). For the quick absorption and release of solar energy, Nafey at el. (2001) used black gravel as storage medium as opposed black rubber. They also came to result that using 20-30 mm black gravel will produced yield 19% higher in 20 L of saline water and glass cover angle of 15^{o}. The production rate also increase by let the cold water flows over an active glass cover. This is confirmed by Kumar and Tiwari (1996) in their study on performance evaluation of an active solar distillation system.

Other parameter for design is water depth in basin. The depth in the basin is predicted to actively influence the performance of a still (Ghoneyem, 1996). There are few studies were conducted to confirmed the fact, mostly involving design optimization of solar stills via the analysis of water depth in basins. Most of the results from past researchers show that the yield decrease as the depth of water in basin increase. Ghassan at el. (2012) did an experimental works on the effect of water depth in the basin and the result shows 3L of water have the average output of 3.924 L/day and 9L of water have the average output of 2.408 L/day. There are researchers who attempt to investigate the effects of different water depth basin solar stills on the heat and mass transfer coefficients for passive and active models such as Khalifa et al. (2009); Phadatare and Verma (2007); Tiwari and Tiwari (2007); and Triphati and Tiwari (2005).

The selection of materials is one of the factors in designing a still. The still cover, is one of the most crucial components should have its constituent material carefully vetted. Among of the possible selection are glass and plastics. For the efficiency, glass cover is more preferable, but plastic cover is cheaper in cost. Cover plates play a role as a medium for heat transfer. A solar still with glass cover plate 3mm thick increase the production rate by 16.5% compared to a 6mm thick glass cover (Ghoneyem, 1997). To increase the production rate, the incident solar radiation also needs to increase by increasing the absorptivity of solar still. Cooper (1972) add charcoal and coal to water increase the solar radiation absorbed in water , which will result in increases of absorptivity and reduces heat lost. Other than coal, the black rocks or gravels also can absorb incident solar radiation better than metallic wiry sponges and enhances the output by almost 20% (Abdallah et al., 2009). The same result is obtain and the still output found to increase 17%-20% (Sakthivel and Shanmugasundaram, 2008).

As stated before, the black rocks or gravels absorb more incident solar radiation than metallic wiry sponges. Actually it is due to the color of material used. Instead of using black rocks or gravels, some experimental works have been done by coloring the water. The mixing of dye with water will cause it to absorb almost all solar radiation, and the water will then transport heat right to bottom, which will then be passed to the surrounding via insulation (Sodha, 1980). An experiment is done by Rajvanshi (1981) where comparing the production rate of two color of water; water with dye and water without dye. The result of this experiment shows the productivity of still is increased by 29%. In this experiment, the dye used is black napthylamine. The productivity of a solar still depends on the temperature gradient between water and the glass cover. The temperature gradient is act as the driving force for the distillation process (Velmurugan, 2011). To create a temperature gradient, some enhancement has been made which is the water is flow on the glass cover plate. Bapeshwar and Tiwari (1984) have investigated these variables and they conclude that its performance was superior. Some other effects includes the total number covers are used. A study shows that by using double glass cover, the production rate decreasing by 25%-30%. This result quite disappointed as the cost will be increased as the glass cover is doubled (Ghoneyem, 1997).

Over the years, there are a lot of researchers done the studies on enhancing the productivity of solar still and the number are growing todays. From the past research, as many literature reviews had been done, the author found out that the study on sand or soil is not specified or detailed as much as other parameters.. So, the author has initiatives to investigate the correlation between productivity with black sand and black paint basins. Theoretically, dark colour of materials used for basins will absorb more solar radiations and can reduce the losses to atmosphere. Since to maintain the environmentally and economically devices, the propose design would like to use used soil or sand. In further study of enhancing the productivity of solar still, the author would like to do several experimental and numerical investigations on double-sloped solar still with black paint and black soil basins.

CHAPTER 3: RESEARCH METHODOLOGY & PROJECT ACTIVITIES

3.1 Research Methodology

The method of study adopted for this research is data gathering. The data gathered are consisting of the data on designing a double slope solar still and variables affect the production rate. In the preliminary research, the research on solar still was carried out through several literature study and some input are obtained. From literature study, various configurations of solar stills have been studied by other researcher along with their methodology, variables, efficiency and production rate. As the input data obtained, a double slope solar still designed was based on past research results and from the results, some enhancement can be made for obtained an optimized result.

In secondary research, the data is collected by experimental activities. After the design of double slope solar still completely fabricated, the data such as temperature and production rate are obtained. The production rate is depends on variables used; in this work, proposed variables used are number of cover and basin used, comparison the single-sloped and double-slopes solar still and comparison between water with dye and without dye. The proposed design is consist of two inclined cover, basin and a compartment for distilled water collected.

No.	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Selection of Project Topic	■	■												
2	Preliminary Research Work		■	■	■	■									
3	Submission of Extended Proposal						●								
4	Proposal Defence								■	■					
5	Project work continues										■	■	■		
6	Submission of Interim Draft Report													●	
7	Submission of Interim Report														●

● Suggested milestone

■ Process

Figure 3.1: Timeline for FYP1

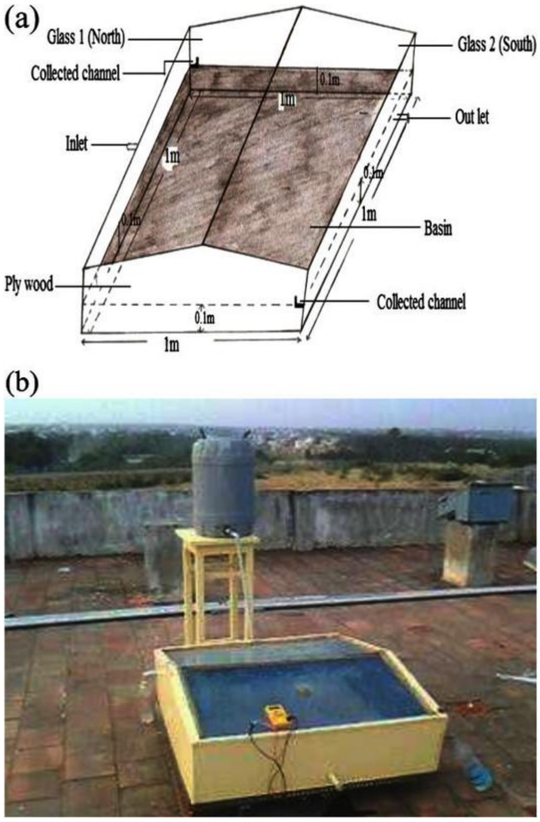

Figure 3.2: a) proposed shcematic diagram of double-slope solar still
b) proposed experimental still photograph

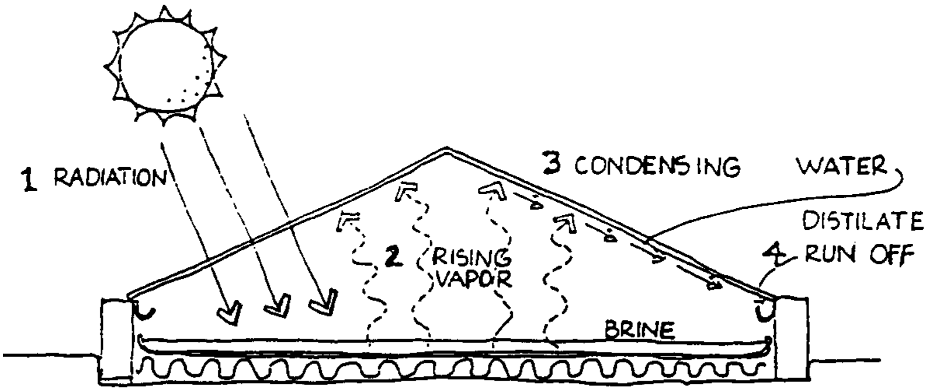

Figure 3.3: Basic process involved in still

In FYP I, the crucial part is the literature reviews where the basic knowledge of solar distillation are obtained. For the FYP II, the project is start with fabrication of a model. After the fabrication of models is done; planning to fabricate four glass cover solar still, the several experiments can be done by varying the variables or combine the variables. Experiment is done to collect data and then calculated by numerical formulas and data analysis can be done at that time. Lastly, from the data analysis, the result is obtained that tells which variables or which configuration of solar still is has the highest production rate of distilled water.

