Use Of Hexagonal Cork Sheets For Evaporation Control: An Experimental Study

By

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Dissertation submitted in partial

Fulfilment of

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Universiti Teknologi PETRONAS

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Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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Approved by,

____

(Dr Teh Hee Min)

UNIVERSITI TEKNOLOGI PETRONAS

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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 references and acknowledgements, and that the original work contained have not been conducted or done by unspecified sources or persons.

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MUHAMMAD NASHRUN NAIM BIN ABDUL MANAF

ABSTRACT

Large water storages like reservoirs and open lakes are the primary source of drinking water and energy production. As a result of the change in climate, particularly the increase in surface air temperatures, evaporation is expected to increase throughout Indonesia/Malaysia. One way of saving available water resources is to reduce evaporation that leads to the loss of a large amount of water from reservoirs and open lakes. Many physical, chemical and biological methods have been tested and developed all over the world to save water from evaporation process. For evaporation reduction in reservoirs, physical methods are more viable than the chemical and biological methods due to the surface area of the water bodies. Some of commonly used physical methods are solar photovoltaics PV cover, shade balls, shade cloths, etc. Nevertheless, these technologies are costly and difficult to install. This research aims to develop an innovative, economical and sustainable technology (physical method) to reduce evaporation in reservoirs. The technology developed in this study is hexagonal cork sheets that are placed on water surfaces. This research evaluates the performances of the proposed technology in the open field with the aid of evaporation pans Class A. The measured parameters are wind speed, relative humidity, air and water temperatures, and hourly water level drop. The evaporation rates were estimated based on the water level drops, and the performance efficiency of the technology was calculated. The performance efficiency of the proposed technology is up to 58.72 %. The proposed material is suitable due to its low impacts to the environment and low cons cost.

ACKNOWLEDGEMENTS

All praises to the almighty for giving me the strength and determination to complete this project successfully. From this project, I have managed to gain new knowledge about experimental works related to civil engineering. Unfortunately, due to the COVID 19 pandemic, I was able to utilize laboratory facility in my campus because of travel restrictions. This project was initiated and done remotely from my home

I would like to use this opportunity to convey my sincere gratitude to my supervisor, Dr Teh Hee Min for giving me this valuable opportunity to work under this supervision. Not to forget my senior colleague; Yau Wen Jae who have guided me a lot. thanks to their guidance, I was able to complete my FYP 2 on time. I am considered lucky to be surrounded with these brilliant people who continuously lend their upmost support, reviewing my work progress from beginning until completion. Lasty, I am forever indebted towards my family for their endless love and support which have given me the strength and determination to finish this project with flying colours

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Water is a gift from nature that keeps life on the planet alive. Depending on the availability of this resource, people all across the world have flourished or perished. The overall water resources on the planet are estimated to be roughly 1360 million cubic kilometres, with freshwater accounting for just about 33.5 million cubic kilometres. Despite the fact that water covers more than 70% of the planet's surface area. Only 1% of that water is fit to consume. In addition, population growth, pollution, and global warming are putting unprecedented strain on the planet's scarce water supplies. As a result, over the last ten years, the cost of water has risen considerably in many countries with arid or semi-arid climates. Evaporation is a major environmental activity that can diminish the quality and amount of water accessible for industrial, agricultural, and home purposes.

In hydrologic and water resource studies, evaporation has always been a major factor. In the past, water resource authorities (such as the provincial and federal governments) maintained evaporation pan networks. These data were useful in various disciplines of science, including water resource management (Chin et al. 2005)For example, in lake studies, where it is an important component of the water budget study (Fennessey 2000; Reis and Dias 1998), the rate of evaporation has been particularly important. Evaporation is especially significant in studies of stream temperature modelling (Caissie et al. 2007; Benyahya et al. 2010), as well as in agriculture for estimating water shortfalls and irrigation needs (Phene et al. 1992 Evaporation monitoring and estimate have always been difficult due to their complexities in connection to climatic conditions As a result, numerous research have been conducted

The principal source of drinking water and electricity production is large water storages such as reservoirs and open lakes. As a result of climate change, especially the rise in surface air temperatures. In Indonesia and Malaysia, evaporation is projected to increase. Reduced evaporation, which results in the loss of a huge volume of water from reservoirs and open lakes, is one strategy to save available water resources. To save water from evaporation, several physical, chemical, and biological approaches have been researched and developed all around the world. Physical methods are more viable than chemical and biological strategies for reducing evaporation in reservoirs due to the surface area of the water bodies. Physical, chemical, and biological approaches can all be used to minimise the loss of water due to evaporation.

1.2 Problem statement

Climate change directly impacts the availability of water resources and reservoir storage due to evaporation. So, due to changes in temperature and precipitation patterns, water availability will be affected. This temperature is predicted to rise in most areas, as it is generally expected to increase more inland areas and at higher latitudes. Hence, this leads to increase loss of water through evaporation at higher temperature. The warming of climate usually related to an increase in energy at the surface. Evaporation will increase as climate warms but the increase is not as fast that of water vapor content in the atmosphere. The mean residence time of water vapor in the atmosphere will decrease. Due to climate change driven by human activities, changes in precipitation and evaporation as it results in changes of water availability.

However, due to many factors affecting evaporation, quantity of evaporative loss is difficult to be measure in reservoirs. Evaporation of water from large water bodies influences the hydrological cycle, leading to large quantity of water is lost every year by evaporation from storage reservoirs.

With events caused by climate change driven by human activities, water cycle will be disrupted which results in changes of precipitation, condensation, evaporation and evapotranspiration. Eventually affecting the water reserves in river, lakes and dams.

There are several ways to mitigate such issues, but not every evaporation technologies are suitable and economical to be adopted in large water storage. As local technologies are not available in Asia.

1.3 Objectives

This study embarks on the following objectives:

1. To develop a sustainable and economical physical evaporation reduction device for large reservoirs
2. To asses the reliability of the proposed evaporation reduction technology using a small scaled physical method

1.4 Research Questions

Based on the study, the following research questions have been prompted:

1. Not all evaporation technologies are suitable and economical to be adopted in Pidekso reservoir/ large water storage basins. What are the technologies that are suitable to be adopted to reduce evaporation for large water storage reservoirs in tropical countries?
2. Would the proposed evaporation reduction technologies posed adverse impact to the environment and local community?

1.5 Scope of Study

The scope of study of this project involves:

1. evaporation reduction technology is limited to physical methods.
2. Assessment of evaporation rates for 1 proposed technology and a controlled model Class A evaporation pan .

CHAPTER 2

LITERATURE REVIEW

2.1 Type of technologies (physical method) used to sustain evaporation losses in reservoirs.

There is various way to mitigate the issues to reduce evaporation. As the efforts to reduce evaporation from water reservoirs started in the 1960s using monolayer molecular films as an impermeable barrier for the water surface. Since then, a lot of methods that provide better control of evaporation losses have been developed. Among these methods, physical methods such as floating covers or suspended covers atmosphere. In addition, physical methods of evaporation reduction can save a large percentage of water (between 70% and 95%,) they would cost high, but their maintenance costs are not expensive.

For the first category which is use floating covers. These are the methods that can reduce evaporation in reservoirs which are floating continuous covers and floating modular covers.

2.1.1 Floating continuous covers

To prevent evaporation, floating continuous coverings provide an impermeable barrier that floats on the water surface. Polystyrene, wax, and foam have all been tried as materials for floating continuous overs, but polyethylene plastic has shown to be the most effective. The most suitable and long-lasting material for this type of cover. Tests have revealed that Evaporation from open water can be reduced by over 95% using floating sheets like E-VapCa

2.1.2 Floating modular covers

Modular floating covers, as opposed to continuous floating covers, are discrete units that can float freely and do not entirely cover the water surface, increasing dissolved oxygen DO transmission through the open gaps generated between them. Floating modular covers such as aqua caps and shade balls are common.

(A) Aqua caps

Figure 2.1 aqua caps (source: https://www.e3s-conferences.org/articles/e3sconf/pdf/2019/23/e3sconf_form2018_05044.)

Aqua caps , which are spherical, dom-shaped floating modules with a diameter of around 1.1 m and are manufactured of food-grade polypropylene and high density polyethylene (HDPE). When the aqua cap is placed on the water, a single hole around 10 mm in diameter is drilled in the centre to enable pressure equalisation and to evacuate air.

(B) Shade balls

Referring to the figure below, shade balls are plastic eco-friendly balls that can be utilised in lakes, ponds, streams, and dams. The Los Angeles Department of Water and Power (LADWP) first utilised these balls in 2011 to limit evaporation and block UV radiation, preventing the creation of hazardous organisms, algae, and carcinogens.

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Figure 2.2 shade balls (source- https://www.e3s-conferences.org/articles/e3sconf/pdf/2019/23/e3sconf_form2018_05044)

As for the second category which is categorised as modular covers. The technologies that has been made were Shadecloth and solar photovoltaics PV.

(C) Shadecloth

As for the second category which is categorised as modular covers. The technologies that has been made were Shadecloth and solar photovoltaics PV. Shadecloth is a type of suspended construction that is put over water surfaces and is supported by steel cables and poles. This cover minimises evaporation rates from water surfaces by reducing wind activity and blocking incoming solar light Shadecloth is a cost-effective option for small reservoirs under 10 hectares in size. The main downside of this approach is its relatively high construction capital cost, however this has already been overcome in Malaysia thanks to a new shadecloth knitting machine that produces wider rolls and so reduces the number of installed cables

Figure 2.3 shadecloth(source- https://www.e3s-conferences.org/articles/e3sconf/pdf/2019/23/e3sconf_form2018_05044)

(D) Solar photovoltaics PV

Covering the canals with a solar photovoltaics system (SPVS) is expected to significantly reduce evaporation. However, Evaporation rates from flowing canals can take values as high as 5–20 mm/day. . India has been a pioneer country in the field of canal-top solar projects. In February 2014 was inaugurated a 10 MWp project of this kind in India with a total cost of $18.3 billion. The system lays over 3.6 km of the Narmada irrigation canal in Gujarat's Vadodara city in western India, consists of 33,816 solar panels as shown in Owing to using this system, 6 acres of land and about 9 million litters of water are saved every year. Natural cooling of SPVS is an additional advantage of using solar panels over irrigation canals, leading to increase the efficiency of the solar panels by 7%, compared to ground SPVS

Figure 2.4 SP PV (source- https://www.e3s-conferences.org/articles/e3sconf/pdf/2019/23/e3sconf_form2018_05044)

(E) Method of evaporation reduction by injection of air bubbles into water (bubble plume)

as for injection of air bubbles into water is phenomenally called stratification. Artificial destratification will happen when injecting a bubble plume in the cold deep layer. As evaporation reduced by uniform Ing temperature gradients over the depth of the storage. Diffusers which is an injection of bubble plumes are placed at the determined height above the bottom of reservoir as to prevent the disruption of the bed sediments and carrying back to surface

Table 2.1:Summary of technologies used in reducing evaporation in reservoirs

Author	Technology used	Advantages	Disadvantages
Youssef and Khodzinskaya	Aqua caps	• plastic eco friendly • Block UV rays to prevent formation of harmful organisms	• Up for most maintenance
	Shade balls	• To prevent the formation of carcinogenic chemical, bromate	• Put to economical risks
	Solar photovoltaics PV	• Avoid land use conflicts	• Food chain impact of the ecosystem
	Shade cloths	• Strong and durable • Resistant to tearing an	• Gives negative impact as it affect tourism, Fishing, navigation
	Injection of air bubbles into water (bubbles plume	• Prevents hypolimnetic water from being mixed with the epilimnion water	• Fish species could be destroyed

2.2 Factors affecting the rate of evaporation in reservoirs

Evaporation is the transformation of a liquid into a vapour. Water molecules are constantly moving and some of them have enough energy to break through the water surfaces and escapes as vapour into the air. Evaporation in general is a beneficial phenomenon in maintain the global water balance. As it's the same phenomenon that's causing significant losses from the hydrological cycle.

