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SOLAR ROOF DISTILLING TILES

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by

Muhammad Shameer Bin Mohd Sharil

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Dissertation submitted in partial fulfilment of
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Universiti Teknologi PETRONAS,

32610, Bandar Seri Iskandar,

Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Civil Engineering Programme
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in partial fulfilment of the requirement for the
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(CIVIL ENGINEERING)

Approved by,

____

(AP Dr Nasiman Sapari)

UNIVERSITI TEKNOLOGI PETRONAS
BANDAR SERI ISKANDAR, PERAK
September 2016

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.

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MUHAMMAD SHAMEER BIN MOHD SHARIL

ABSTRACT

Solar distillation is a great way to overcome water shortage and energy demand in this present day, where the energy from the sun is utilize to produce drinking water from seawater. A roof solar distilling tiles was developed with three different design to study the productivity based on the design. The study was focused on a scale study which means the experiment was conducted in one place which is in Universiti Teknologi Petronas, Sri Iskandar, Perak which the result may differ if conducting in other places where the weather is different. The solar roof distilling tiles were made as an enclosed chamber (0.3 x 0.25 m^2); side and bottom are made of 2mm steel and the top side is covered with glass cover with inclination of 25^o. A collector tray is installed at the end of the chamber to collect the condense water. Another two design were painted black with one of the basin will be occupied with aluminum fins. The solar roof performance was influenced by the solar radiation at the location, design of the basin and the water depth in the basin. The volume of water collected by the solar tiles was recorded per day. The solar roof distilling tiles are tested for 10 days and the highest production is from basin that painted black with aluminum fins which is 2.8 L per day. The water quality and the efficiency of each basin are also tested. The highest efficiency is from the basin with the aluminum with 44%.

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First of all, I would like to thank my family and friends that happen to be in my life and get me in this intensity and individuals who support whether directly or indirectly by sharing ideas and also helping me in every possible way.

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CHAPTER 1

INTRODUCTION

1.1 Background

Solar distillation is a great way to overcome water shortage and energy demand in this present day, where the energy from the sun is utilize to produce drinking water from seawater. This is beneficial for places that has limited access to water resources or places where conventional sources of energy are either not available or not cost effective. In order to encourage the usage of solar distillation, this project attempt to develop a roof tiles system that can distilled water by using the sun energy itself. The tiles will integrate the passive solar still technology where it has a single slope basin type. Although it is simple in construction and has low productivity, the multiple use of it will increase the productivity. The solar roof distilling size will be small compared to conventional solar still, thus the cost will be reduced and multiple usage will not be costly.

Generally, solar still operates using evaporation and condensation process. The water in the solar still is evaporated by solar energy and condensate as it come in contact with the glass. The condensate is collected as the distilled water output.

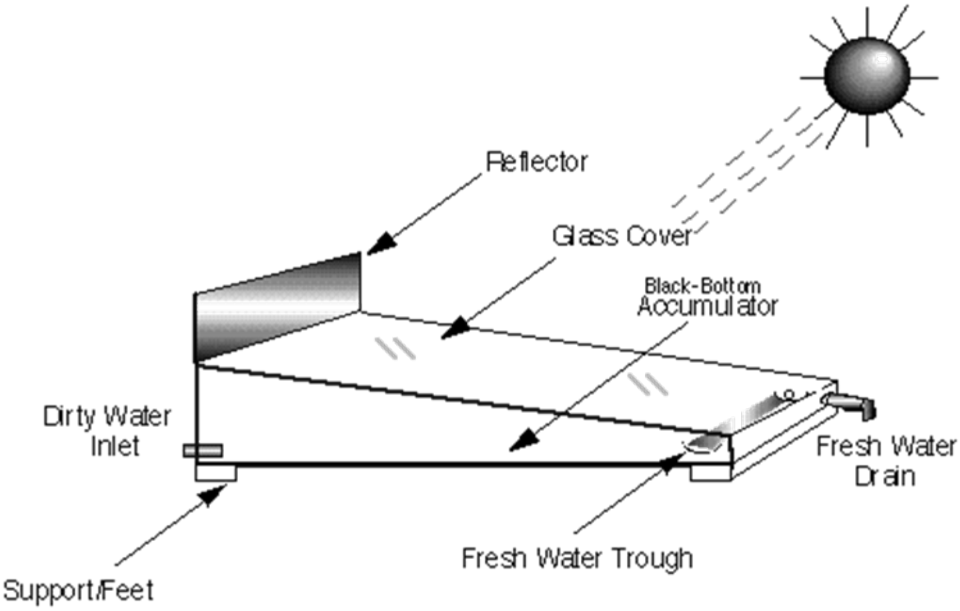


Figure 1: Single Slope Solar Still

Figure 1 above show the single slope solar still that will be integrated into the roof tiles. As the solar still is heat up by the sun, the water evaporate then condensate due to the glass cover. The condensate will go down to the water drain and then being collected. The performance of the roof solar still will depend on the solar energy. In order to maximize the performance, three roof solar still will be tested with each having different additional component.

1.2 Problem Statement

Water scarcity and non-renewable energy shortage will be faced by the world as the global population increased. This will give a great impact on the country that have water resources limited to seawater only such as Middle East and North Africa. In order to produce fresh water from seawater, desalination of the seawater is required and solar distillation is a great approach to overcome this problem however, low productivity make it less favoured to be used.

1.3 Objective

- Develop solar roof distilling tiles
- Study the effect of different design of the solar roof distilling tiles towards productivity

1.4 Scope of Study

The study will only be focused on a scale study which means the experiment will only be conduct in one place which is in Universiti Teknologi Petronas, Sri Iskandar, Perak. The heat and light energy may be varied from one place to another depends on the weather conditions at the location. The concept however can be used in developing a larger scale which can be applied at any places that receive adequate solar energy.

CHAPTER 2

LITERATURE REVIEW

2.1 Global Water Availability

"Concerns about global water availability and its impacts have been expressed during the last decades under the alarming terms of global water crisis when referring to the struggles around the allocation of this resource" (Fragkou & McEvoy, 2016). Due to this arising apprehensions, water managers and policy makers worldwide are turning to water demand management solutions (Saleth, 2000).

Proper water management need to be implement in order to minimized the water crisis in near future. The consequences of not managing water properly will give a great impact towards global population. For instance, according to McKie, across the globe, reports reveal huge areas in crisis today as reservoirs and aquifers dry up. More than a billion individuals – one in seven people on the planet – now lack access to safe drinking water (2015).