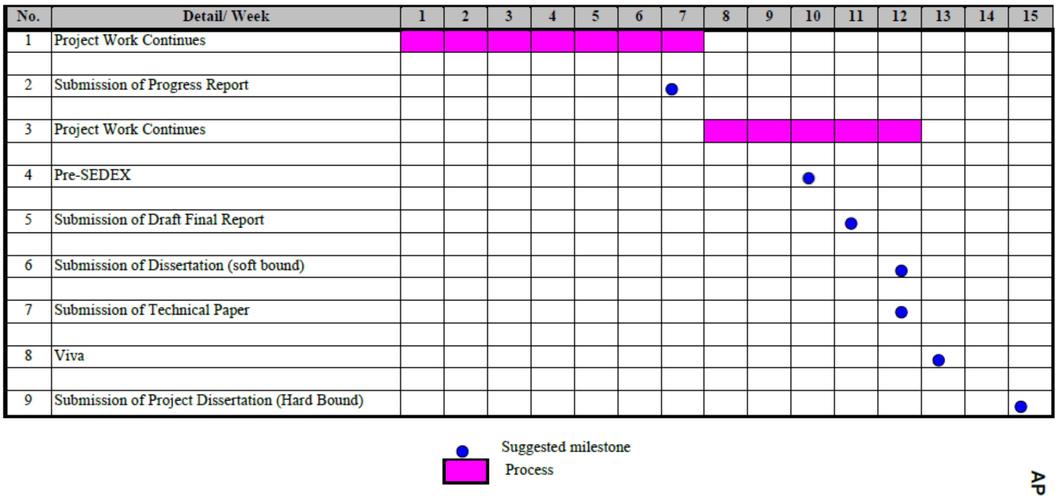

Figure 3.4: Timeline for FYP II

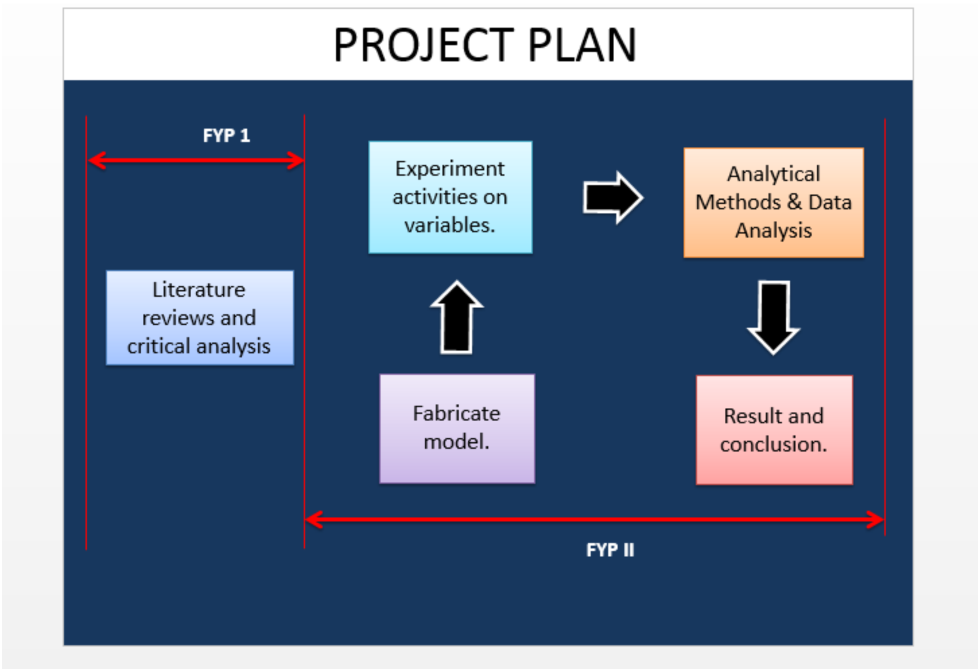

Figure 3.5: Project plan for FYP

3.2 Experiment – Basin Materials Absorbtion

For the experiment, which is the comparison between black soil, black paint, and conventional basin. The size of the basin are 50 cm x 30 cm which have an area of 150cm^2 (0.15m^2).

Figure 3.6: polythene film cover solar still

From the figure above, there are three type of basin (from left to right). The first one the the basin which have black in colour. The purpose of blacken the basin is to reduce the solar energy lost to surrounding and increase the absorbtion of the energy. The second basin, the proposed material used is 2cm depth of black sand which is enough to cover the bottom surface area. The sand help to reduce the reflectivity of the basin. The third basin is the conventional basin which act as control of black paint and black sand layer comparison.

The experiment is done by taking the several temperature's readings such as ambient temperature, outer cover temperature, inner cover temperature, humadity temperature and the temperature of water in the basin. Other parameter that measured is the volume of distillate. The reading of temperature and volume of distillate are taken every 30 minutes from 9.00 am to 6.00 pm for each solar still for three consequent days. The reason why the readings were taken in small interval was to get the result more accurate.

The distillate for each still were kept in separate container to be used in the water quality test. Distillate were test for alkalinity, turbudity, iron, sulphate, and nitrate. After the result for water quality have released, the result are then compare with standard water quality.

3.3 Materials &Equipment Required

(for experiment – Basin Materials Absorption)

Materials

- Polythene film
- steel sheet, frame
- glass
- black paint
- rubber nose
- PVC pipe
- aluminium sheet
- black sand
- stainless steel basin
- connecting pipes

Equipment

- thermometer (to collect ambient temperature, glass cover, water temperature in basin).
- Pyronometer (solar radiation).
- Water tank (for storage).

Figure 3.7: digital thermometer

Figure 3.8: digital pyronometer

Materials &Equipment Required (for Water Quality Test)

Materials

- Distillate from each solar still
- SulfaVer® 4 Reagent Powder Pillows (to test sulfate)
- FerroVer® Iron Reagent Powder Pillow (to test iron)
- NitraVer® Nitrate 5 Reagent powder pillow (to test nitrate)