The hydrologic cycle, sometimes known as the water cycle, is a term used to describe the material flow of water on Earth. This sequence of actions explains how water travels across the globe and changes forms. Water is circulated between oceans, the atmosphere, and the land as a result of these precise stages. Precipitation, such as rain and snow, river drainage, and the return of water to the atmosphere through evaporation and transpiration are all part of the water cycle. Because of the natural cycling of water across a multitude of different regions on the Earth, the amount of water has remained largely constant throughout the Earth's history. (Craig, 2001) Over the years, little has been added or taken away, and this water has been in constant motion.

A body of water controlling evaporation from land-based water bodies has remained one of the most difficult challenges Water conservation strategies are primary pillars. As there are factors that affect the rate of evaporation in reservoirs.

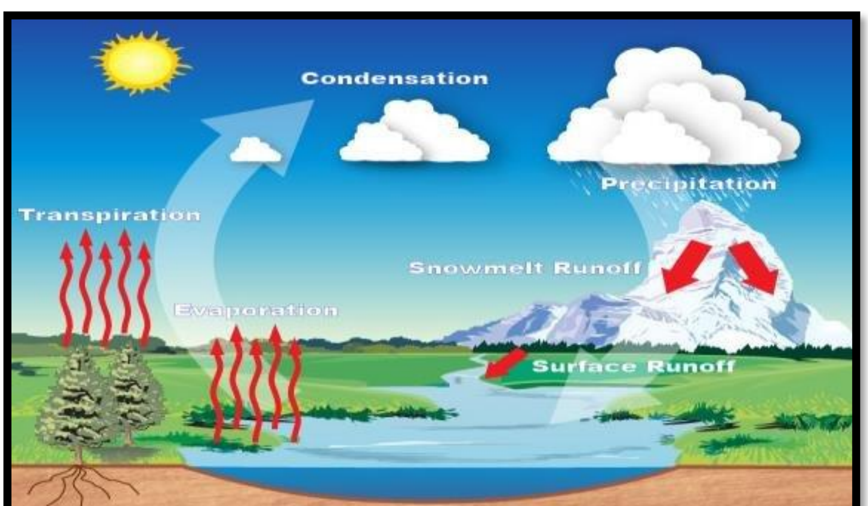

Figure 2.5 Hydrological cycle

The following factors are stated as below:

2.2.1 Water Surface Area

Evaporation is a surface process as the amount of water lost through evaporation from stored water is exactly proportional to the amount of its surface exposed to the atmosphere

2.2.2 Water Temperature

The rate of evaporation is affected by the temperature of the water and the air above it. Temperature affects the rate at which molecules are emitted from liquid water. The rate evaporation increases as the temperature rises

2.2.3 Vapour Pressure Difference

The pace at which molecules exit the surface is determined by the liquid's vapour pressure. Similarly, the pace at which molecules enter water is determined by the air's vapour pressure. The difference between the saturation vapour pressure at the water temperature and the dew point of the air determines the rate of evaporation. The greater the difference, the more evaporation occurs.

2.2.4 Wind Effect

The more the air movement above the water, the more water vapour is lost. Experiments on the relationship between wind speed and evaporation have shown that the two have a direct relationship up to a particular wind velocity, after which the relationship may break down. Surface roughness and the size of the water body have been reported to play a significant influence.

2.2.5 Atmospheric Pressure

Other factors affecting evaporation are linked to atmospheric pressure. As a result, evaluating its impact independently is challenging. With increasing pressure, the quantity of air molecules per unit volume increases. As a result of the high pressure, there is a greater possibility that vapour molecules may form

2.3 Characteristics of weather in Malaysia and Indonesia

2.3.1 Weather condition in Malaysia

Malaysia is an Asian country just north of the equator, it naturally has an equatorial climate, which means it is humid, and wet all year. Temperatures are high and stable, with a slight drop in November and January, when highs drop to 29/30 °C), at least in the north, and a slight increase (which is felt due to the high humidity) from March to August, when highs hover around 32/33 °C and lows around 23/25 °).

Rainfall is regular throughout the year; in fact, finding a location with less than 2,000 millimetres (79 inches) each year or a month with less than 100 mm (4 in) is uncommon yet, it is feasible. to locate periods when it is not excessively high, though these do not exist everywhere.

The monsoon system causes the rainfall, but because Malaysia lies near the Equator and surrounded by water, there is no true dry season. Furthermore, the rains are likely different as years passed by , as they are located in tropical countries.

The monsoons, on the other hand, make precipitation more abundant and frequent in areas directly exposed to these winds: the northeast monsoon dominates between mid-October and January, affecting particularly the east coast of Peninsular Malaysia and the north-east coast of Borneo, while the southwest monsoon dominates between June and September, affecting especially the east coast of Peninsular Malaysia and the north-east coast of Borneo.

Averages	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall (mm)	199.9	146.4	170.4	198.3	203	177.3	180.2	200.6	249.4	294.8	317	301.6
Temp (°C)	25.8	26.1	26.5	26.9	27	26.7	26.5	26.4	26.2	26.2	26	25.8
Min Temp (°C)	22.1	22.1	22.4	22.8	22.9	22.6	22.4	22.4	22.3	22.4	22.3	22.2
Max Temp (°C)	29.5	30.2	30.9	31.3	31.3	31	30.6	30.6	30.4	30.3	29.8	29.5

Figure 2.6 Average rainfall and temperature

Based on the table above, it shows that the average of rainfall is increasing and also the temperature changes in those 12 months.

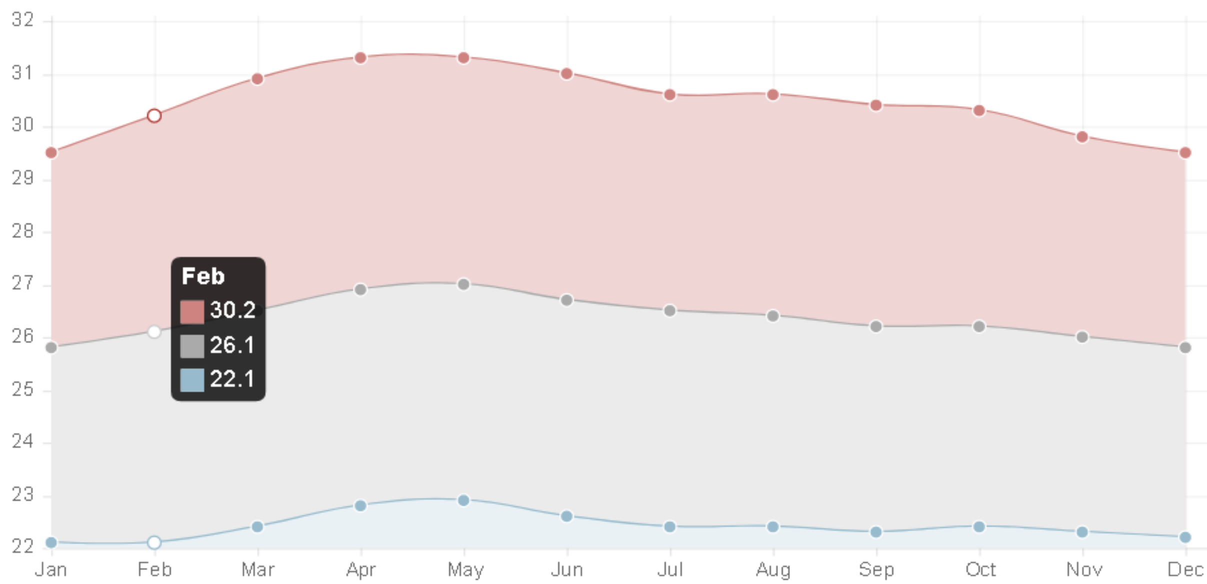

Figure 2.7 Annual average temperature in Malaysia

2.3.2 Weather condition in Wonogiri, Central Java

The rainy season in Wonogiri is overcast, the dry season is partly cloudy, and the weather is hot and uncomfortable all year. The temperature normally ranges from 72°F to 89°F throughout the year, with temperatures rarely falling below 68°F or rising over 94°F.