In the middle east where the least available water resources due to arid climate is going to be affected the most. For example, Jordan in year 2025, per capita water supply will fall from the current 145 m^3/yr to only 91 m^3/yr, putting Jordan in the category of having an absolute water shortage (Hadadin, Qaqish, Akawwi, & Bdour, 2010). This will put Jordan as a water-poor country as stated by Al-Jayyousi in his journal where most experts consider countries with a per capita water production below 1000m^3/yr to be water-poor countries (1995). There are several more countries that share the same fate as Jordan such as Algeria with 339.5 m^3/year and Malta with 124.1 m^3/year (ChartsBin, 2011).

In order to maximize the global water availability, the world largest water resources should be utilized which is the ocean. The ocean itself comprise 97.3% of the total water on earth and consists of 5 oceans: Atlantic, Pacific, Indian, Arctic, and Southern. The current range for the volume of the world's ocean is from 1.3 to 1.5 billion cubic kilometers and it will still get larger and larger as time passes (Elert, 2016). In pursuance of this, water desalination is needed to convert seawater to freshwater which is achievable with the current technology. Solar distillation is a great approached to desalinate seawater as it is driven by renewable energy which is the sun to operate.

2.2 Single Basin Single Slope Solar Still

The very basic system for desalinating water by using solar as driving source is called solar still (Nudra, Aziz, El Hadad, Rahim & Ne, 2016). Solar is a great source of energy because it is indefinitely renewable. As reported by Kaushal & Varun in their research, a solar still operates using condensation and evaporation technic where impure water that flow into the distillation basin will evaporated by the sun, then the pure water vapour condenses on top and drips down to side, where it is collected and removed (2010).

The performance of a solar still is depends on various factor such as the materials used, the water feeding system and the design of the solar still itself. In this research, the focus will be on the design of the solar still where it will adopt the single slope solar still. According to Phadatare & Verma, water depth is influencing the productivity and their research indicate that maximum distillate output of 2.1 L/m^2/day with efficiency of 34% was obtained with 2cm water depth (2007). Phadatare & Verma have test with several different depth and the most optimum depth is the thinnest which is in their research is 2cm. This can be concluded that, the thinnest the water depth, the higher the output produce. This statement is supported by Elango & Kalidasa Murugavel in their research where they conclude that the maximum of 4.401 L/m^2/day was obtained at 1cm water depth (2015).

CHAPTER 3

METHODOLOGY

3.1 Project Schedule

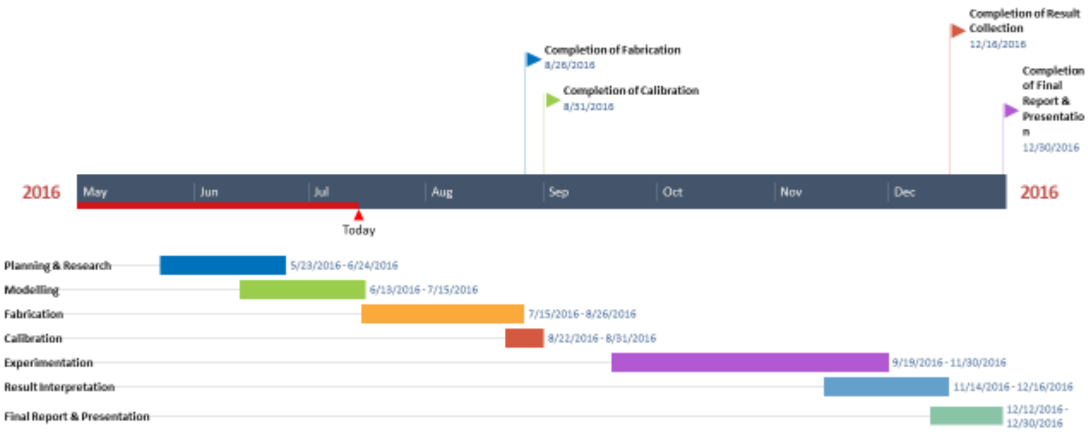


Figure 2: Project Schedule

3.2 Design of Solar Roof Distilling Tiles

3.2.1 Ordinary Solar Roof Distilling Tiles

The solar roof distilling tiles is made as an enclosed chamber (0.3 x 0.25 m^2); side and bottom are made of 2mm steel and the top side is covered with glass cover with inclination of 25^o. A collector tray is installed at the end of the chamber as shown in figure below to collect the condense water.

Figure 3: Illustration of Solar Roof Distilling Tiles

3.2.2 Solar Roof Distilling Tiles with Black Paint

The solar roof distilling tiles will be painted black as black is good in absorbing heat. This may contribute to the productivity as the basin will be receiving greater heat compared to the ordinary solar roof distilling tiles. The size of the solar roof distilling tiles will be the same as the ordinary.

3.2.3 Solar Roof Distilling Tiles with Black Paint and Aluminium Fins

The solar roof distilling tiles will be painted black and modified by using aluminium fins. The aluminium fins will absorbed the reflected heat that touch the water surface and direct the heat towards the basin. This may increase the productivity of the solar distilling tiles.

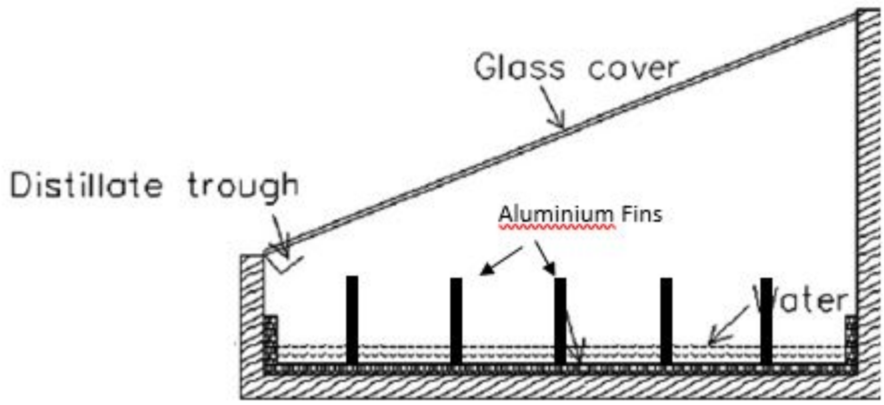


Figure 4: Solar Roof Distilling Tiles with Aluminium Fins

3.3 Experimental Setup

The 3 solar roof distilling tiles will be tested in University Teknologi Petronas, Seri Iskandar, Perak. The sun radiation energy may be varied in different places which will influence the productivity of the system. The sun radiation energy for the particular area is shown in the appendix. The experiment is conducted in a field where it will be exposed to direct sunlight.