Equipment

- Spectrometer
- pH meter
- cylinder
- turbidimeter
- beaker

Figure 3.9: spectometer

Figure 3.10: reagents

Figure 3.11: pH meter

Figure 3.12: turbidimeter

CHAPTER 4: RESULT AND DISCUSSION

4.1 The result for the experiment as shown as below:

i) Result for 10th July 2014

Table 4.1: Result for Conventional basin

Time/ Parameters	Ta	Toc	Th	Tic	Tw	Tb	Whexp (ml)	Whexp cumulative (ml)
8.00 am	24	24	23	23	23	23	0	0
8.30 am	24	24	24	24	24	24	0	0
9.00 am	25	26	27	27	27	27	0	0
9.30 am	25	26	28	28	28	28	0	0
10.00 am	27	25	31	31	31	31	0	0
10.30 am	27	26	37	37	36	35	0	0
11.00 am	29	27	35	35	38	38	0	0
11.30 am	29	28	36	36	40	40	0	0
12.00 pm	29	28	36	36	40	40	0	0
12.30 pm	29	27	36	36	42	42	0	0
1.00 pm	30	27	39	39	43	43	2	2
1.30 pm	29	31	37	37	43	43	4.5	6.5
2.00 pm	30	29	41	41	42	42	12	18.5
2.30 pm	30	29	37	37	43	43	2	20.5
3.00 pm	30	27	36	36	42	42	6.5	27
3.30 pm	30	28	35	35	41	41	9.5	36.5
4.00 pm	30	28	36	36	40	41	4	40.5
4.30 pm	31	30	36	36	41	41	13	53.5
5.00 pm	30	28	35	35	40	40	5.5	59
5.30 pm	30	26	33	33	38	38	0	59
6.00 pm	30	26	32	32	37	37	2	61

Where,

T_a = Ambient temperature

T_{oc} = Temperature of outer cover of solar still

T_h = Temperature of humidity in solar still

T_{ic} = Temperature of inner cover of solar still

T_w = Temperature of water in basin of solar still

T_b = Temperature of basin

W_{hexp} = Hourly water production of solar still

Table 4.2: Result for Black Soil Basin

Time/ Parameters	Ta	Toc	Th	Tic	Tw	Tb	Whexp (ml)	Whexp cumulative (ml)
8.00 am	24	24	23	23	23	23	0	0
8.30 am	24	24	25	25	25	25	0	0
9.00 am	25	26	28	28	28	28	0	0
9.30 am	25	26	28	28	29	28	0	0
10.00 am	27	28	32	31	33	29	0	0
10.30 am	27	27	33	32	35	33	0	0
11.00 am	29	29	34	34	36	36	0	0
11.30 am	29	27	34	33	37	37	0	0
12.00 pm	29	29	34	33	39	39	0	0
12.30 pm	29	27	35	33	41	41	9.5	9.5
1.00 pm	30	27	35	34	42	43	10.5	20
1.30 pm	29	28	36	34	42	43	8.5	28.5
2.00 pm	30	27	37	35	43	44	14.5	43
2.30 pm	30	30	38	36	43	44	8.5	51.5
3.00 pm	30	30	35	36	42	43	5	56.5
3.30 pm	30	28	35	33	42	43	13	69.5
4.00 pm	30	29	36	35	41	41	4	73.5
4.30 pm	31	28	35	34	41	41	25	98.5
5.00 pm	30	29	35	34	40	41	5	103.5
5.30 pm	30	26	33	32	39	40	5.5	109
6.00 pm	30	27	32	32	38	39	7.5	116.5

Where,

T_a = Ambient temperature

T_{oc} = Temperature of outer cover of solar still

T_h = Temperature of humidity in solar still

T_{ic} = Temperature of inner cover of solar still

T_w = Temperature of water in basin of solar still

T_b = Temperature of basin

W_{hexp} = Hourly water production of solar still

Table 4.3: Result for Black Paint Basin

Time/ Parameters	Ta	Toc	Th	Tic	Tw	Tb	Whexp (ml)	Whexp cumulative (ml)
8.00 am	24	24	23	23	23	23	0	0
8.30 am	24	24	25	25	25	25	0	0
9.00 am	25	26	28	28	28	28	0	0
9.30 am	25	26	29	29	29	28	0	0
10.00 am	27	27	33	32	32	32	0	0
10.30 am	27	28	34	33	37	37	0	0
11.00 am	29	29	35	34	39	39	0	0
11.30 am	29	28	35	34	41	41	0	0
12.00 pm	29	29	36	35	42	42	13	13
12.30 pm	29	28	36	34	43	43	12	25
1.00 pm	30	28	37	34	44	44	9	34
1.30 pm	29	29	38	36	45	45	9	43
2.00 pm	30	25	40	35	45	45	19	62
2.30 pm	30	27	37	35	44	44	15	77
3.00 pm	30	29	36	35	42	42	18	95
3.30 pm	30	27	36	34	41	41	25.5	120.5
4.00 pm	30	28	36	35	41	41	6	126.5
4.30 pm	31	29	36	35	42	42	14	140.5
5.00 pm	30	27	36	35	41	41	18	158.5
5.30 pm	30	27	33	33	39	39	9	167.5
6.00 pm	30	27	32	31	38	38	9	176.5

Where,

T_a = Ambient temperature

T_{oc} = Temperature of outer cover of solar still

T_h = Temperature of humidity in solar still

T_{ic} = Temperature of inner cover of solar still

T_w = Temperature of water in basin of solar still

T_b = Temperature of basin

W_{hexp} = Hourly water production of solar still

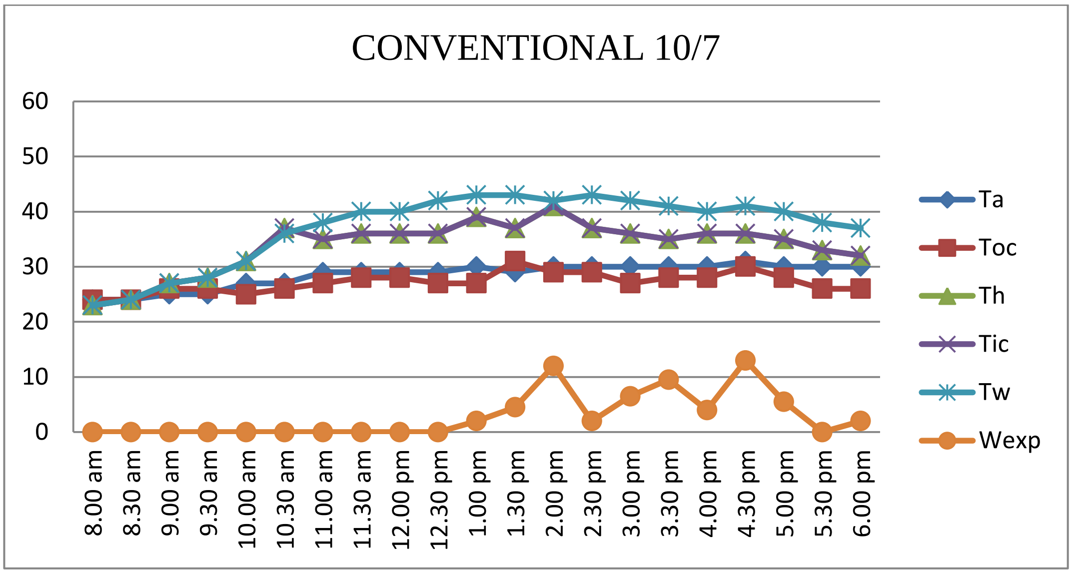

Figure 4.1: Temperature vs Time (10th JULY 2014)