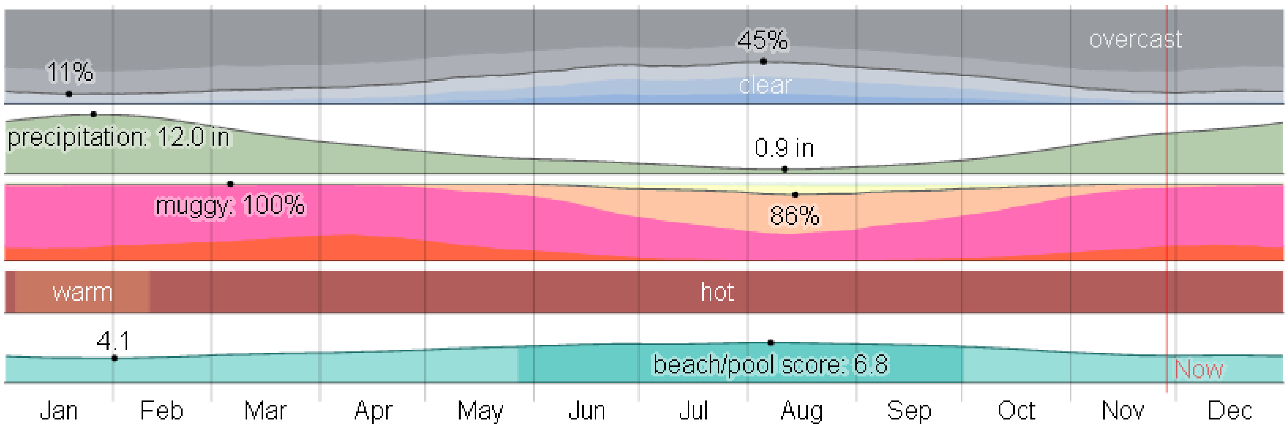

Figure 2.8 Climate in Wonogiri

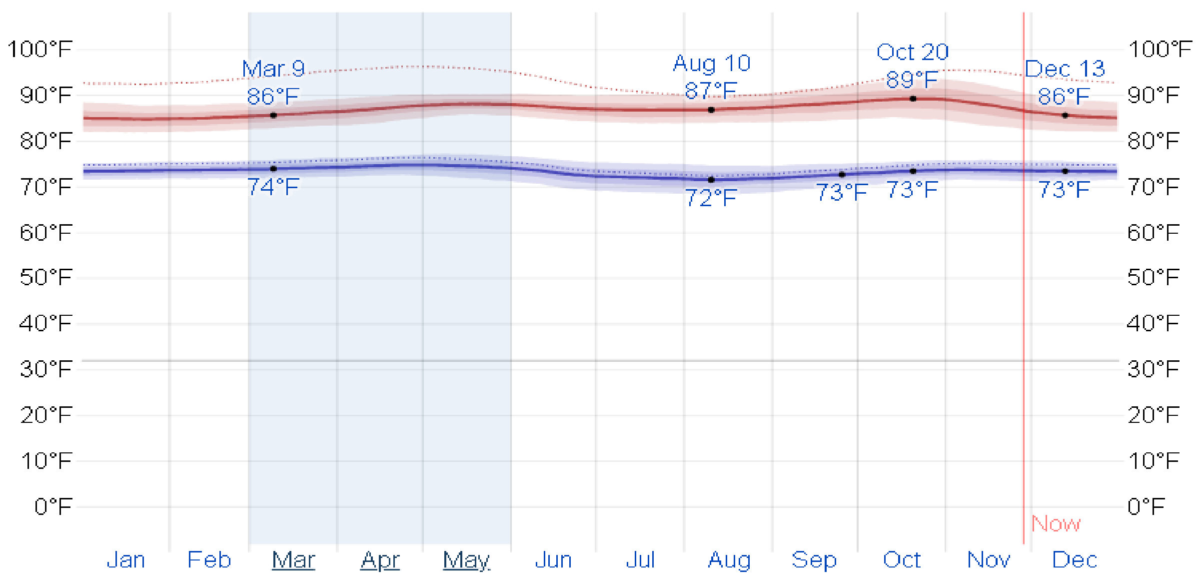

Figure 2.9 Average high and low temperature in Wonogiri

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Over the course of the year, the average water temperature varies slightly depending on the season.

Warmer water is available for 6.0 months, from November 29 to May 28, when the average temperature is over 83°F. The month with the warmest water in Wonogiri is March, with an average temperature of 84°F.

The cooler water period lasts 2.5 months, from July 24 to October 8, with an average temperature of less than 79°F. August is the coolest month in Wonogiri, with an average temperature of 20°C.

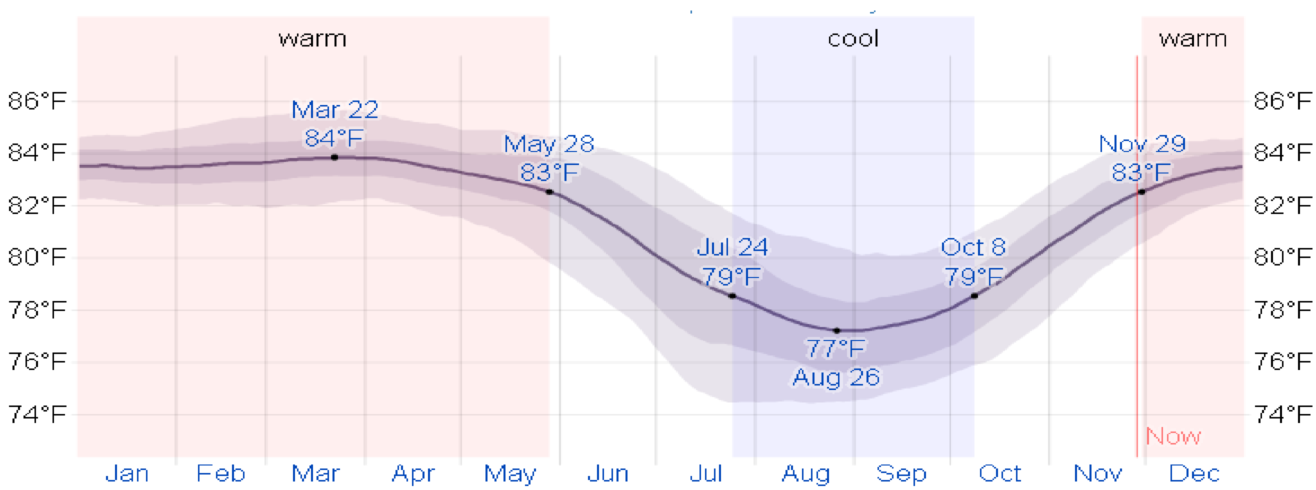


Figure 2.10 Average water temperature

2.4 Benefits of using cork (cork oak tree) as a sustainable material for floating technology.

There are many physical properties of a cork which is buoyancy .It is light weight. Air consists 50 % of the cell volume of a cork piece. Cork has a specific gravity of 25 and it is one of the lightest solid that is available **.** (Pereira et al, 2015) It has resistance to moisture and liquid penetration. The cell structure that gives out high resistance to penetration of water. Next ,low thermal conductivity .One of the most efficient of heat conductors is divided minutely by a dead air space. As the material of the cork has its own neutrality for health. This substance is not detrimental to one's health. It is not hazardous when it comes into touch with the skin or when it enters the gastrointestinal tract by accident. There are no allergies associated with it

It is Impermeability to liquids and gases. Liquids and gases are not able to pass through. The greater amount of suberin in Cork is responsible for this characteristic. The weight of the substance ranges from 39 to 45 percent of the cork's mass. This chemical has a waterproofing structure, as well as the ability to fortify and insulate against heat.

Furthermore , Flexibility and compressibility. Cork's cell membranes are exceedingly flexible, which means it remains compressible and elastic after pressure is removed, and it returns to its original shape.

2.4.1 Absorption of water in cork

A study has carried out on the absorption of water in cork, the study identified that the cork which had been soaked in water for 3 days as the result obtained was that there are microscopic images of the cork and also can be directly identified in a surface examination.

An ability of a cork of its cellular structure to resist water. The aim of the cork is the components which are suberin. Suberin can be important as in coffering the hydrophobicity to cork.(Marta H. Lopes , et al. 2000) Cork has been used in the industrial for many years now such as life jackets, floating devices and also wine stopper. Water absorption causes a cubic inch of solid cork immersed in water for 48 hours to gain less than 3% of its original weight. If buried for 48 hours, a cubic inch of solid wood or unglazed clay-bodied ceramic tile would gain many times this proportion in weight of water.

Table 2.2 Comparison of water absorption on different materials

Fibers	Size of fibers (mm)	Water absorption up to saturation (%)	References
Sisal	0.2–0.227	110–240	[27,28]
Banana	0.2	407	[27]
Cork	0.2	85–105	[27]
Eucalyptus	0.2	643	[28]
DPF3	2.5–3.15	241	
DPF6	3.16–16	179	

The table shows the size of fibers and water absorption for material. It is identified that cork is the least water absorption with the range of 85-105%

2.4.2 Proposed shape of model using cork (Hexagon)

The hexagonal shape can use for many purposes in designs, as it can be a potential design to be used as a floating device. The hexagonal shape can be technically defined as a wave friendly design.

A study has been carried out using a solar in hexagonal shape which justify the hexagonal shape is very effective comparing to circular shape as the reason of higher value or the covered area. The advantage of using a hexagonal shape is that the distance between the centroids are similar in all six directions (corners) .in fact, hexagon is one of the natural shape. For example , bee honeycombs and one of the structures which is Giant's Causeway in Northern Ireland.

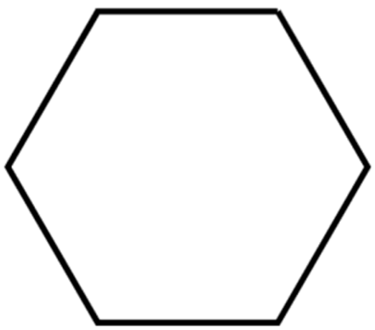


Figure 2.11 hexagon shape

Figure 2.12 Giant's causeway

2.5 Summary of literature review

All the literature review have been done on evaporation for getting more information and knowledge . Topics that are related are the factors of evaporation has been studied on and the type of mitigation technologies that can be used for reservoirs. Besides that, the topic that has been research is the benefits of cork and its physical properties, as this is important as it will be tested and compared with the control model which is the Class A evaporation pan. The efficiency of evaporation has been calculated to determine the evaporation that occur from both models.

CHAPTER 3

METHODOLOGY

3.1 Project flowchart

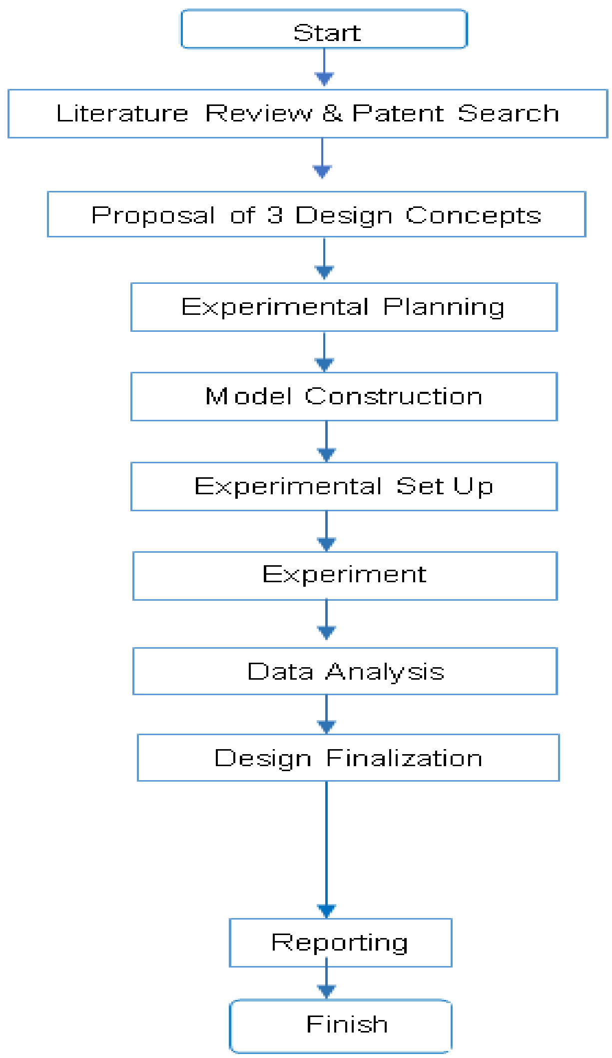


Figure 3.1 Project flowchart

The figure shows the flowchart of the project process throughout the duration of FYP I and FYP II. As the primary focus is to develop a sustainable and economical evaporation reduction technology that will be reduce the evaporation rate for Pidekso reservoir . The effectiveness of the proposed technology will be evaluated using a small scales experimentation.