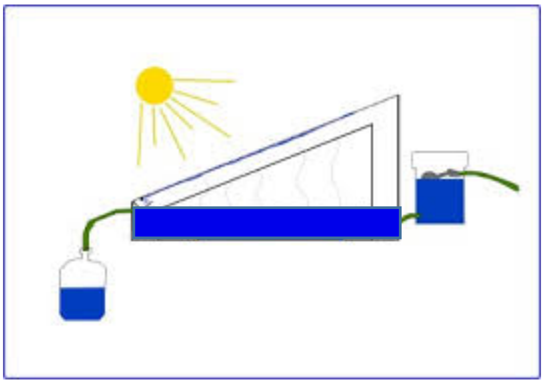
The details of the experiment are shown below:

Apparatus and materials:

1. Solar Roof Distilling Tiles
2. Output Water Storage Tank
3. Input Water Storage Tank
4. Thermometer
5. Measuring Cylinder

Procedure:

1. Setup the experiment as figure below.



2. Open the water input channel and let it flow into the basin.
3. The overspill will flow out through the overspill channel.
4. The temperature will be recorded and the replacement of water input will be done at intervals of one-hour, for 8h during the periods of testing.
5. Tabulate the data recorded.

3.4 Water Quality Test

The test will be conducted in UTP Wastewater Lab. The water quality will be test on pH value, turbidity and color. The procedure of each test are shown below.

3.4.1 pH Test

Apparatus and materials:

1. pH meter
2. Water Sample

Procedure:

1. Calibrate the pH electrode.
2. Rinse the electrode with distilled water.
3. Submerge the electrode into the water sample.
4. Record the value when the pH meter stabilizes.
5. Repeat for every water sample.

3.4.2 Color Test

Apparatus and materials:

1. Spectrophotometer
2. Water Sample

Procedure:

1. Turn on the spectrophotometer.
2. Insert the water sample in the spectrophotometer.
3. Navigate to color measurement and press measure.
4. Record the value of the measurement.
5. Repeat for every water sample.

3.4.3 Turbidity Test

Apparatus and materials:

1. Turbidity meter
2. Water Sample

Procedure

1. Calibrate the turbidity meter.
2. Prepare blank using distilled water.
3. Insert blank in turbidity meter and press zero.
4. Take out blank after the turbidity stabilize.
5. Insert water sample and press read.
6. Record the turbidity value.
7. Repeat for other water sample.

3.5 Efficiency

The efficiency is calculated based on below formula. (Al-Hayeka & Badran, 2004)

$$\boldsymbol{E}(\%) = \frac{\boldsymbol{Qe}}{\boldsymbol{Qt}}$$

$$\boldsymbol{Qe} = \boldsymbol{Me\ x\ L}$$

where

Qe = amount of energy utilized in vaporizing water ($MJ/m^2/d$)

Qt = incident solar energy ($MJ/m^2/d$) (14.616 MJ/m^2 in Ipoh)

Me = daily distilled water output ($kg/m^2/d$)

L = latent heat of vaporization of water (MJ/kg) (2.264 MJ/kg)

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Production Rate Per Day

The test is conducted for 10 days between 2nd November 2016 and 13th November 2016. The water output will be recorded at interval one-hour for 9 hours (8am – 5pm).

The solar energy for Ipoh in November is 14.616 $MJ/m^2/d$. This energy will be used to calculate the efficiency of the solar roof distilling tiles.

The results for production rate are shown below for each day.

Legend:

Output A: Solar Roof Distilling Tiles with Black Paint and Aluminium Fins

Output B: Solar Roof Distilling Tiles with Black Paint

Output C: Ordinary Roof Distilling Tiles

2nd November 2016

Table 1: Nov 2 Hourly Production

Time (h)	Output (ml/h)		
	A	B	C
8.00 am	0	0	0
9.00 am	5	3	3
10.00 am	10	8	6
11.00 am	16	13	11
12.00 pm	25	23	15
1.00 pm	36	28	20
2.00 pm	41	35	29
3.00 pm	39	25	22
4.00 pm	16	13	12
5.00 pm	10	9	7

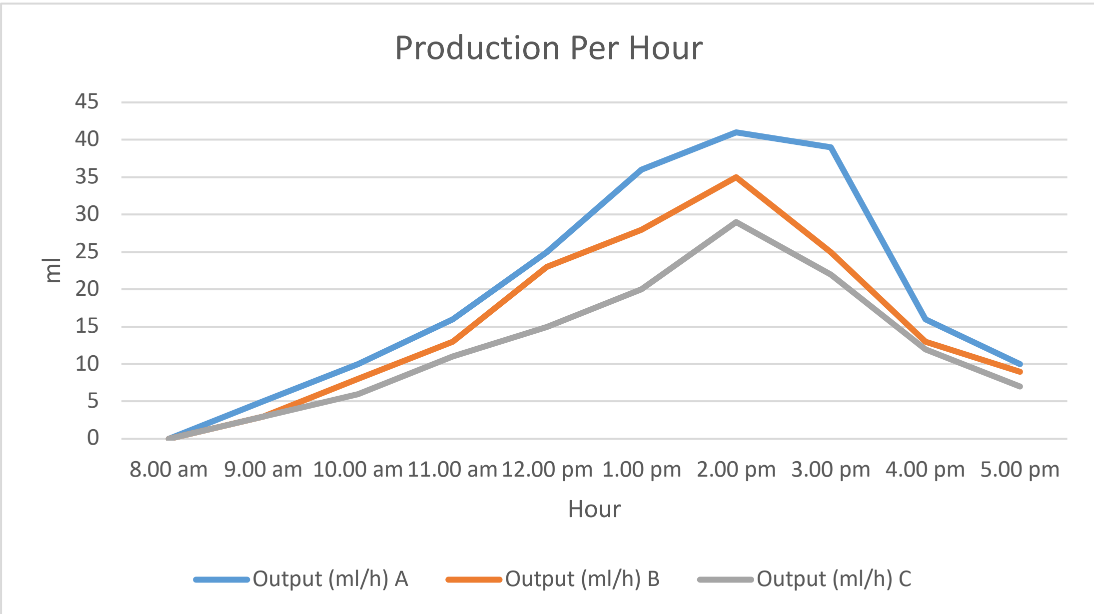


Figure 5: Nov 2 Production

Table 2: Nov 2 Production Summary

Area/Production	A(ml)	B(ml)	C(ml)
Per 0.0775 m^2	198	157	125
Per 1.00 m^2	2555	2026	1613

3rd November 2016

Table 3: Nov 3 Hourly Production

Time (h)	Output (ml/h)		
	A	B	C
8.00 am	0	0	0
9.00 am	7	5	4
10.00 am	11	8	7
11.00 am	18	14	12
12.00 pm	24	21	16
1.00 pm	37	27	22
2.00 pm	44	38	25
3.00 pm	38	29	19
4.00 pm	18	14	13
5.00 pm	12	8	5