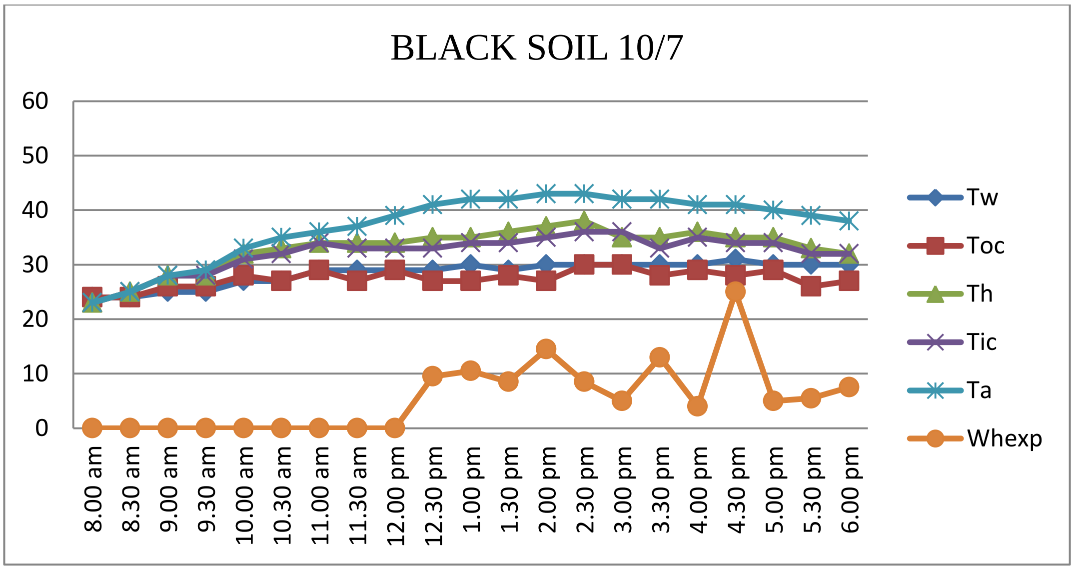

Figure 4.2: Temperature vs Time (10th JULY 2014)

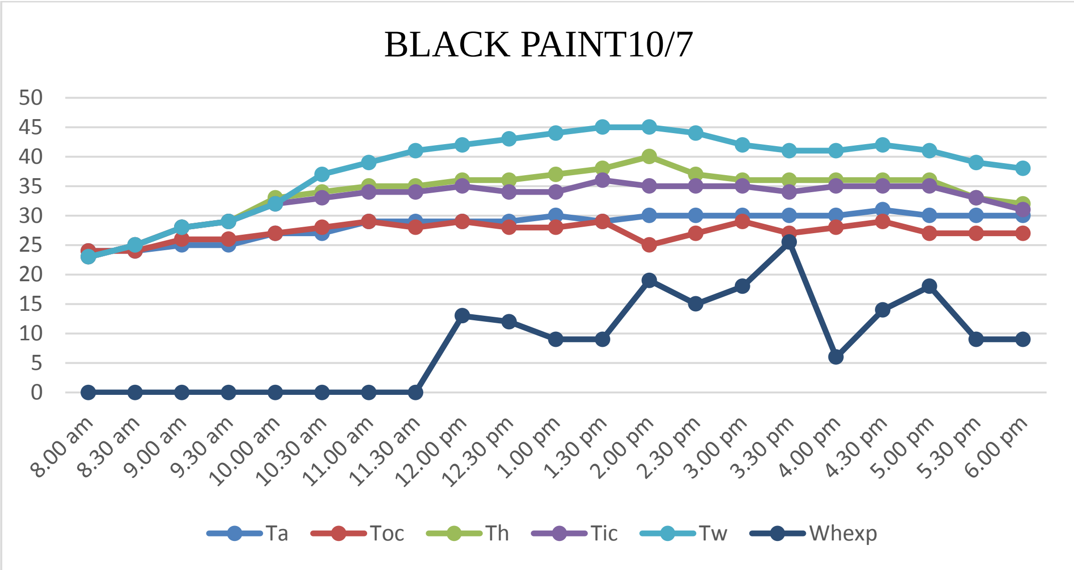

Figure 4.3: Temperature vs Time (10th JULY 2014)

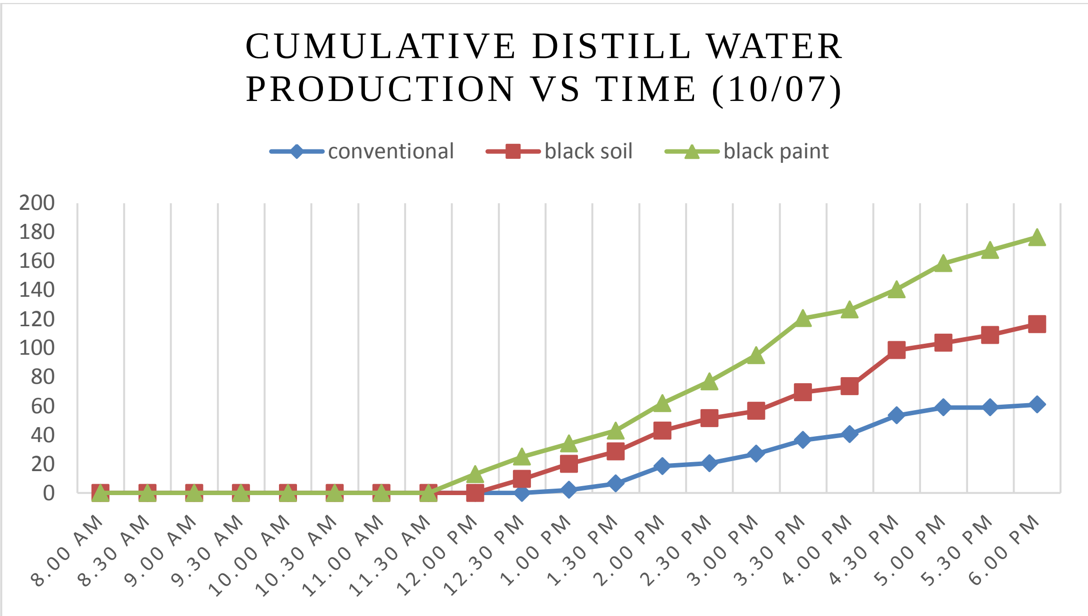

Figure 4.4: Cumulative Distill Water production vs Time (10th JULY 2014)

ii) Result for 11th July 2014

Table 4.4: Result for conventional Basin

Time/ parameter	Ta	Toc	Th	Tic	Tw	Tb	Whexp	Whexp cumulative
9.00 am	25	24	31	29	28	29	0	0
9.30 am	25	24	29	28	32	32	0	0
10.00 am	26	25	29	27	33	33	0	0
10.30 am	26	25	29	27	33	33	6.5	6.5
11.00 am	28	27	32	31	35	35	4	10.5
11.30 am	30	27	36	35	40	40	8	18.5
12.00 pm	30	27	39	37	44	45	7.5	26
12.30 pm	32	38	41	38	48	48	9.5	35.5
1.00 pm	31	33	41	38	48	48	4	39.5
1.30 pm	32	35	43	41	49	49	19	58.5
2.00 pm	33	38	43	39	49	49	15	73.5
2.30 pm	32	38	42	38	49	49	10	83.5
3.00 pm	33	36	39	36	46	46	11	94.5
3.30 pm	30	34	38	36	45	46	8	102.5
4.00 pm	32	36	39	37	44	44	16	118.5
4.30 pm	32	34	38	36	44	44	11	129.5
5.00 pm	31	33	38	35	42	42	7	136.5
5.30 pm	29	31	34	33	42	42	10	146.5
6.00 pm	29	30	33	31	40	40	5	151.5