3.2 Development of Design Concept

Literature review and patent search will be conducted to explore the existing evaporation reduction technologies available in market. These products are foreign technologies. Less viable to be adopted in Malaysia and Indonesia due to high initial cost and transportation problems. Strengths and limitations of these foreign technologies will be identified using SWOT. Based on the merits, one design concepts of the evaporation technology will be developed.

3.2.1 Hexagonal cork sheet

The method and technology that to conduct is using a sheet (floating)type of technology which will be using cork material in hexagonal shape. Cork is one of the sustainable material that can be used to conduct models as cork is a versatile material for industrial and consumer. It is extremely durable and has a high friction coefficient. The cork is sustainable and also renewable as it comes from the cork oak tree, as the tree will be harvested and not cut down.

As the technology is needed to use sustainable and economical material, cork sheet will be cut into hexagonal shape with the side of 15 cm and experimented in reducing the evaporation for reservoirs for the project. This model will be experimented in an evaporation pan with the dimension of 120.7 cm x 25 cm)

The details and design of the model will be in hexagonal shape.. The proposed model is a hexagonal shape that was cut out from a cork sheet, the hexagonal cork sheet will float as cork repels water and the hexagonal shape helps in reducing the surface area of the water in the pan .Plus the hexagonal shape was identified as a wave friendly design which contributes in the experiment and also applied to the reservoir.

Each side of the hexagonal shape cork will be 15 cm (each side) with the area of 584 cm squared. Dimensional analysis will be calculate as to approximate the size for Pidekso Dam

Figure 3.2 Hexagonal cork sheet in pan evaporation

3.2.1 Percentage of coverage ratio

The percentage of coverage ratio for the experiment would be as follow:

Area of tank(cm^2)= $11442cm^2$

Area of each hexagonal cork sheet (cm^2) = 548.6 cm^2

Total Area of hexagonal cork sheet (cm^2) = 5261.4 cm^2

Coverage ratio percentage (%) $= \frac{\text{Total area of hexagonal cork}}{\text{surface area of tank}} X\ 100$

$$= \frac{5261.4}{11442} X\ 100$$

$$= 45.98\ \%$$

The percentage of coverage for the proposed model is 45.98 % and for controlled model is 0% . This project also aims on the surface area exposed within the pan . As it could be ratio with the dimension of the Pidekso Dam

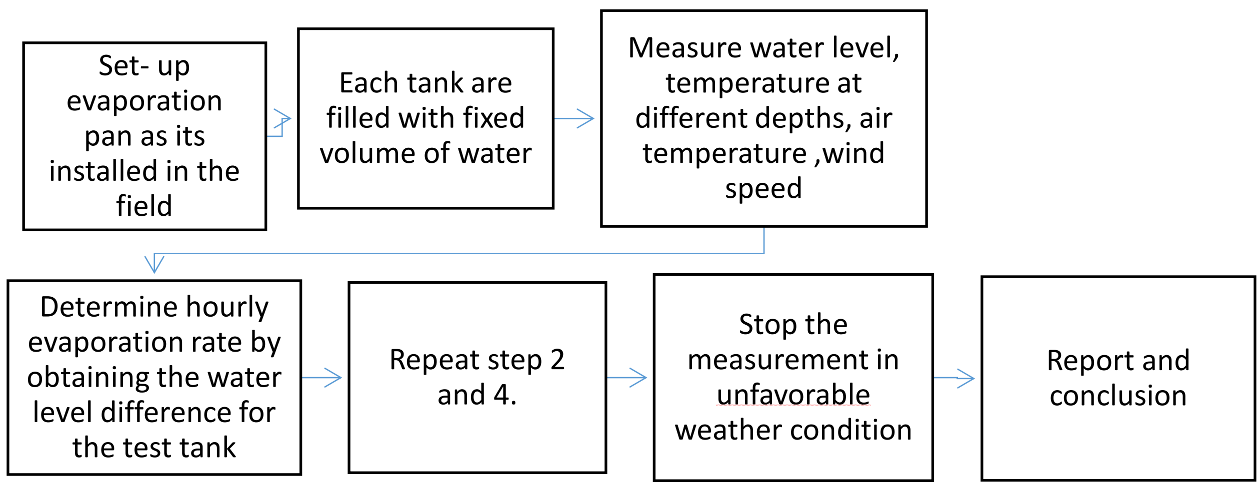
3.3 Proposed Technology Concepts

The efficiency of the design concept will be evaluated using evaporation pans/ water basin. There will be many instruments are in use for evaporation measurements from free water surfaces. Pan evaporation study will be conducted at open site at Universiti Teknologi PETRONAS, whereby the experiments are conducted using 4 identical evaporation pans (119 cm width x 25 cm depth) with the area of 34940 cm squared. One tank will be used a control sample, without cover and other 3 will be covered using the proposed technology. Test site is located at open field that is away from obstructions. For example, trees and buildings. The spacing between each tank should be in proximity. The pools shall be embedded into the ground to mimic the temperature of the ground. The experiments shall be taken place in a controlled environment without rainfall and wind actions. To limit the effects of wind and rainfall, the experiment will be conducted during clear sunny day. Otherwise, the test will be delayed. The test site will be fenced using transparent plastics or covered fence to prevent external disturbance.

3.4 Class A evaporation pan steps

Figure shows the steps on how the test will be conducted. If evaporation pan is used for measurement of evaporation, the pan effect should be addressed by a correlation factor between actual evaporation on the reservoir and the class A pan, which is 0.70 to 0.80 for temperate climates. This adjustment factor is necessary to account for the heat gains that the steel evaporation pans receive through their sides during daytime hours and lower emissivity to direct sunlight (infra-red heat reflection) of the metal construction as compared to actual natural reservoir conditions.

Table 3.1 Class A evaporation pan steps



3.5 Measuring equipment / facilities

The summary of equipment and measurement given below:

Table 3.2 Summary of equipment and measurement

Measurement	Accuracy	Apparatus Needed
Air Temperature (˚C)	± 1 ˚C	Hygrothermograph
Water Temperature (˚C)	± 1 ˚C	Thermometer
Relative humidity (%)	± 3%	Hygrothermograph
Evaporation (mm)	± 0.02 mm	Evaporation pan/Water tank

The measurements will be conducted on a daily basis for 15 days. The data collected will be statistically to determine the correlation between the hourly evaporation rates of the respective test case with air and water temperature, relative humidity, wind speed, and water level drop . Based on the results, the technology will be compared the controlled model which is the pan without the technology. . Model construction will be conducted using ruler to measure water level to identify evaporation of the proposed technology that will be developed in this project.

Figure 3.3 Thermometer

Figure 3.4 Evaporation pan on site

Figure 3.5 anemometer

Figure 3.6 Measuring Cylinder

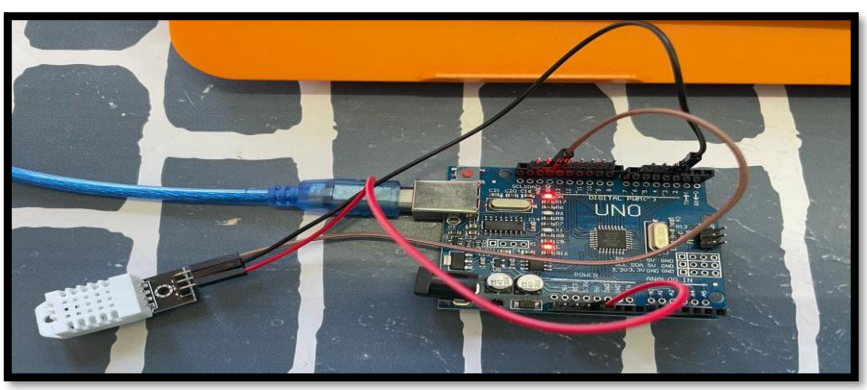


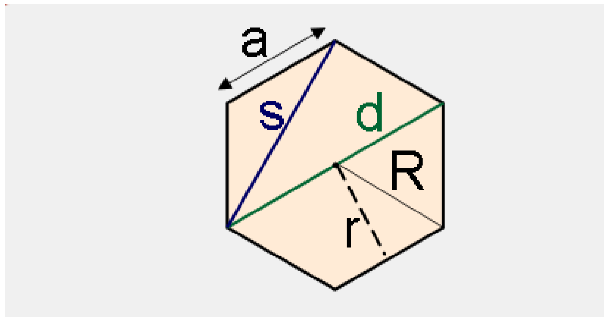
Table 3.2 List of equipments and functions

Equipment	Quantity	Function
Evaporation tank	4	Used to fill water
Fences	4	To prevent external disturbance from animals
Hygrothermograph	1	To measure relative humidity
Thermometer	1	To measure water temperature
Anemometer	1	To measure the wind speed
Measuring Cylinder	2	To measure volume of water

3.6 Hexagonal cork sheet

The model will be developed using the items below:

The measurement and the area is a per figure below:



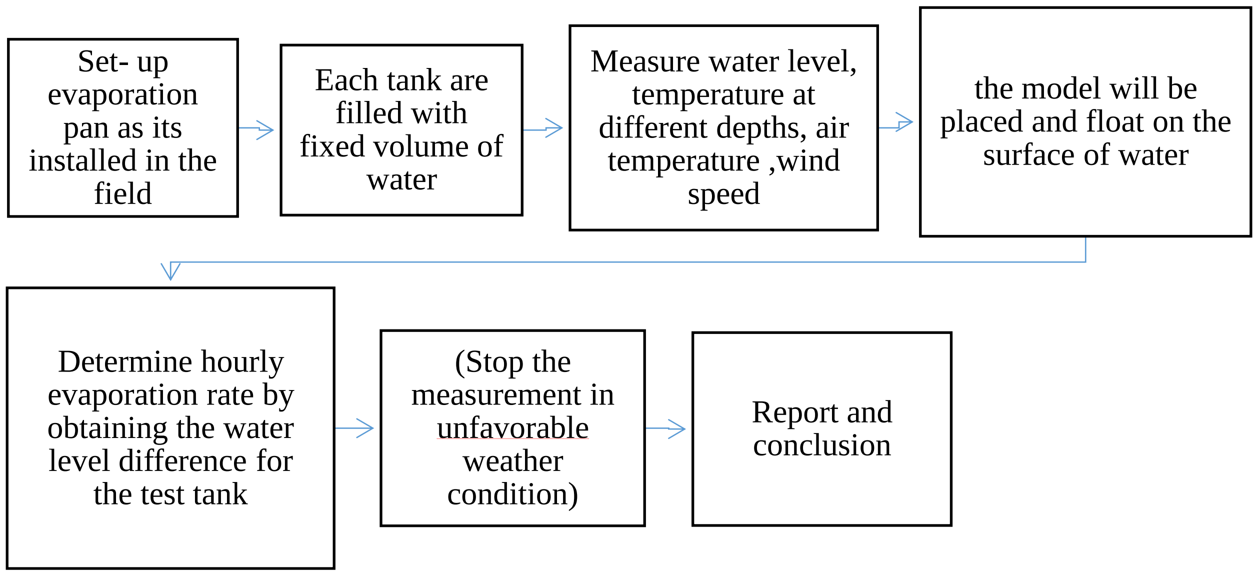
Side (a)	15 cm
Area	584.6 cm²
Perimeter	90 cm
Long diagonal (d)	30 cm
Short diagonal (s)	25.98 cm
Circumcircle radius (R)	15 cm
Apothem (r)	12.99 cm

Figure 3.8 Area of Hexagonal cork

3.6.1 Steps using the hexagonal cork sheet

The following steps on using hexagonal cork sheet is as below.