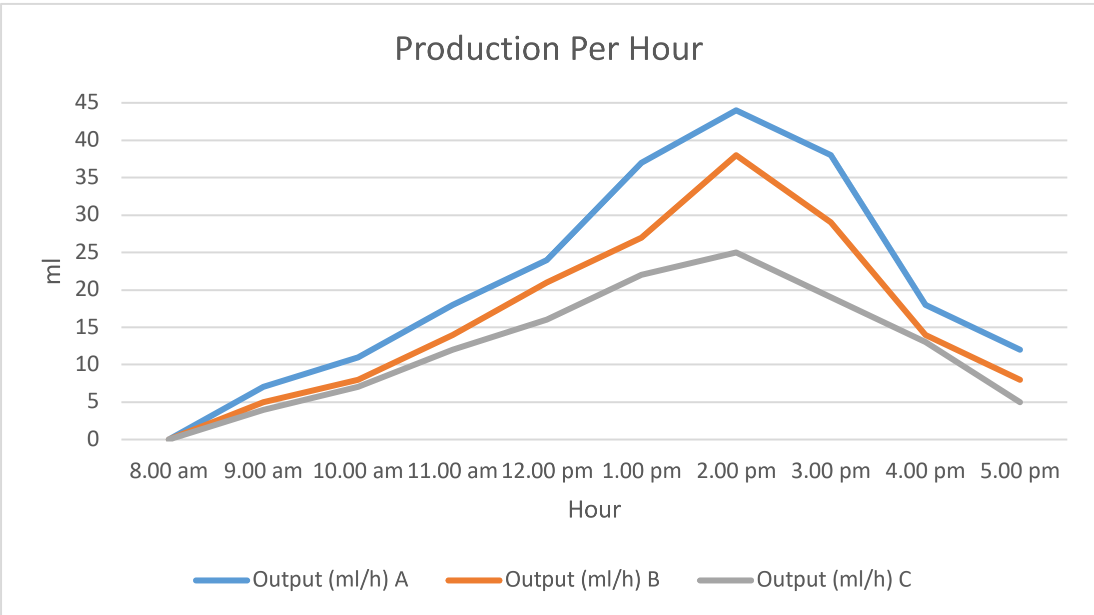


Figure 6: Nov 3 Production

Table 4: Nov 3 Production Summary

Area/Production	A(ml)	B(ml)	C(ml)
Per 0.0775 m^2	209	164	123
Per 1.00 m^2	2697	2116	1587

5th November 2016

Table 5: Nov 5 Hourly Production

Time (h)	Output (ml/h)		
	A	B	C
8.00 am	0	0	0
9.00 am	0	0	0
10.00 am	4	2	2
11.00 am	13	10	6
12.00 pm	20	17	12
1.00 pm	31	24	19
2.00 pm	33	29	23
3.00 pm	21	19	14
4.00 pm	9	7	6
5.00 pm	4	2	0

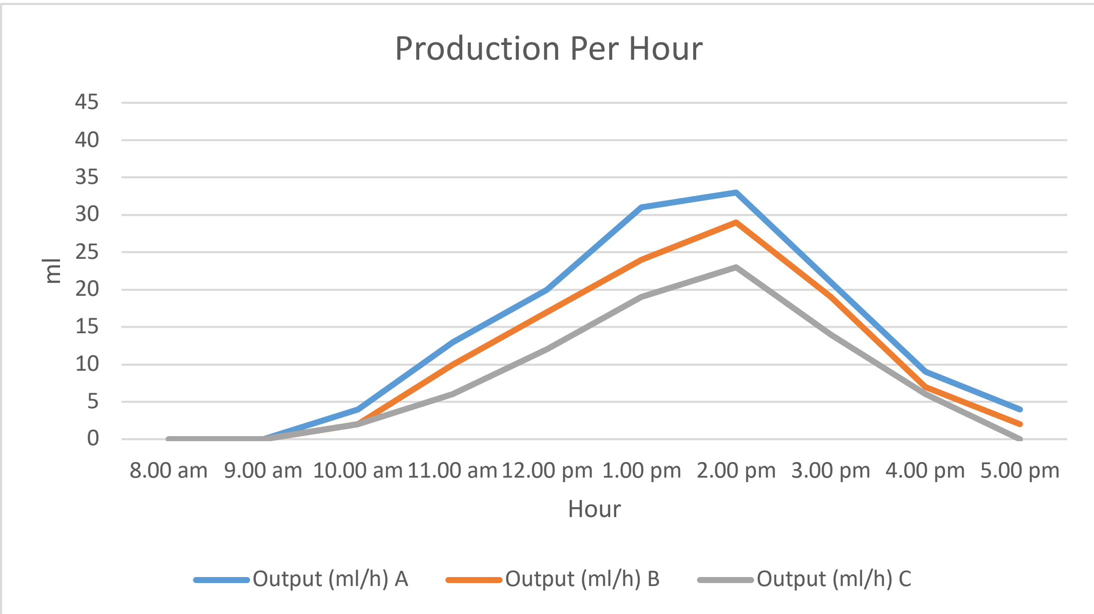


Figure 7: Nov 5 Production

Table 6: Nov 5 Production Summary

Area/Production	A(ml)	B(ml)	C(ml)
Per 0.0775 m^2	135	110	82
Per 1.00 m^2	1742	1419	1058

6th November 2016

Table 7: Nov 6 Hourly Production

Time (h)	Output (ml/h)		
	A	B	C
8.00 am	0	0	0
9.00 am	4	2	3
10.00 am	10	6	5
11.00 am	15	11	9
12.00 pm	27	22	15
1.00 pm	33	27	21
2.00 pm	37	32	24
3.00 pm	30	24	19
4.00 pm	22	17	12
5.00 pm	14	11	7