Where,

T_a = Ambient temperature

T_{oc} = Temperature of outer cover of solar still

T_h = Temperature of humidity in solar still

T_{ic} = Temperature of inner cover of solar still

T_w = Temperature of water in basin of solar still

T_b = Temperature of basin

W_{hexp} = Hourly water production of solar still

Table 4.5: Result for Black Soil basin

Time/ parameter	Ta	Toc	Th	Tic	Tw	Tb	Whexp	Whexp cumulative
9.00 am	25	25	29	29	29	28	0	0
9.30 am	25	24	28	28	32	32	0	0
10.00 am	26	25	29	27	33	33	0	0
10.30 am	26	26	29	28	33	33	11.5	11.5
11.00 am	28	25	32	30	35	35	4.5	16
11.30 am	30	26	36	34	40	39	5	21
12.00 pm	30	27	37	36	43	43	9	30
12.30 pm	32	28	38	37	46	47	29	59
1.00 pm	31	33	39	37	47	47	8	67
1.30 pm	32	34	42	38	48	48	15	82
2.00 pm	33	30	41	38	48	48	29	111
2.30 pm	32	36	40	38	49	49	8	119
3.00 pm	33	32	39	38	46	46	28	147
3.30 pm	30	29	39	36	45	46	22	169
4.00 pm	32	30	39	36	44	44	20	189
4.30 pm	32	29	36	35	44	44	13	202
5.00 pm	31	30	37	35	44	44	11	213
5.30 pm	29	29	35	34	42	42	10	223
6.00 pm	29	27	33	32	40	40	5	228

Where,

T_a = Ambient temperature

T_{oc} = Temperature of outer cover of solar still

T_h = Temperature of humidity in solar still

T_{ic} = Temperature of inner cover of solar still

T_w = Temperature of water in basin of solar still

T_b = Temperature of basin

W_{hexp} = Hourly water production of solar still

Table 4.6: Result for Black Paint basin.

Time/ parameter	Ta	Toc	Th	Tic	Tw	Tb	Whexp	Whexp cumulative
9.00 am	25	25	29	29	30	30	0	0
9.30 am	25	24	29	29	33	33	0	0
10.00 am	24	25	29	29	34	34	0	0
10.30 am	26	26	30	28	32	34	11	11
11.00 am	28	26	32	30	36	36	9.5	20.5
11.30 am	30	30	36	35	41	41	11	31.5
12.00 pm	30	27	38	36	45	45	14	45.5
12.30 pm	32	29	44	39	49	49	26	71.5
1.00 pm	31	31	39	38	48	48	16	87.5
1.30 pm	32	34	42	38	49	49	23	110.5
2.00 pm	33	31	41	38	49	49	29	139.5
2.30 pm	32	32	41	40	49	49	21	160.5
3.00 pm	33	31	40	38	45	45	28	188.5
3.30 pm	30	31	38	36	46	46	27	215.5
4.00 pm	32	29	39	36	45	45	28	243.5
4.30 pm	32	30	38	35	44	44	19	262.5
5.00 pm	31	28	36	34	42	42	15	277.5
5.30 pm	29	27	35	31	42	42	19	296.5
6.00 pm	29	26	32	31	40	40	10	306.5

Where,

T_a = Ambient temperature

T_{oc} = Temperature of outer cover of solar still

T_h = Temperature of humidity in solar still

T_{ic} = Temperature of inner cover of solar still

T_w = Temperature of water in basin of solar still

T_b = Temperature of basin

W_{hexp} = Hourly water production of solar still

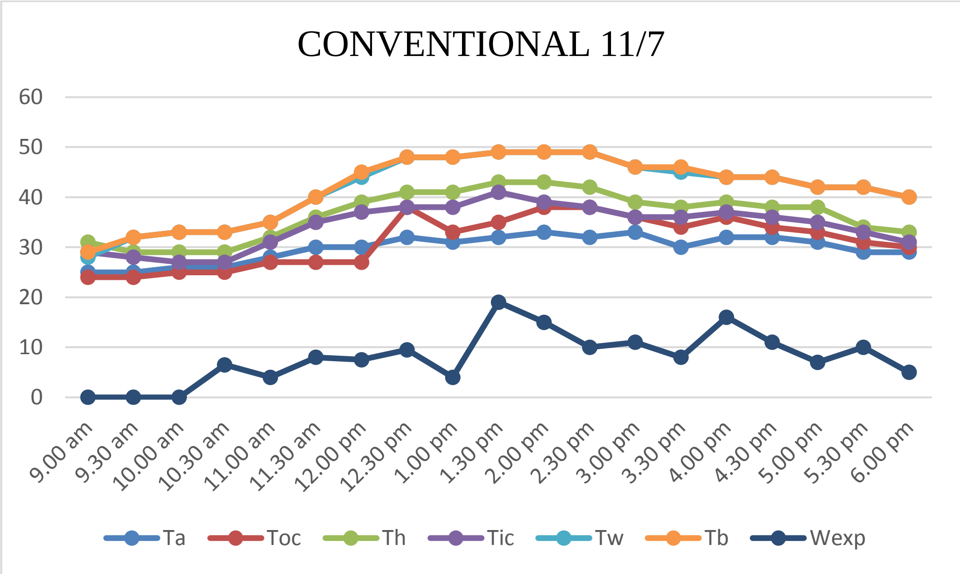

Figure 4.5: Temperature vs Time (11th JULY 2014)

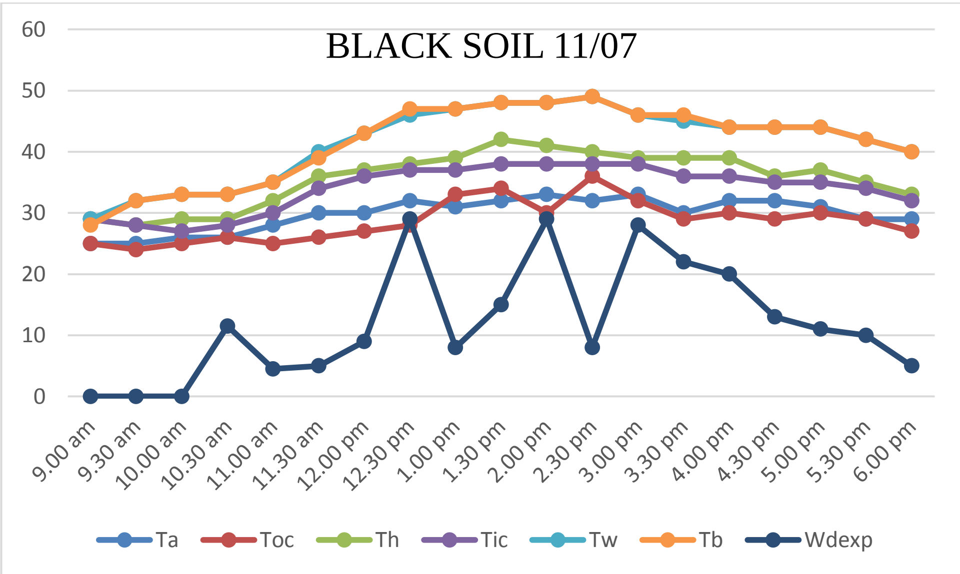

Figure 4.6: Temperature vs Time (11th JULY 2014)