Table 3.3 Hexagonal Cork sheet steps



3.7 Software / Tools

As this project will be conducting experiments on wind speed, relative humidity, water level, air and water temperature. Software will be used as to manage the data execution.

3.7.1 Microsoft Excel

Microsoft Excel is a software that uses spreadsheets to organize numbers and data with functions and formulas. For this project, test run and dimensional analysis will be conducted and also results and data to create graph easily.

3.7.2 Arduino Integrated Development Environment (IDE)

The Arduino integrated development environment (IDE) is a software that contains a text editor for writing code , text console, a toolbar with buttons for common functions and a series of menus. It will be used for obtaining the result from the anemometer and hygrothermograph . The result will be obtained as the apparatus setup. All of the data will be verified and uploaded in the serial monitor. For the software, coding is needed for each one of the test that will be conducted.

The figure below shows the coding that is needed to measure wind speed using anemometer and relative humidity and air temperature using hygrothermograph.

DHT22_SENSOR

```
#include <DHT.h>
#include <DHT_U.h>

#include <DHT.h>
#include <DHT_U.h>

#include "DHT.h"          //DHT Library
#define DHTPIN 3          //Data Pin Connected to Arduino Uno Board
#define DHTTYPE DHT22     // DHT 22  (AM2302)

DHT dht(DHTPIN, DHTTYPE);
float h; //stores humidity value
float t; //stores humidity value

void setup()
{
  Serial.begin(9600);
  Serial.println("DHT Test");
  Serial.println();
  Serial.println("Enter number for checking option:");
  Serial.println();
  Serial.println("1. Humidity");
  Serial.println("2. Temperature");
  dht.begin(); //begin the sensor
}

void loop()
{
  char user_input; //allow user to key-in input
  if (isnan(t) || isnan(h)) //if they are not a number (nan)
```

Figure 3.9 (Coding for hygrothermograph (DHT22 Humidity Sensor and air temperature) speed_test

```
/*****************************************************************
 * Project: Wind Sensor Test Code in m/s (meter per second)
 * Name    : MYBOTIC www.mybotic.com.my
 * Date    : 8 April 2021
*****************************************************************/

#define READ_TIME 1000 //ms
#define WIND_SENSOR_PIN 2 //wind sensor pin
#define WIND_SPEED_20_PULSE_SECOND 1.75  //in m/s this value depend on the sensor type
#define ONE_ROTATION_SENSOR 20.0

volatile unsigned long Rotations; //Cup rotation counter used in interrupt routine

float WindSpeed; //Speed meter per second

unsigned long gulStart_Read_Timer = 0;

void setup(){
  Serial.begin(9600);
  pinMode(WIND_SENSOR_PIN,INPUT_PULLUP);
  attachInterrupt(digitalPinToInterrupt(WIND_SENSOR_PIN),isr_rotation, CHANGE); //Set up the interrupt

  Serial.println("Rotations\tm/s");
  sei(); //Enables interrupts
  gulStart_Read_Timer - millis();
}
```

Figure 3.10 Coding for anemometer

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In the study regarding hexagonal cork. All of the data and information was obtained were put into analysation to conclude the results. The results will consists of wind speed , water temperature, water surface area, water level drop ,air temperature and relative humidity and it is to consult the rate of evaporation for the tank using the controlled model and model.

4.2 Wind speed

As wind moving over water or surface can carry away water vapor. Wind test was performed as wind is one of the factor of evaporation, as we will be using with the model and one without the model. We will be using the wind speed anemometer in the wind speed test to identify the wind speed. The data that was collected and analyse the relationship between wind speed and water level drop .

Based on figure 4.1, the graph indicates the water level drop against wind speed, it is to determine the effect of evaporation which is wind speed . The water level drop for the control model is 20 mm in the range of 0.15 m/s – 0.2 m/s of wind speed. For the proposed model, the highest water level drop that can be identified is 10 mm in the range of 0.01 m/s – 0.16 m/s. The test was a success as it can be proved that wind speed is an affect of evaporation.. As the proposed model is proven to reduce evaporation in the experiment although the wind speed is similar for both model as it is measured at the same site.

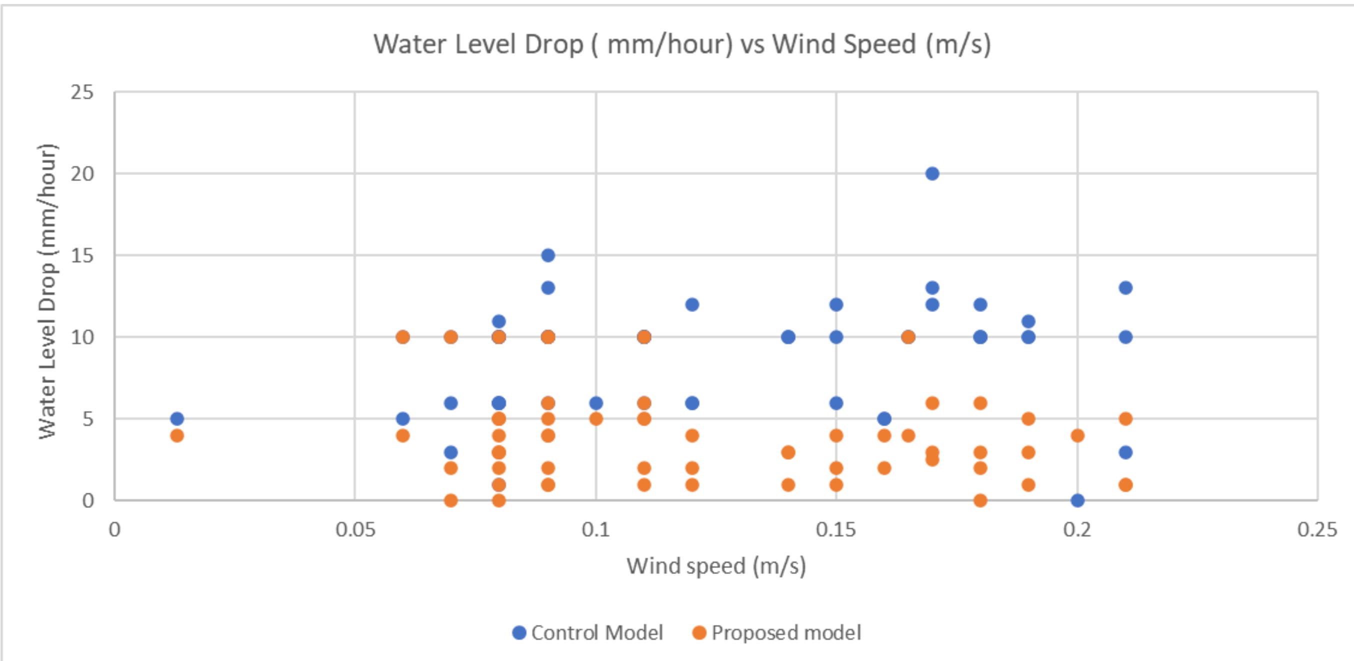


Figure 4.1 Water level drop against wind speed

4.3 Water Temperature

Evaporation occurs in room-temperature and even cold water because a percentage of the water molecules have enough energy to break away from other water molecules at those temperatures (evaporate). Even though most of the other molecules are travelling more slowly, a faster-moving molecule at the surface can break away from other molecules. Water evaporates on chilly days, although at a slower rate than it would on a hot day.

As this project needs to measure water temperature using thermometer, the data below shows that water temperature for both controlled model and proposed model.

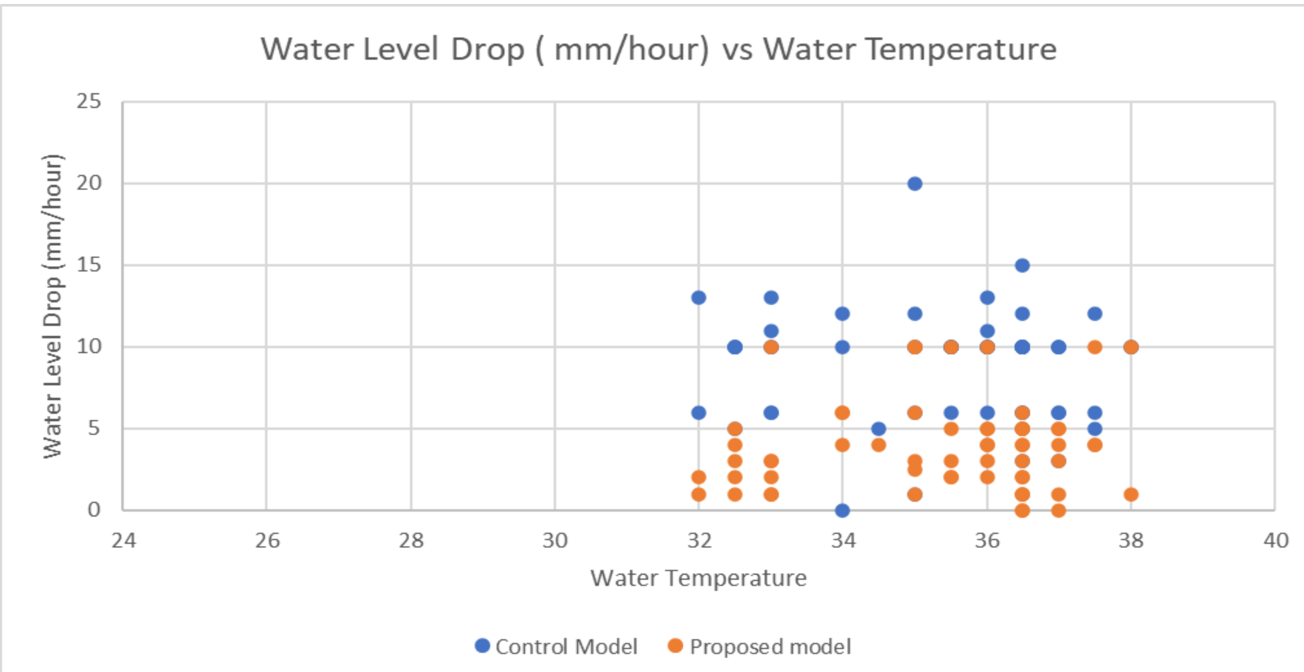


Figure 4.2 Water level drop against water temperature

Referring to figure 4.2 , the graph shows the water level drop against water temperature for controlled model and proposed model . it shows the comparison between water level drop of control model and proposed model. The rate of evaporation depends on the water level drop. As for the control model , the highest water level drop is 20 mm at 35 degree Celsius and the highest water level drop for proposed model is 10mm at 33, 35,36,and 38 degree Celsius respectively.