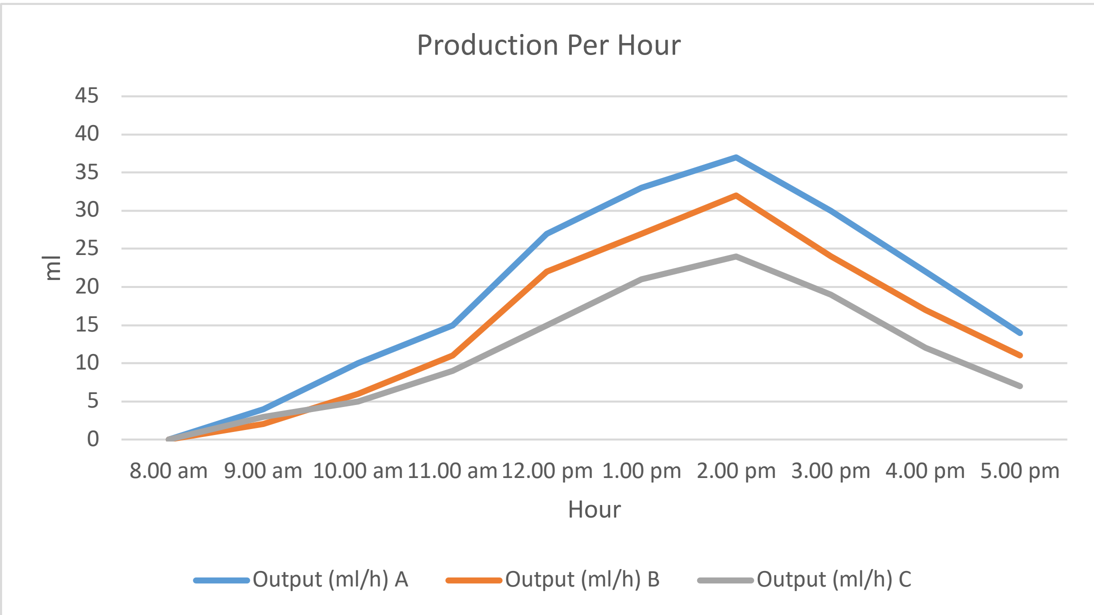


Figure 8: Nov 6 Production

Table 8: Nov 6 Production Summary

Area/Production	A(ml)	B(ml)	C(ml)
Per 0.0775 m^2	192	152	115
Per 1.00 m^2	2477	1961	1484

7th November 2016

Table 9: Nov 7 Hourly Production

Time (h)	Output (ml/h)		
	A	B	C
8.00 am	0	0	0
9.00 am	8	5	2
10.00 am	12	9	6
11.00 am	17	15	11
12.00 pm	23	22	16
1.00 pm	34	29	21
2.00 pm	47	38	29
3.00 pm	41	29	26
4.00 pm	23	19	17
5.00 pm	16	12	9

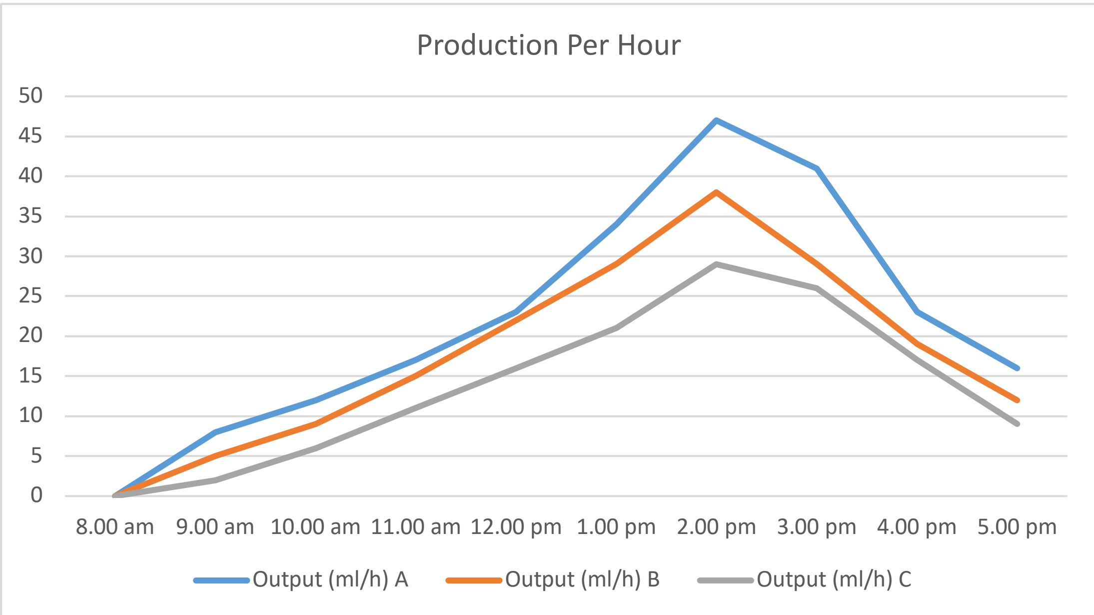


Figure 9: Nov 7 Production

Table 10: Nov 7 Production Summary

Area/Production	A(ml)	B(ml)	C(ml)
Per 0.0775 m^2	221	178	137
Per 1.00 m^2	2852	2297	1768

8th November 2016

Table 11: Nov 8 Hourly Production

Time (h)	Output (ml/h)		
	A	B	C
8.00 am	0	0	0
9.00 am	3	1	0
10.00 am	9	5	6
11.00 am	12	10	7
12.00 pm	25	18	13
1.00 pm	33	27	20
2.00 pm	40	33	25
3.00 pm	37	20	19
4.00 pm	19	13	12
5.00 pm	9	7	4

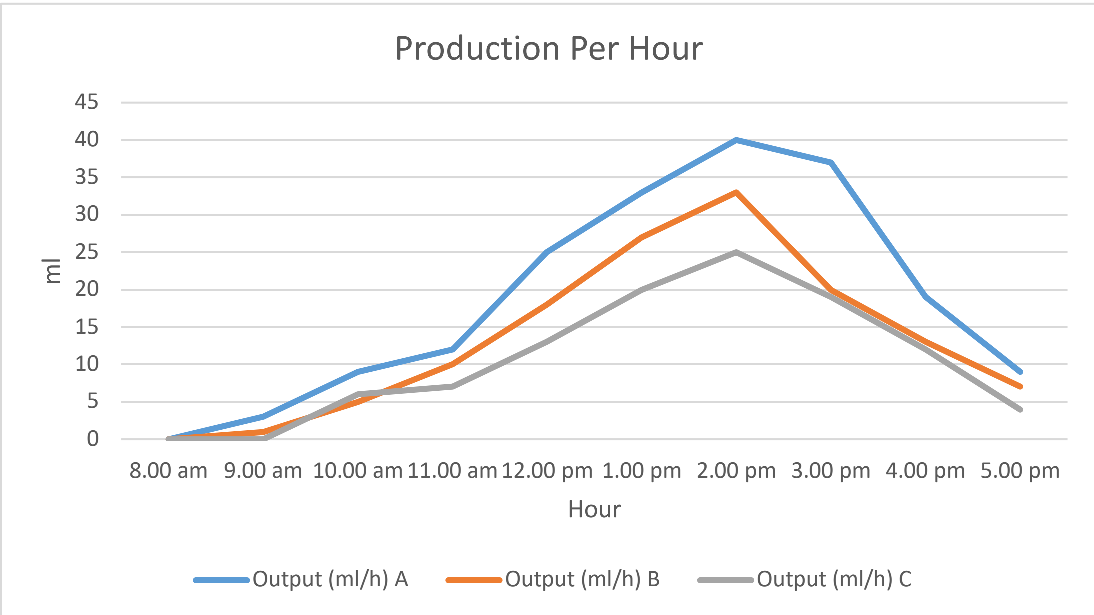


Figure 10: Nov 8 Production

Table 12: Nov 10 Production Summary

Area/Production	A(ml)	B(ml)	C(ml)
Per 0.0775 m^2	187	134	106
Per 1.00 m^2	2413	1729	1368