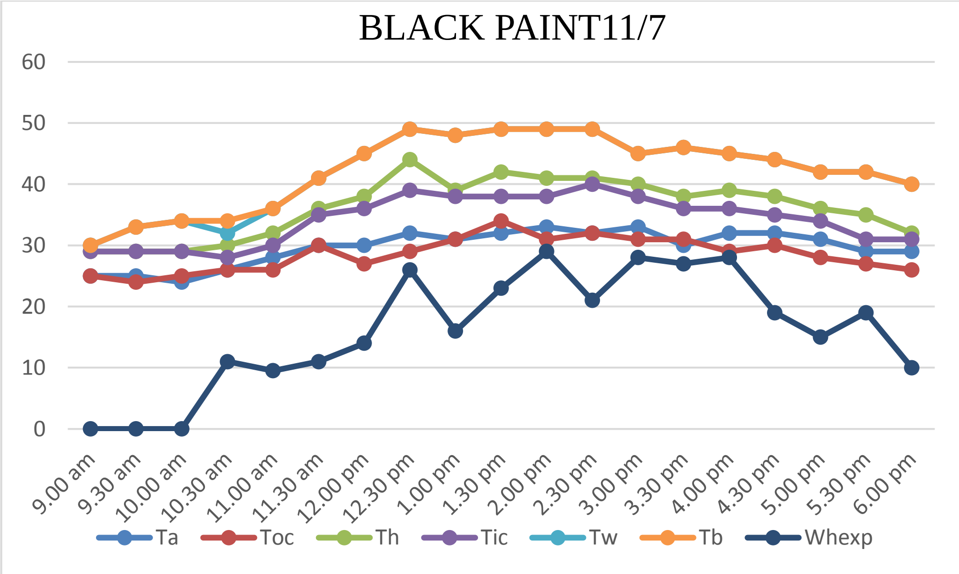

Figure 4.7: Temperature vs Time (11th JULY 2014)

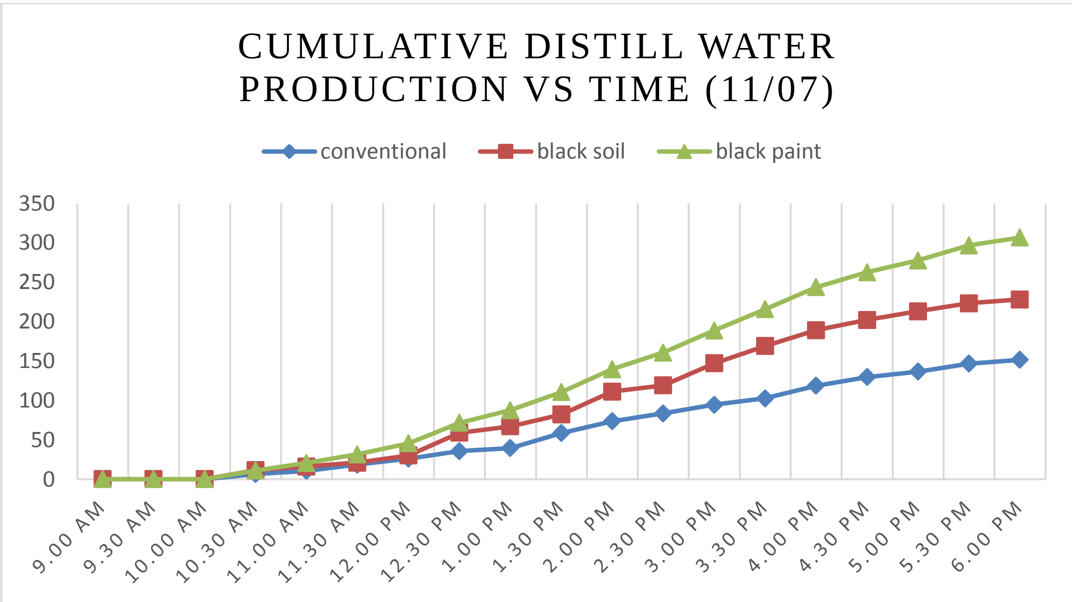

Figure 4.8: Cumulative Distill Water production vs Time (11th JULY 2014)

iii) Result for 12th July 2014

Table 4.7: Result for Conventional Basin.

Time/ Parameters	Ta	Toc	Th	Tic	Tw	Tb	Whexp (ml)	Whexp cumulative (ml)
8.00 am	24	24	24	23	23	23	0	0
8.30 am	26	24	25	25	25	25	0	0
9.00 am	26	27	28	28	27	28	0	0
9.30 am	25	25	28	28	29	29	0	0
10.00 am	29	30	32	31	33	34	1.5	1.5
10.30 am	25	30	34	33	36	36	7	8.5
11.00 am	29	31	33	32	38	38	1	9.5
11.30 am	32	29	34	33	41	41	3	12.5
12.00 pm	29	31	37	36	43	43	10.5	23
12.30 pm	32	34	40	36	46	46	6	29
1.00 pm	32	34	41	38	46	46	12	41
1.30 pm	33	35	39	35	46	46	13	54
2.00 pm	32	36	40	38	46	46	9	63
2.30 pm	34	37	42	39	47	47	14	77
3.00 pm	32	37	42	39	47	47	10	87
3.30 pm	33	35	40	37	46	45	20	107
4.00 pm	33	36	40	38	46	46	14	121
4.30 pm	31	34	39	38	44	44	12	133
5.00 pm	27	29	36	35	42	42	10	143
5.30 pm	31	33	36	34	41	42	10	153
6.00 pm	29	30	34	33	40	40	8	161

Where,

T_a = Ambient temperature

T_{oc} = Temperature of outer cover of solar still

T_h = Temperature of humidity in solar still

T_{ic} = Temperature of inner cover of solar still

T_w = Temperature of water in basin of solar still

T_b = Temperature of basin

W_{hexp} = Hourly water production of solar still

Table 4.8: Result for Black Soil basin.

Time/ Parameters	Ta	Toc	Th	Tic	Tw	Tb	Whexp (ml)	Whexp cumulative (ml)
8.00 am	24	24	24	24	24	24	0	0
8.30 am	26	24	25	25	25	25	0	0
9.00 am	26	25	27	27	27	27	0	0
9.30 am	25	25	27	27	28	29	0	0
10.00 am	29	26	30	29	31	32	0	0
10.30 am	25	27	31	30	34	35	6	6
11.00 am	29	28	31	30	35	36	9.5	15.5
11.30 am	32	27	34	33	39	40	12.5	28
12.00 pm	29	26	33	31	41	44	4	32
12.30 pm	32	27	38	37	44	45	11.5	43.5
1.00 pm	32	29	39	36	45	47	9	52.5
1.30 pm	33	30	37	36	45	46	16	68.5
2.00 pm	32	29	38	36	47	47	16	84.5
2.30 pm	34	30	39	38	47	47	15	99.5
3.00 pm	32	31	40	38	47	47	18	117.5
3.30 pm	33	30	39	36	46	46	29	146.5
4.00 pm	33	30	37	37	46	46	15	161.5
4.30 pm	31	29	38	37	45	45	14	175.5
5.00 pm	27	27	38	34	44	44	10	185.5
5.30 pm	31	33	35	34	42	42	10	195.5
6.00 pm	29	27	35	34	41	41	5	200.5

Where,

T_a = Ambient temperature

T_{oc} = Temperature of outer cover of solar still

T_h = Temperature of humidity in solar still

T_{ic} = Temperature of inner cover of solar still

T_w = Temperature of water in basin of solar still

T_b = Temperature of basin

W_{hexp} = Hourly water production of solar still

Table 4.9: Result for Black Paint basin.