4.4 Relative Humidity

As this will be showing results of relative humidity on site. evaporation is also influenced by humidity, or the amount of water vapour in the air. The lower the relative humidity, the dryer the air is and the faster it evaporates. The higher the humidity, the closer the air is to saturation, and the less evaporation is possible

The water vapor content of air is measured by relative humidity (RH). It's the amount of water vapor in the air represented as a percentage (percent RH) of the amount required to reach saturation at the same temperature**.**

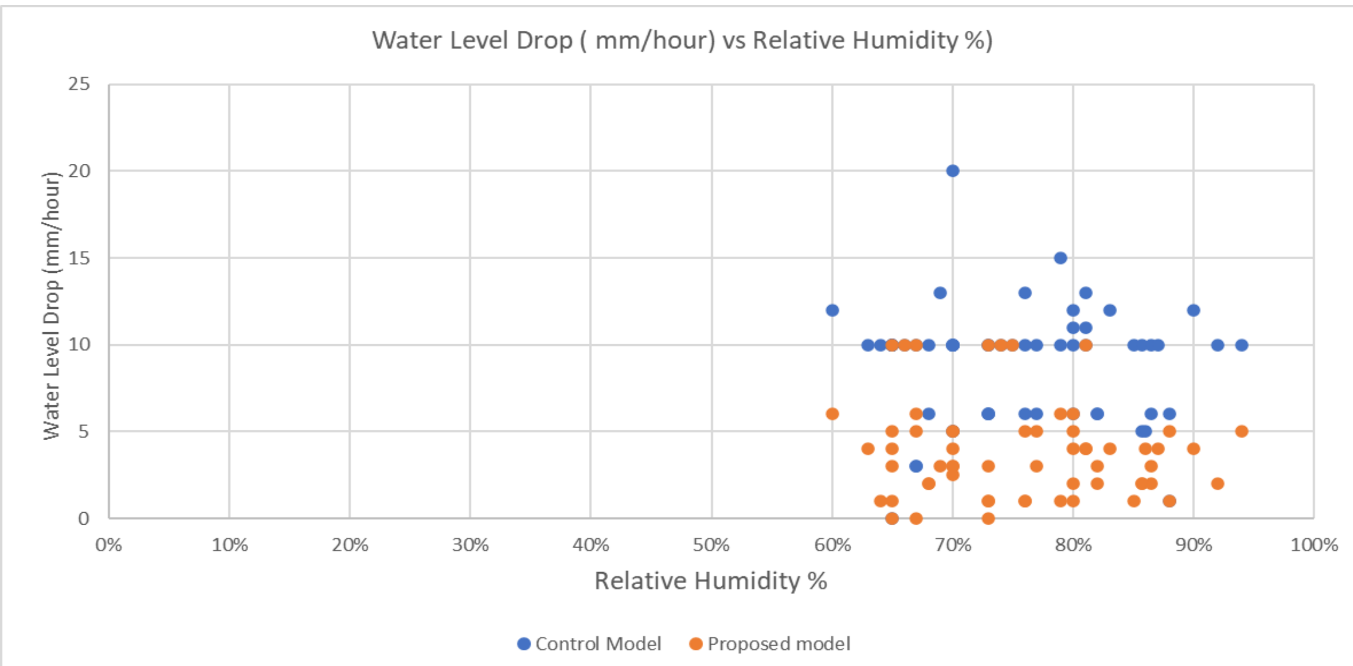


Figure 4.3 Water level drop against relative humidity

From the figure 4.3, it can identify the rate of evaporation occur on both models but with different water level drop. Relative humidity for both models are similar due to same site location. The rate of evaporation happens to control model the most as it shows that on 70% relative humidity, the water level drop is 20 mm and the highest water level drop for proposed model is 10 mm at the range from 65% - 81% relative humidity.

4.5 Air Temperature

As air temperature also effects the rate of evaporation, Air temperature was conducted using hygrothermograph, the results came out in data using Arduino software. The data below are the results from test.

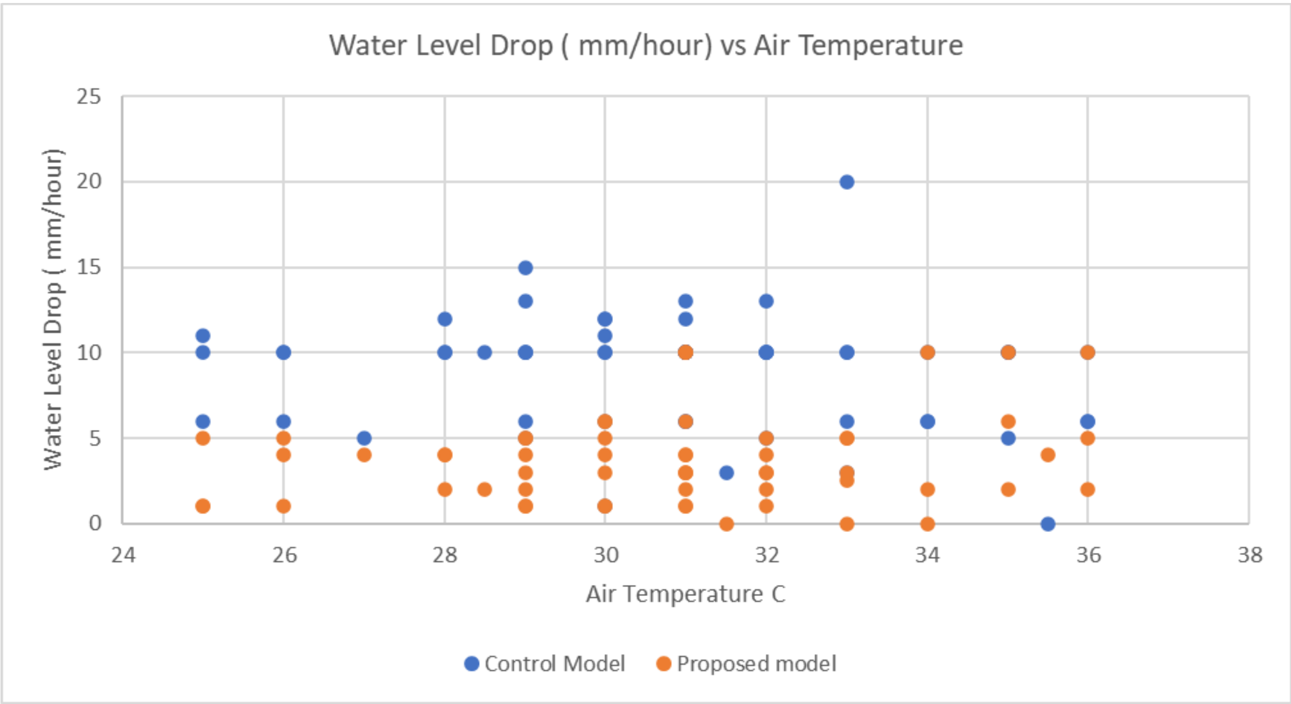


Figure 4.3 Water level drop against air temperature (C)

For figure 4.3, the graph shows the water level drop against water temperature, as the water temperature is constant for both models. The comparison is that the water level drop for control model is the highest which is 20 mm at 35 degree Celsius and for the water drop level for proposed model is 10 mm in the range of 33 – 38 degree Celsius. It is to conclude that the proposed model which is the hexagonal cork sheet give less evaporation than controlled model

4.6 Water Level Drop

As evaporation can be identified with water level drop, as the measurement was taken using a ruler and the initial water level for the control model and proposed model will be 200 mm. The graph below shows the result

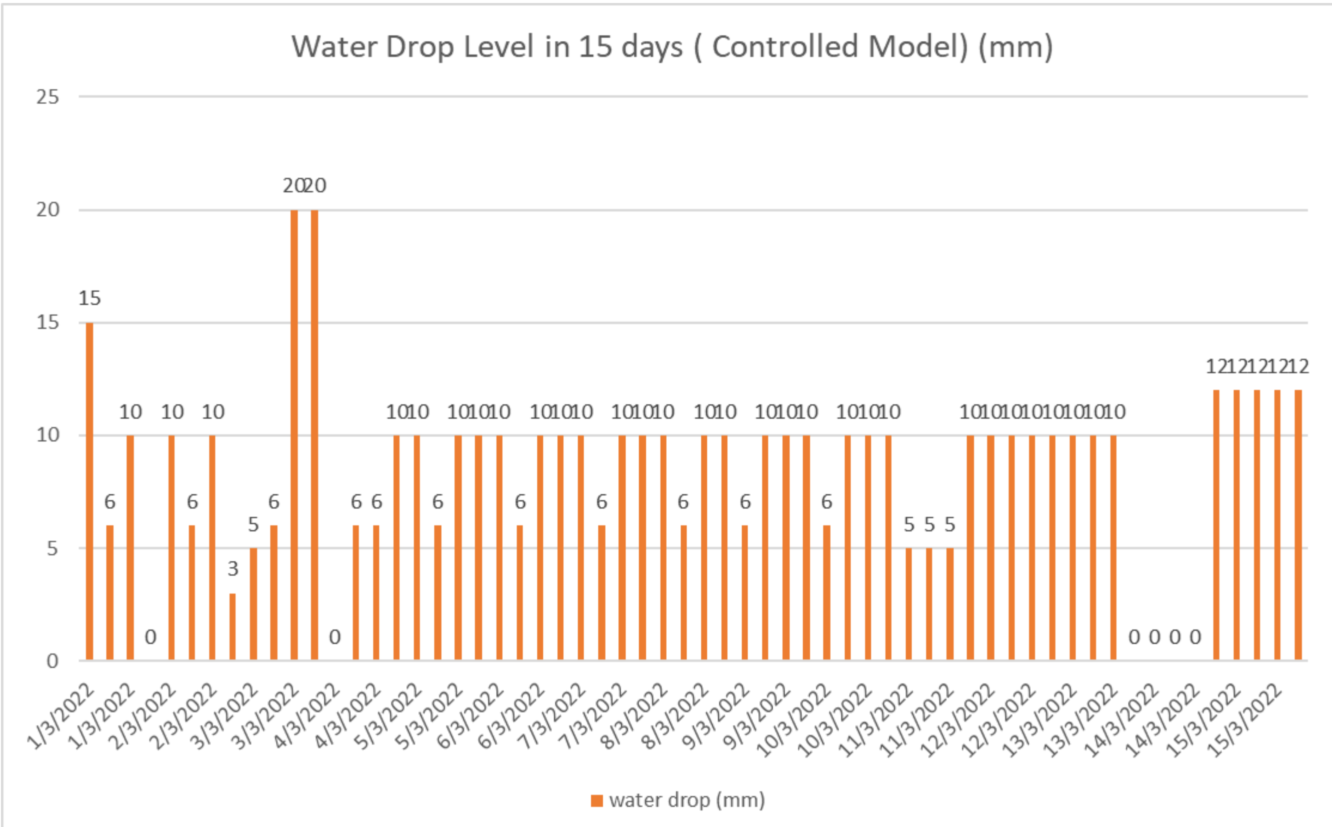


Figure 4.4 Water level drops according to dates(controlled model)

The figure above shows the water level drop in 15 days for controlled model (Class A evaporation pan) , the test was carried out at site using a ruler and according to the time which is (4 hours a day) . The highest water drop level according to the figure is on the date (3/2/32022) which is . It shows that evaporation occur as 200 mm of initial water level – Final Water level) according to time identify the evaporation occur for controlled model.