9th November 2016

Table 13: Nov 9 Hourly Production

Time (h)	Output (ml/h)		
	A	B	C
8.00 am	0	0	0
9.00 am	0	0	0
10.00 am	0	0	0
11.00 am	3	1	0
12.00 pm	7	4	2
1.00 pm	21	17	11
2.00 pm	35	27	24
3.00 pm	37	27	23
4.00 pm	17	13	11
5.00 pm	7	4	2

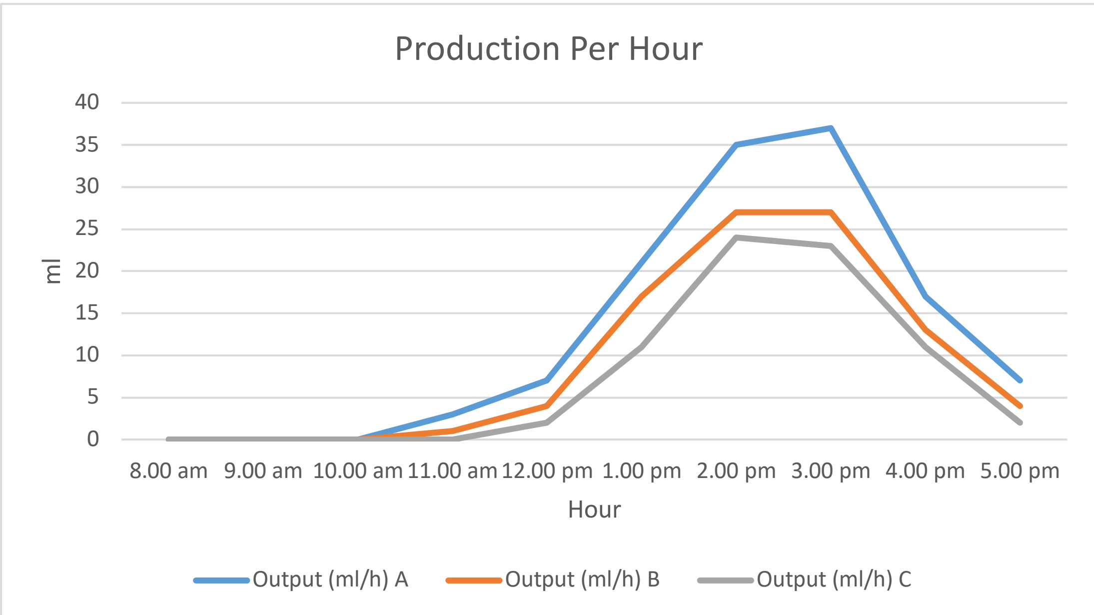


Figure 11: Nov 9 Production

Table 14: Nov 9 Production Summary

Area/Production	A(ml)	B(ml)	C(ml)
Per 0.0775 m^2	127	93	73
Per 1.00 m^2	1639	1200	942

10th November 2016

Table 15: Nov 10 Hourly Production

Time (h)	Output (ml/h)		
	A	B	C
8.00 am	0	0	0
9.00 am	3	1	0
10.00 am	9	7	5
11.00 am	14	13	10
12.00 pm	26	23	17
1.00 pm	36	29	21
2.00 pm	42	35	30
3.00 pm	34	24	22
4.00 pm	17	13	10
5.00 pm	0	0	0

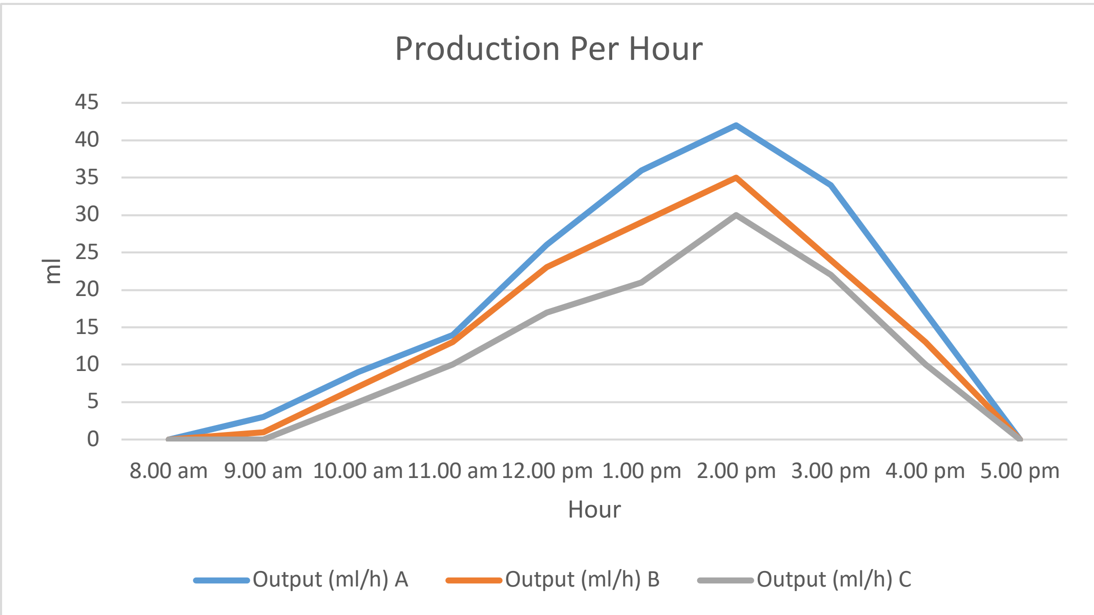


Figure 12: Nov 10 Production

Table 16: Nov 10 Production Summary

Area/Production	A(ml)	B(ml)	C(ml)
Per 0.0775 m^2	181	145	115
Per 1.00 m^2	2335	1871	1484

12th November 2016

Table 17: Nov 12 Hourly Production

Time (h)	Output (ml/h)		
	A	B	C
8.00 am	0	0	0
9.00 am	0	0	0
10.00 am	0	0	0
11.00 am	0	0	0
12.00 pm	25	22	14
1.00 pm	31	23	19
2.00 pm	37	33	27
3.00 pm	39	31	25
4.00 pm	19	16	11
5.00 pm	10	7	5