Time/ Parameters	Ta	Toc	Th	Tic	Tw	Tb	Whexp (ml)	Whexp cumulative (ml)
8.00 am	24	24	24	24	24	24	0	0
8.30 am	26	24	25	25	25	25	0	0
9.00 am	26	25	28	28	28	28	0	0
9.30 am	25	26	29	29	29	30	0	0
10.00 am	29	26	31	31	33	33	16	16
10.30 am	25	27	32	31	36	37	2	18
11.00 am	29	27	33	32	38	38	14	32
11.30 am	32	28	36	34	41	41	6	38
12.00 pm	29	28	36	36	42	43	12	50
12.30 pm	32	28	39	38	46	47	8	58
1.00 pm	32	29	39	37	47	47	18	76
1.30 pm	33	31	40	38	47	47	20	96
2.00 pm	32	31	40	38	47	47	25	121
2.30 pm	34	30	40	38	47	47	22	143
3.00 pm	32	30	41	38	48	48	21	164
3.30 pm	33	28	36	38	47	47	37	201
4.00 pm	33	29	39	38	46	46	26	227
4.30 pm	31	28	38	36	44	44	20	247
5.00 pm	27	26	37	37	41	41	10	257
5.30 pm	31	33	36	35	42	42	10	267
6.00 pm	29	26	35	33	41	41	10	277

Where,

T_a = Ambient temperature

T_{oc} = Temperature of outer cover of solar still

T_h = Temperature of humidity in solar still

T_{ic} = Temperature of inner cover of solar still

T_w = Temperature of water in basin of solar still

T_b = Temperature of basin

W_{hexp} = Hourly water production of solar still

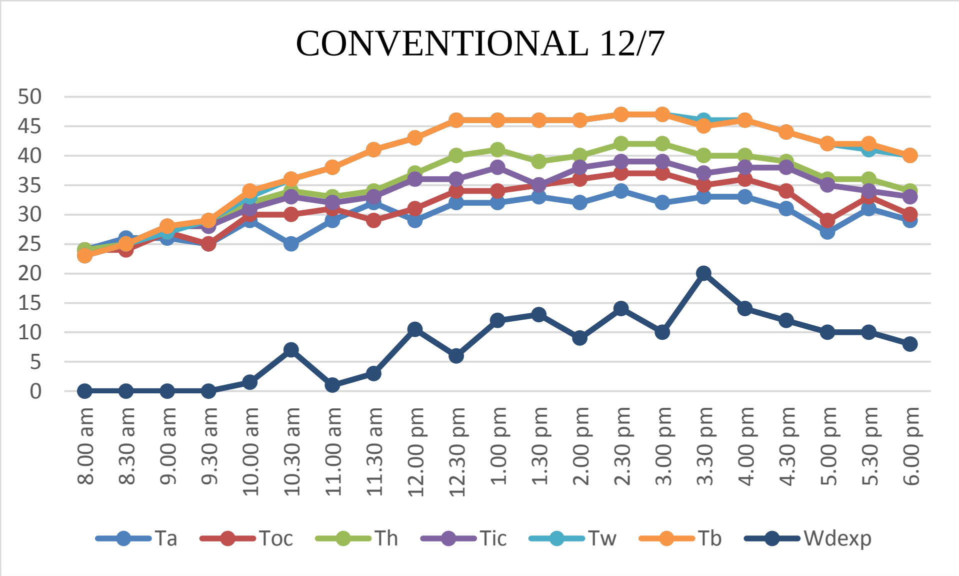

Figure 4.9: Temperature vs Time (12th JULY 2014)

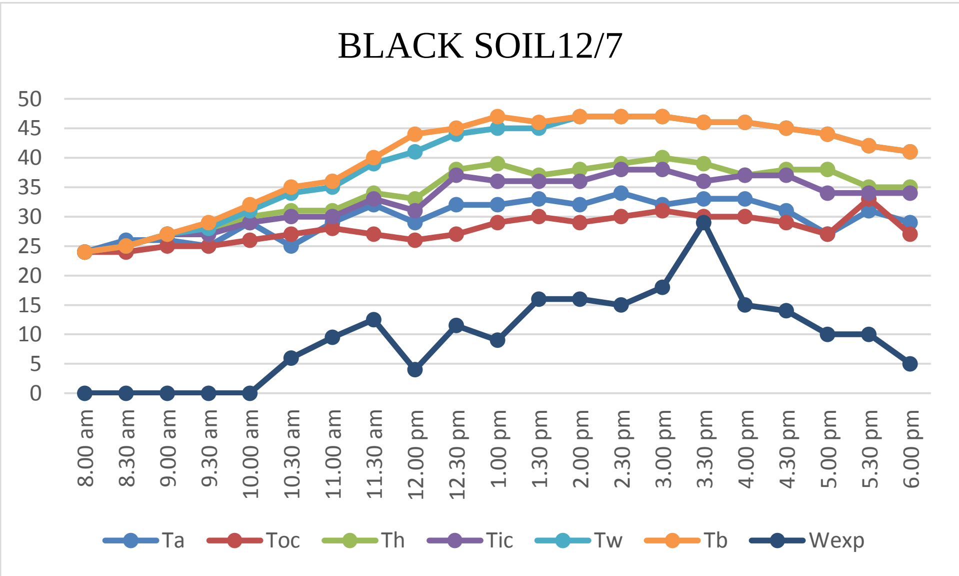

Figure 4.10: Temperature vs Time (12th JULY 2014)

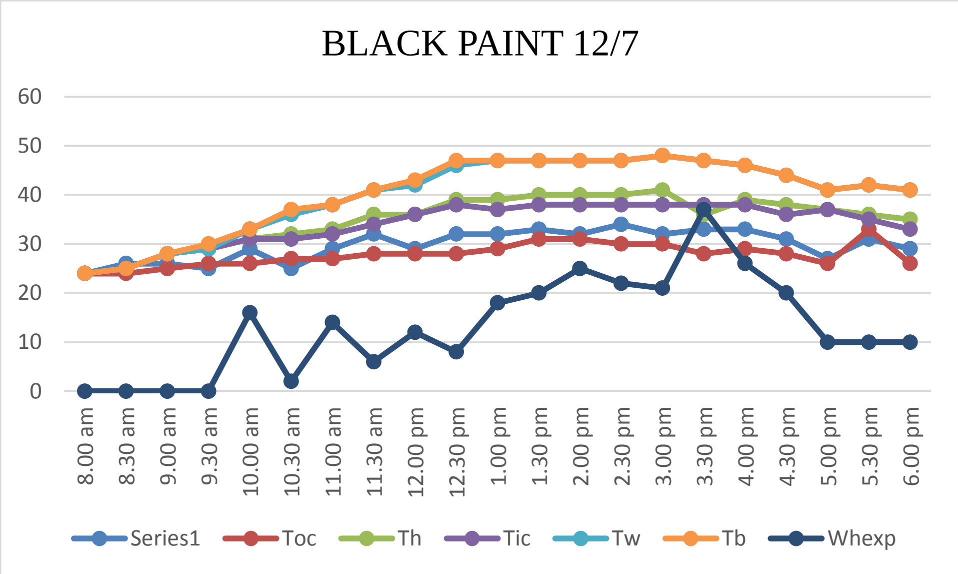

Figure 4.11: Temperature vs Time (12th JULY 2014)