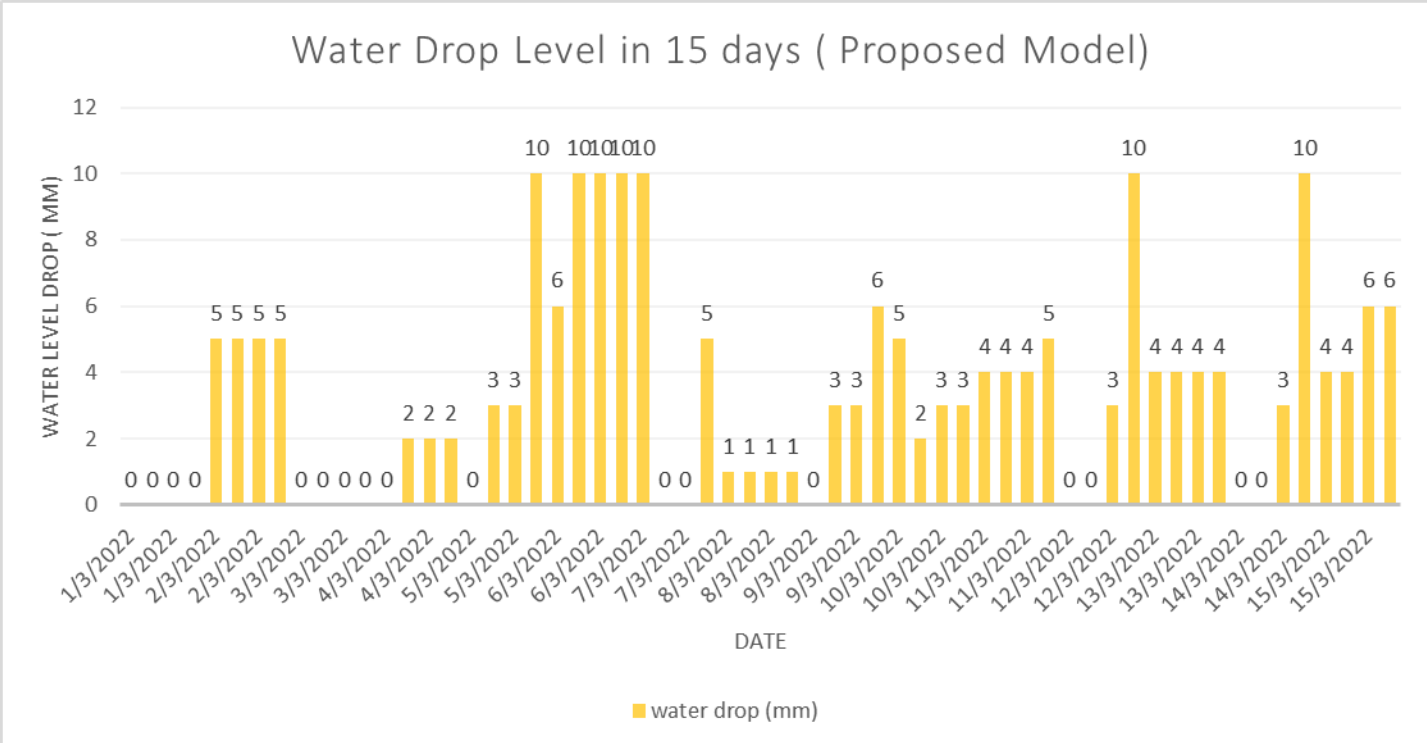


Figure 4.5 Water level drops according to dates(proposed model)

The figure above shows the water level drop in 15 days for proposed model (Floating Hexagonal Cork) , the test was carried out at site using a ruler and according to the time which is (4 hours a day according to the table) . The highest water drop level which is 10 mm occur on many dates . It shows that evaporation occur 10 mm the highest. This value is compared to controlled model as this project is to identify the rate of evaporation by using sustainable technology which is floating hexagonal cork.

As it does conclude that using floating hexagonal cork can reduce the rate of evaporation as it was tested successfully .It shows that by using floating hexagonal cork can reduce the rate of evaporation as compared to controlled model. It proves that the factor of evaporation which are water surface area that will be exposed to sunlight

The data for the experiment on water drop shows that the test was conducted from (9 – 11am) and (2-4pm) and the data that shows missing are the time that rains heavily at site that the test would be rejected if it was conducted during unfavourable weather

4.7 The efficiency of evaporation rate

The efficiency of evaporation rate from both models will be calculated to obtain the percentage by using this calculation. The average of water level drop for control model and proposed model will be included in the calculation to obtain the efficiency of evaporation rate.

Efficiency of evaporation rate (%)

$$= \frac{\text{Average water level drop (Control model)} - \text{Average water level drop (proposed model)}}{\text{Average water level drop (control model)}} X\ 100$$

$$= \frac{8.12 - 3.35}{8.12} X\ 100$$

$$= 58.72\ \%$$

The efficiency of evaporation rate is 58.72 %.

CHAPTER 5

CONCLUSION

5.1 Conclusion

In this study , developing a sustainable and economical physical evaporation reduction device as it is small scaled. The idea of using hexagonal cork sheet has embrace some potential as the experiments were done successfully. As wind speed, relative humidity, water and air temperature, and water level drop was measured during the test . The data that was collected was for the controlled model and proposed model which has proved that evaporation can be reduce if using floating hexagonal cork would work. The water level drop proves the evaporation occur on site using the models as the water level drop for the controlled model which is Class A evaporation pan up to 20mm loss of water and controlled model which is the Floating Hexagonal Cork evaporates up to 10mm . It is proven that the technology can reduce evaporation as it is to applied to Pidekso Dam in Indonesia. The Floating Hexagonal Cork has an area of 584.6 cm square as the test was tested out using 9 pieces of floating hexagonal cork which makes the coverage of surface area of water is 45.98 % of the pan compared to the controlled model which is 0% of coverage of surface area of water .The efficiency of evaporation rate was calculated which is 58.76 %. The efficiency of evaporation rate that was calculated justify that the technology can be used a small scale physical method to reduce evaporation .The sustainability of the material which is cork, it is proven in studies that cork is one of the sustainable material that could be used for industrial or experiments . From this finding it is conclude that hexagonal cork sheet reduce evaporation.

5.2 Recommendations

A small scaled physical technology to reduce evaporation could aid in reducing evaporation in small water bodies as it could be implemented to large water bodies like reservoir. Further research should be done on more sustainable material that is compatible and can reduce evaporation . Chemical method could also be done in the future studies . The data that was collected by each of apparatus are link to Arduino software which will compile in coding in a computer and the data would be more accurate with high precision apparatus.

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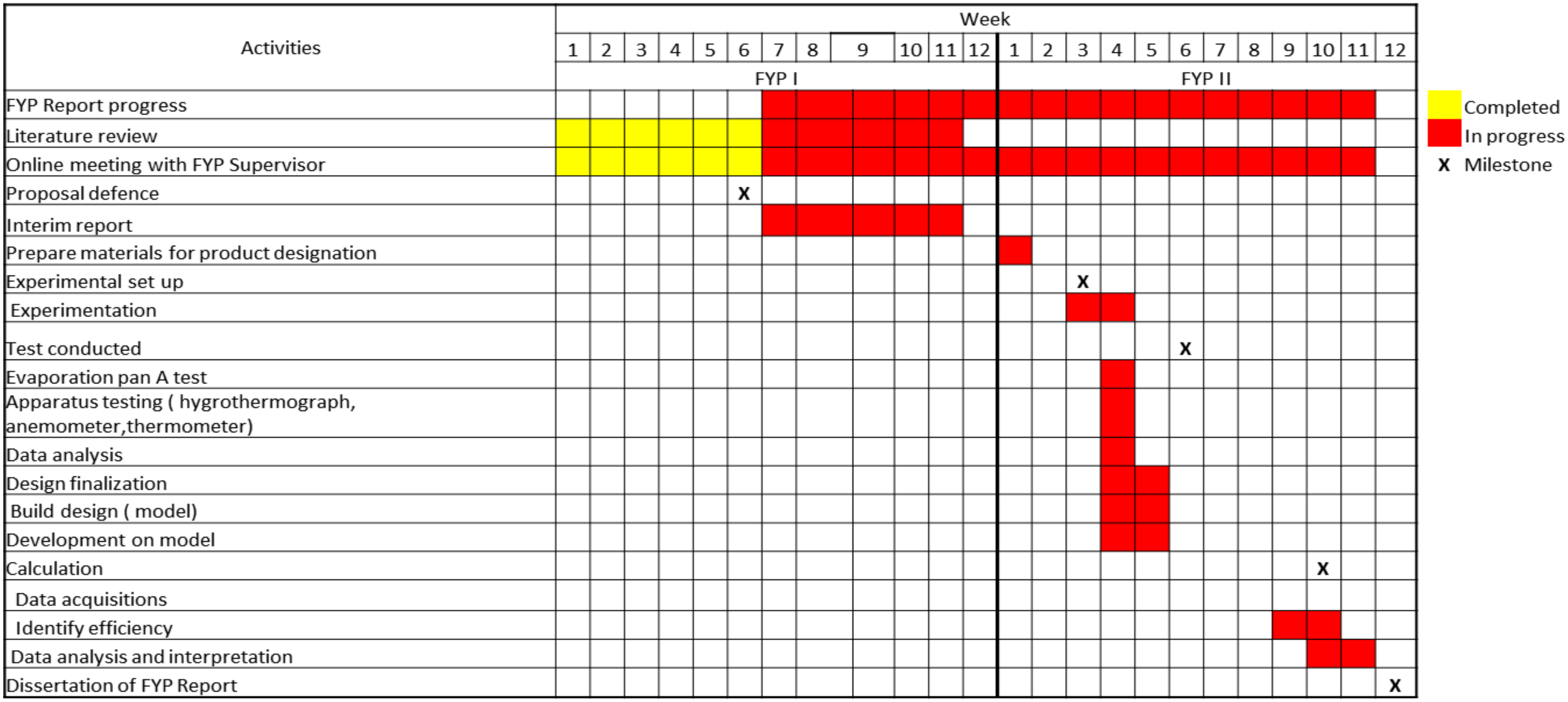
APPENDICES