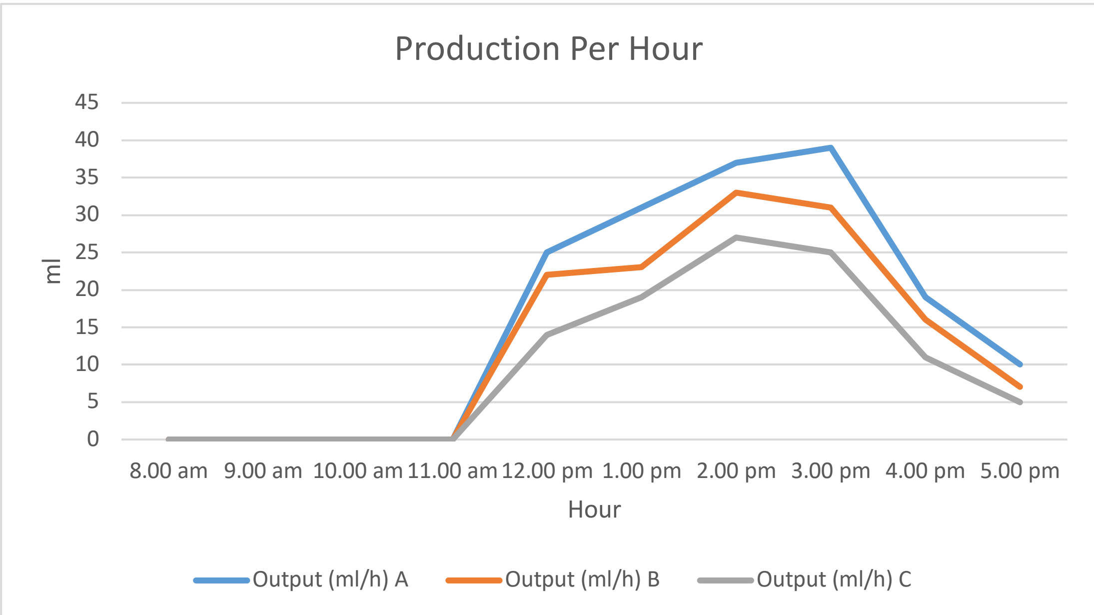


Figure 13: Nov 12 Production

Table 18: Nov 12 Production Summary

Area/Production	A(ml)	B(ml)	C(ml)
Per 0.0775 m^2	161	132	101
Per 1.00 m^2	2077	1703	1303

13th November 2016

Table 19: Nov 13 Hourly Production

Time (h)	Output (ml/h)		
	A	B	C
8.00 am	0	0	0
9.00 am	2	0	0
10.00 am	10	8	5
11.00 am	15	11	10
12.00 pm	26	21	14
1.00 pm	33	27	21
2.00 pm	40	36	27
3.00 pm	31	27	22
4.00 pm	15	11	7
5.00 pm	7	4	0

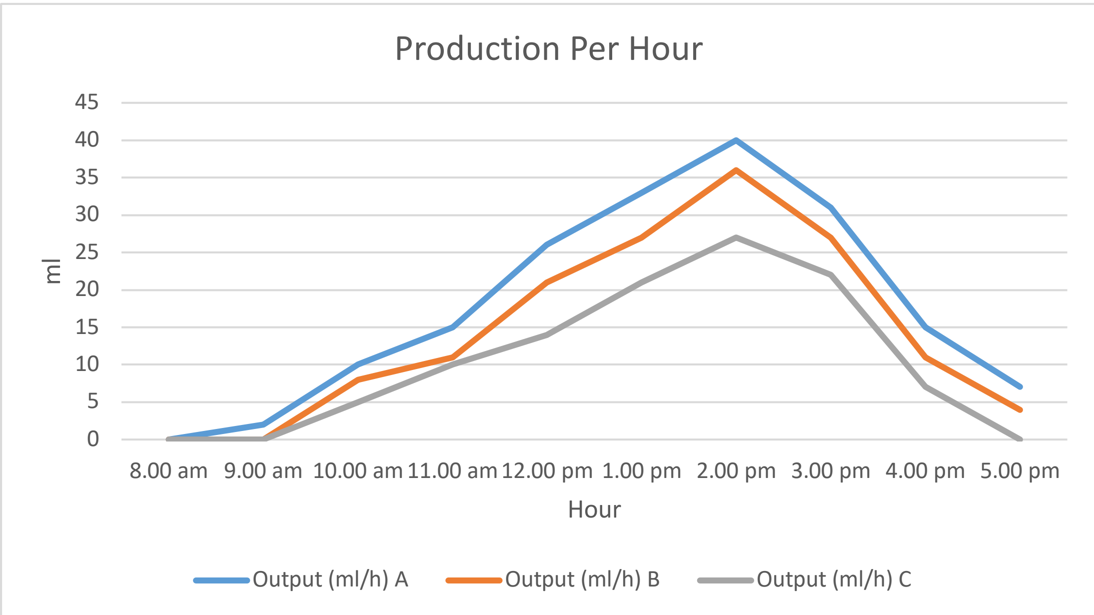


Figure 14: Nov 13 Production

Table 20: Nov 13 Production Summary

Area/Production	A(ml)	B(ml)	C(ml)
Per 0.0775 m^2	179	145	106
Per 1.00 m^2	2310	1871	1368

Below is the compilation of all the results within the 10 days testing period.

Table 21: Compilation of Production

Day	Output (ml/h)						Daily Solar Radiation(kWh/m2/day)
	A		B		C		
	0.0775 m^2	1.00 m^2	0.0775 m^2	1.00 m^2	0.0775 m^2	1.00 m^2	
2-Nov	198	2555	157	2026	125	1613	4.13
3-Nov	209	2697	164	2116	123	1587	4.14
5-Nov	135	1742	110	1419	82	1058	3.86
6-Nov	192	2477	152	1961	115	1484	4.11
7-Nov	221	2852	178	2297	137	1768	4.16
8-Nov	187	2413	134	1729	106	1368	4.11
9-Nov	127	1639	93	1200	73	942	3.85
10-Nov	181	2335	145	1871	115	1484	4.07
12-Nov	161	2077	132	1709	101	1303	4.01
13-Nov	179	2310	145	1871	106	1368	4.07