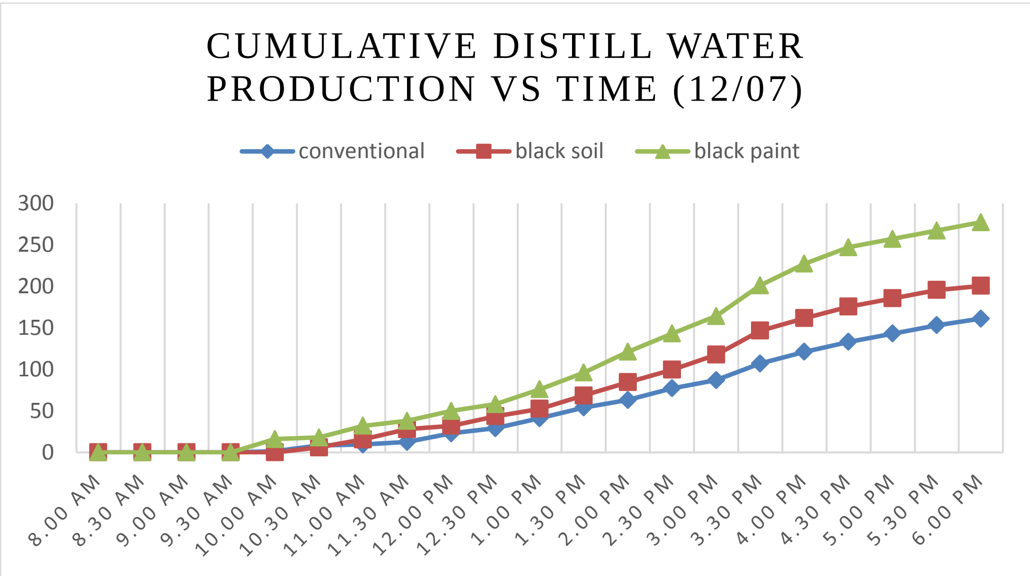

Figure 4.12: Cumulative Distill Water production vs Time (12th JULY 2014)

Discussion

From the three days experiment, results shows the black paint material produced the largest amount of distillate; 701 ml compared to black soil and conventional basin which are 546 ml and 374 ml respectively. This is due to the black paint characteristic itself, the heat is easy to absorb and easy to release heat to the surface. For the black soil basin, the soil is takes several time to absorb heat and after a while, only then the heat is released. The amount of distillate from conventional basin is the lowest because the heat from solar radiation is hard to absorb. The easier for the heat release to the surface, the rate for the distillate to produce is higher.

Naturally, the ambient temperature for Malaysia is increasing from morning till afternoon, then the temperature is decreasing starts from afternoon till evening. The temperature is a crucial factor in producing the distillate. From the graphs, the temperatures are increasing from morning till afternoon and then starts to decrease till evening. But, the volume of distillate are not increase as the temperature are increasing. This is because the temperature alone is not the factor of distillate production, there are a lot more factors that affect the distillate production. The possible reason why the distillate's volume is not increase as the temperature increase is that, the difference of ambient temperature and humidity temperature (temperature gradient). That is why the volume of distillate, based on the graphs above are fluctuated.

While conducting the experiment, there is significance different in volume of the distillate early in the morning for black paint and black soil where, the volume of distillate produced for black soil is higher than black paint basin. The reason is that, the black soil has the capability to store heat. As the result, the distillate is still produced in the evening. The best solar still in producing distillate during the day is solar still with black paint basin and for the night is that solar still with black soil basin.

4.2 Results for laboratory test

Figure 4.13: Lake Water mix with black soil

Figure 4.14: Distillate

Table 4.10: Results for water quality test

	lake water	distillate (conventional)	distillate (black soil)	distillate (black paint)	standard
pH	6.78	6.7	6.68	6.63	6.5 - 9
turbidity (NTU)	33.57	0.87	0.5	0.62	0 - 5
sulphate (mg/l)	18.67	0.55	0.45	0.33	0 - 250
nitrate (mg/l)	2.37	0.93	0.73	0.67	0 - 10
iron (mg/l)	0.98	0.2	0.14	0.13	0 - 0.3
colour	greenish	colourless	colourless	colourless	colourless
odour	have adour	odourless	odourless	odourless	odourless

Discussion

The water quality test is conducted to test and compare the component such as alkalinity, turbidity, sulphate, nitrate, iron, colour and odour in lake water and distillate that produced. The table above shows the result of the water quality test. The results shows, all the distillate that produced have no significance different and all the values meets water quality standard.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

Throughout the experiment, the results shows the solar still with black paint basin is produced the largest volume of distillate compared to solar still with black soil basin and conventional. The amount are 701 ml, 546 ml and 374 ml per day respectively. Solar still with black paint basin is best used during the day and solar during the night, the best solar still is the solar still with black soil basin.

For the recommendation for future study, the experiment should be done with more materials. In such, instead of using polythene film, used glass cover or plastic cover because theoretically, the glass cover or plastic cover have capability to absorb solar radiation faster compared to polythene cover. The main objective of this project is to maximize the production of distillate. In order to complete that objective, more experiment should done by using materials that possibly can increase the solar radiation absorption.

Furthermore, the configuration of the solar still itself can be improve by add on a filtration system at the collector. So that, the distillate that produced are already filtered. From the conducted experiment, the distillate are collect manually. Where the author need to collect the distillate still by still for every 30 minutes and it shows the inefficiency of the model's configuration. The author suggest in future studies, a pump system can be implanted in the configuration. The purpose of the pump is to pump the distillate from the solar still to a storage tank.

One of the objectives of this project is to build up a "solar still farm", where there is a big area that located several or hundreds of solar still to produced drinkable distillate. The meaning of drinkable distillate is the distillate are drinkable that have essential nutrients for humans to lives. The targeted area is where that area have difficulties in obtaining fresh water to use in daily life.

Reference

Garg, H. P., & Mann, H. S. (1976). Effect of climatic, operational and design parameters on the year round performance of single-sloped and double-sloped solar still under Indian arid zone conditions. *Solar Energy, 18*(2), 159-163. doi: http://dx.doi.org/10.1016/0038 092X(76)90052-9

Rubio, E., Porta, M. A., & Fernández, J. L. (2000). Cavity geometry influence on mass flow rate for single and double slope solar stills. *Applied Thermal Engineering, 20*(12), 1105-1111. doi: http://dx.doi.org/10.1016/S1359-4311(99)00085-X

Rajaseenivasan, T., & Kalidasa Murugavel, K. (2013). Theoretical and experimental investigation on double basin double slope solar still. *Desalination, 319*(0), 25-32. doi: http://dx.doi.org/10.1016/j.desal.2013.03.029

Mamlook, R., & Badran, O. (2007). Fuzzy sets implementation for the evaluation of factors affecting solar still production. *Desalination, 203*(1–3), 394 402. doi: http://dx.doi.org/10.1016/j.desal.2006.02.024

Naim, M. M., & Abd El Kawi, M. A. (2003). Non-conventional solar stills Part 1. Non-conventional solar stills with charcoal particles as absorber medium. *Desalination, 153*(1–3), 55-64. doi: http://dx.doi.org/10.1016/S0011-9164(02)01093-7

Nafey, A. S., Abdelkader, M., Abdelmotalip, A., & Mabrouk, A. A. (2001). Solar still productivity enhancement. *Energy Conversion and Management, 42*(11), 1401-1408. doi: http://dx.doi.org/10.1016/S0196-8904(00)00107-2

Kumar, S., & Tiwari, G. N. (1996). Performance evaluation of an active solar distillation system. *Energy, 21*(9), 805-808. doi: http://dx.doi.org/10.1016/0360-5442(96)00015-1

Kandasamy, S., Vellingiri, M., Sengottain, S., & Balasundaram, J. (2013). Performance correlation for single-basin double-slope solar still. *international journal of energy and environmental engineering, 4*(1), 1-6. doi: 10.1186/2251-6832-4-4

Muftah, A. F., Alghoul, M. A., Fudholi, A., Abdul-Majeed, M. M., & Sopian, K. (2014). Factors affecting basin type solar still productivity: A detailed review. *Renewable and Sustainable Energy Reviews, 32*(0), 430-447. doi: http://dx.doi.org/10.1016/j.rser.2013.12.052

Abdallah, S. B., Frikha, N., & Gabsi, S. (2013). Simulation of solar vacuum membrane distillation unit. *Desalination, 324*(0), 87-92. doi: http://dx.doi.org/10.1016/j.desal.2013.06.001