Appendix A: Gantt Chart



Appendix B: Master table-controlled model

Date	Time	initial water level (mm)	final water level (mm)	water drop (mm)	Wind speed velocity (m/s)	water temperature c̊	Relative humidity (%)	Air Temperature c̊
	9:00 AM- 10:00 AM	200	185	15	0.09	36.5	79%	29
	10:00 AM - 11:00 AM	200	194	6	0.12	37	76%	31
	2:00 PM - 3:00 PM	200	190	10	0.15	38	65%	32
1/3/2022	3:00 PM - 4:00 PM	200	197	3	0.07	36.5	67%	31.5
	9:00 AM- 10:00 AM	200	190	10	0.09	36	80%	29
	10:00 AM - 11:00 AM	200	194	6	0.08	37	77%	36
	2:00 PM - 3:00 PM	200	190	10	0.19	36.5	65%	32
2/3/2022	3:00 PM - 4:00 PM	200	197	3	0.21	37	67%	33
	9:00 AM- 10:00 AM	200	195	5	0.16	36.5	86%	35
	10:00 AM - 11:00 AM	200	194	6	0.08	36	87%	34
	2:00 PM - 3:00 PM	200	180	20	0.17	35	70%	33
3/3/2022	3:00 PM - 4:00 PM			0	0.2	34	65%	35.5
	9:00 AM- 10:00 AM	200	199	1	0.08	35	88%	30
	10:00 AM - 11:00 AM	200	194	6	0.12	33	82%	36
	2:00 PM - 3:00 PM	200	194	6	0.15	32	68%	31
4/3/2022	3:00 PM - 4:00 PM	200	190	10	0.18	35.5	68%	32
	9:00 AM- 10:00 AM	200	190	10	0.11	36.5	92%	28.5
	10:00 AM - 11:00 AM	200	194	6	0.08	35	82%	30
	2:00 PM - 3:00 PM	200	190	10	0.14	37	70%	32
5/3/2022	3:00 PM - 4:00 PM	200	190	10	0.165	35.5	74%	
	9:00 AM- 10:00 AM	200	190	10	0.09	36.5	79%	35
	10:00 AM - 11:00 AM	200	194	6	0.09	37.5	73%	34
	2:00 PM - 3:00 PM	200	190	10	0.11	38	65%	36
6/3/2022	3:00 PM - 4:00 PM	200	190	10	0.07	36	75%	31
	9:00 AM- 10:00 AM	200	190	10	0.06	35	66%	35
	10:00 AM - 11:00 AM	200	194	6	0.08	36.5	73%	33
	2:00 PM - 3:00 PM	200	190	10	0.18	37	65%	34
7/3/2022	3:00 PM - 4:00 PM	200	190	10	0.11	36	70%	30
	9:00 AM- 10:00 AM	200	190	10	0.09	36.5	85%	25
	10:00 AM - 11:00 AM	200	194	6	0.11	33	73%	26
	2:00 PM - 3:00 PM	200	190	10	0.14	32.5	64%	31
8/3/2022	3:00 PM - 4:00 PM	200	190	10	0.21	36.5	73%	30
	9:00 AM- 10:00 AM	200	194	6	0.07	35.5	80%	29
	10:00 AM - 11:00 AM	200	190	10	0.08	33	77%	31
	2:00 PM - 3:00 PM	200	190	10	0.18	32.5	65%	33
9/3/2022	3:00 PM - 4:00 PM	200	190	10	0.11	34	67%	31
	9:00 AM- 10:00 AM	200	194	6	0.1	36.5	88%	25
	10:00 AM - 11:00 AM	200	190	10	0.09	32.5	86%	28
	2:00 PM - 3:00 PM	200	190	10	0.08	36.5	87%	31
10/3/2022	3:00 PM - 4:00 PM	200	190	10	0.19	35.5	70%	29
	9:00 AM- 10:00 AM	200	195	5	0.06	37.5	86%	27
	10:00 AM - 11:00 AM	200	195	5	0.013	34.5	70%	29
	2:00 PM - 3:00 PM	200	195	5	0.16	32.5	70%	32
11/3/2022	3:00 PM - 4:00 PM	200	190	10	0.08	32.5	94%	33
	9:00 AM- 10:00 AM	200	190	10	0.11	36.5	76%	26
	10:00 AM - 11:00 AM	200	190	10	0.08	35.5	70%	29
	2:00 PM - 3:00 PM	200	190	10	0.14	33	73%	31
12/3/2022	3:00 PM - 4:00 PM	200	190	10	0.08	35	70%	31
	9:00 AM- 10:00 AM	200	190	10	0.165	36	87%	26
	10:00 AM - 11:00 AM	200	190	10	0.09	37	81%	28
	2:00 PM - 3:00 PM	200	190	10	0.09	36.5	63%	31
13/3/2022	3:00 PM - 4:00 PM	200	189	11	0.08	36	81%	30
	9:00 AM- 10:00 AM	200	189	11	0.19	33	80%	25
	10:00 AM - 11:00 AM	200	187	13	0.21	32	76%	29
	2:00 PM - 3:00 PM	200	187	13	0.17	36	69%	32
14/3/2022	3:00 PM - 4:00 PM	200	187	13	0.09	33	81%	31
	9:00 AM- 10:00 AM	200	188	12	0.12	36.5	90%	28
	10:00 AM - 11:00 AM	200	188	12	0.15	37.5	83%	31
	2:00 PM - 3:00 PM	200	188	12	0.18	34	60%	30
15/3/2022	3:00 PM - 4:00 PM	200	188	12	0.17	35	80%	30

Appendix C: Master table proposed model

Date	Time	initial water level (mm)	final water level (mm)	water drop (mm)	Wind speed velocity (m/s)	Water temperature č	Relative humidity (%)	Air Temperature č
	9:00 AM- 10:00 AM	200	199	1	0.09	36.5	79%	29
	10:00 AM - 11:00 AM	200	199	1	0.12	37	76%	31
	2:00 PM - 3:00 PM	200	199	1	0.15	38	65%	32
1/3/2022	3:00 PM - 4:00 PM			0	0.07	36.5	67%	31.5
	9:00 AM- 10:00 AM	200	195	5	0.09	36	80%	29
	10:00 AM - 11:00 AM	200	195	5	0.08	37	77%	36
	2:00 PM - 3:00 PM	200	195	5	0.19	36.5	65%	32
2/3/2022	3:00 PM - 4:00 PM	200	195	5	0.21	37	67%	33
	9:00 AM- 10:00 AM	200	198	2	0.16	36.5	86%	35
	10:00 AM - 11:00 AM	200	198	2	0.08	36	87%	34
	2:00 PM - 3:00 PM	200	197.5	2.5	0.17	35	70%	33
3/3/2022	3:00 PM - 4:00 PM	200	196	4	0.2	34	65%	35.5
	9:00 AM- 10:00 AM	200	199	1	0.08	35	88%	30
	10:00 AM - 11:00 AM	200	198	2	0.12	33	82%	36
	2:00 PM - 3:00 PM	200	198	2	0.15	32	68%	31
4/3/2022	3:00 PM - 4:00 PM	200	198	2	0.18	35.5	68%	32
	9:00 AM- 10:00 AM	200	198	2	0.11	36.5	92%	28.5
	10:00 AM - 11:00 AM	200	197	3	0.08	35	82%	30
	2:00 PM - 3:00 PM	200	197	3	0.14	37	70%	32
5/3/2022	3:00 PM - 4:00 PM	200	190	10	0.165	35.5	74%	
	9:00 AM- 10:00 AM	200	194	6	0.09	36.5	79%	35
	10:00 AM - 11:00 AM	200	190	10	0.09	37.5	73%	34
	2:00 PM - 3:00 PM	200	190	10	0.11	38	65%	36
6/3/2022	3:00 PM - 4:00 PM	200	190	10	0.07	36	75%	31
	9:00 AM- 10:00 AM	200	190	10	0.06	35	66%	35
	10:00 AM - 11:00 AM	200	200	0	0.08	36.5	73%	33
	2:00 PM - 3:00 PM	200	200	0	0.18	37	65%	34
7/3/2022	3:00 PM - 4:00 PM	200	195	5	0.11	36	70%	30
	9:00 AM- 10:00 AM	200	199	1	0.09	36.5	85%	25
	10:00 AM - 11:00 AM	200	199	1	0.11	33	73%	26
	2:00 PM - 3:00 PM	200	199	1	0.14	32.5	64%	31
8/3/2022	3:00 PM - 4:00 PM	200	199	1	0.21	36.5	73%	30
	9:00 AM- 10:00 AM	200	198	2	0.07	35.5	80%	29
	10:00 AM - 11:00 AM	200	197	3	0.08	33	77%	31
	2:00 PM - 3:00 PM	200	197	3	0.18	32.5	65%	33
9/3/2022	3:00 PM - 4:00 PM	200	194	6	0.11	34	67%	31
	9:00 AM- 10:00 AM	200	195	5	0.1	36.5	88%	25
	10:00 AM - 11:00 AM	200	198	2	0.09	32.5	86%	28
	2:00 PM - 3:00 PM	200	197	3	0.08	36.5	87%	31
10/3/2022	3:00 PM - 4:00 PM	200	197	3	0.19	35.5	70%	29
	9:00 AM- 10:00 AM	200	196	4	0.06	37.5	86%	27
	10:00 AM - 11:00 AM	200	196	4	0.013	34.5	70%	29
	2:00 PM - 3:00 PM	200	196	4	0.16	32.5	80%	32
11/3/2022	3:00 PM - 4:00 PM	200	195	5	0.08	32.5	94%	33
	9:00 AM- 10:00 AM	200	195	5	0.11	36.5	76%	26
	10:00 AM - 11:00 AM	200	195	5	0.08	35.5	70%	29
	2:00 PM - 3:00 PM	200	197	3	0.14	33	73%	31
12/3/2022	3:00 PM - 4:00 PM	200	190	10	0.08	35	67%	31
	9:00 AM- 10:00 AM	200	196	4	0.165	36	87%	26
	10:00 AM - 11:00 AM	200	196	4	0.09	37	81%	28
	2:00 PM - 3:00 PM	200	196	4	0.09	36.5	63%	31
13/3/2022	3:00 PM - 4:00 PM	200	196	4	0.08	36	81%	30
	9:00 AM- 10:00 AM	200	199	1	0.19	33	80%	25
	10:00 AM - 11:00 AM	200	199	1	0.21	32	76%	29
	2:00 PM - 3:00 PM	200	197	3	0.17	36	69%	32
14/3/2022	3:00 PM - 4:00 PM	200	190	10	0.09	33	81%	31
	9:00 AM- 10:00 AM	200	196	4	0.12	36.5	90%	28
	10:00 AM - 11:00 AM	200	196	4	0.15	37.5	83%	31
	2:00 PM - 3:00 PM	200	194	6	0.18	34	60%	30
15/3/2022	3:00 PM - 4:00 PM	200	194	6	0.17	35	80%	30