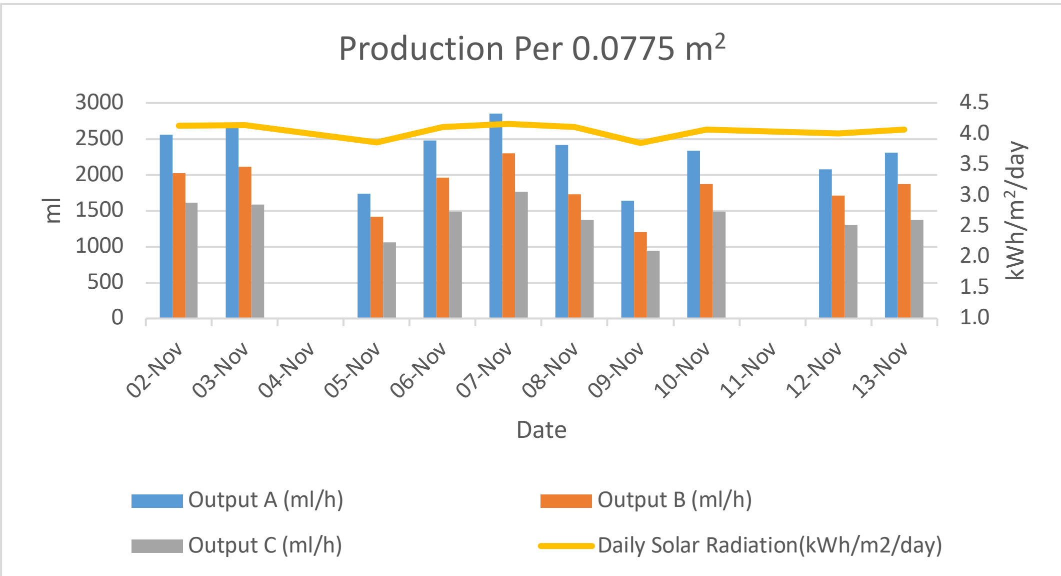


Figure 15: Production Per 0.0775 square meter

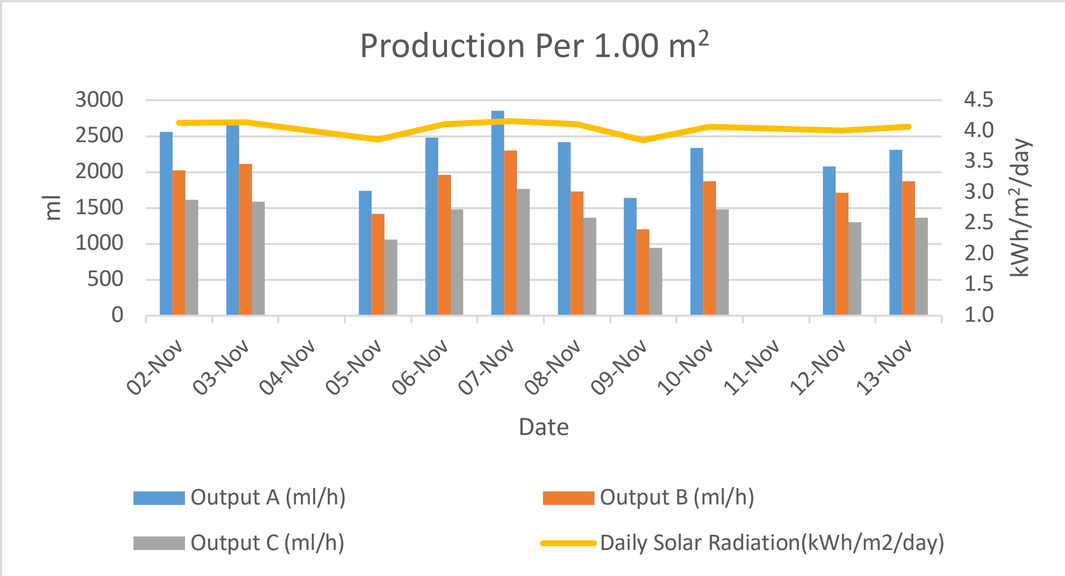


Figure 16: Production Per 1.00 square meter

The results showed that the productivity of the distilled water is based on the solar radiation. The higher the solar radiation on the particular day, the higher the distilled water produced.

The solar roof distilling tiles with black paint and aluminium fins (output A) give the highest productivity compared to output B and output C. This is due to the aluminium fins that absorb the reflected sunlight which give extra heat towards the basin compared to others. This leads to high evaporation rate because of the extra heat.

4.2 Water Quality Test

Water quality test is conducted to check whether the drinking water standard is met. The test is conducted after finished with the production per day test. The test included the pH test, color and turbidity.

The result of the water quality test is shown below.

Table 22: Water Quality Test

Type of Test	Sea Water	Output A	Output B	Output C
pH	6.69	6.94	6.82	6.96
Color	88	29	39	35
Turbidity	26.8	5.37	10.4	9.24

Based on the Malaysia Drinking Water Quality Standard, the pH for all output is met, the color however not met and for the turbidity, only output A is up to standard while output B and C are not.

The condensed water should be clear and met the standard. The reason of the production water does not reach the standard might be because of the improper coating of the basin(steel) making the residue of the basin being mixed up with the water. Proper coating or replacing the material of the basin should solve this issue.

4.3 Efficiency

Basin	Efficiency (%)
A	44.15
B	35.58
C	27.39

The efficiency is calculated on the maximum production which is on 7th November 2016 with the solar radiation of 4.16 kWh/m^2/day. The results showed that basin A has the highest efficiency compared to others. This is due to the aluminum fins that give higher heat towards the basin by absorbing reflected sunlight. The efficiency is also good because average solar distillation efficiency is about 30%. Basin A give 44.15% which is 10% higher due to the aluminum fins.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

The solar roof distilling tiles will be a great alternative towards solving the water scarcity in this world today. It will promote the use of solar distillation as it uses renewable energy to operate which is the solar energy. Although it will not be used to supply water to all area but in coastal area, this will benefit them in term of energy and water resources.

The solar roof distilling tiles with black paint and aluminum fins give the highest production due to the fins that enable the basin to trap more heat than compared to other basin. This will result to higher efficiency. Basin A efficiency is above average which is good compared to others. Lastly, for the water quality, all the basin need to use good material and proper coating in order to prevent the residue being mixed up with the distilled water. This is prove that different design give different productivity.

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APPENDIX A

Ipoh

Average Solar Insolation figures

Measured in kWh/m2/day onto a horizontal surface:

Jan	Feb	Mar	Apr	May	Jun
4.54	5.14	5.22	5.20	4.85	4.77

Jul	Aug	Sep	Oct	Nov	Dec
4.73	4.61	4.61	4.42	4.06	4.01

APPENDIX B

Drinking Water Quality Standard

Drinking water quality standard

Parameter	Group	RECOMMENDED RAW WATER QUALITY	DRINKING WATER QUALITY STANDARDS
		Acceptable Value (mg/litre (unless otherwise stated))	Maximum Acceptable Value (mg/litre (unless otherwise stated))
Total Coliform	1	5000 MPN / 100 ml	0 in 100 ml
E.coli	1	5000 MPN / 100 m	0 in 100 m
Turbidity	1	1000 NTU	5 NTU
Color	1	300 TCU	15 TCU
pH	1	5.5 - 9.0	6.5 - 9.0