DESIGN AND DEVELOPMENT OF SOLAR POWERED AERATION SYSTEM

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This thesis is submitted is partial fulfilment of the requirements for the award of the Bachelor of Electrical Engineering (Hons.) (Power System)

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ABSTRACT

With the drastic increment in the demand of aquaculture products i.e. fishes and crustaceans, the need to ensure good quality of products has been a major concern. Although literatures proven that there are three main factors affecting the quality, yet the mitigation aspect has yet to be explored. The current aeration system powered by grid electricity has also appeared to be costly based on ground survey. Therefore, in this project, a prototype of solar powered aeration system has been developed and 13 experiments on water quality have been carried out using the monitoring system prototype. From the experiments, it is found that temperature increment in the afternoon causes decrement in dissolved oxygen level while at night and during raining, oxygen content increases due to temperature drop and water movement caused by raindrops. Despite of these, the water condition is still not ideal for aquaculture farming due to high oxygen intake for fishes' respiration. Therefore, when underwater aeration system is installed, it is found that the content of dissolved oxygen is sufficient to maintain ideal water condition as it compensate to the losses of dissolved oxygen caused by the factors studied. The solar stand-alone system is also able to provide sufficient electricity for the aeration system. Thus, with the help of monitoring system and solar powered aeration system, the quality of aquaculture product is able to be improved. This project increases the understanding of important factors in aquaculture farming to produce higher quality products in faster duration and the renewable energy potential in the country as source of electricity in aquaculture industry.

ABSTRAK

Dengan kenaikan mendadak permintaan produk akuakultur iaitu ikan dan krustasia, keperluan untuk memastikan kualiti produk yang lebih baik telah menjadi kebimbangan utama. Walaupun kesusasteraan membuktikan bahawa terdapat tiga faktor utama yang mempengaruhi kualiti produk, namun aspek mitigasi masih belum diterokai. Sistem pengudaraan semasa dikuasakan oleh elektrik grid juga telah muncul menjadi mahal berdasarkan kaji selidik yang dijalankan. Oleh itu, dalam projek ini, prototaip sistem pengudaraan solar telah dibangunkan dan 13 uji kaji ke atas kualiti air telah dijalankan dengan menggunakan prototaip sistem pemantauan. Dari eksperimen, didapati bahawa kenaikan suhu pada sebelah petang menyebabkan susutan dalam tahap oksigen terlarut manakala pada waktu malam dan semasa hujan, meningkatkan kandungan oksigen kerana penurunan suhu dan pergerakan air yang disebabkan oleh titisan hujan. Walaubagaimanapun, keadaan air masih tidak sesuai untuk pertanian akuakultur disebabkan pengambilan oksigen yang tinggi untuk pernafasan ikan. Oleh itu, apabila sistem pengudaraan air dipasang, didapati bahawa kandungan oksigen terlarut adalah mencukupi untuk mengekalkan keadaan air ideal kerana ia menebus kembali untuk penggunaan oksigen terlarut yang disebabkan oleh faktor-faktor yang dikaji. Sistem solar “stand-alone” juga terbukti dapat menyediakan bekalan elektrik yang mencukupi untuk sistem pengudaraan. Oleh itu, dengan bantuan sistem pemantauan dan sistem pengudaraan berkuasa solar, kualiti produk akuakultur mampu dipertingkatkan. Projek ini meningkatkan pemahaman faktor-faktor penting dalam akuakultur pertanian untuk menghasilkan produk berkualiti tinggi dalam tempoh lebih cepat dan potensi tenaga boleh diperbaharui di negara ini sebagai sumber elektrik dalam industri akuakultur.

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CHAPTER 1

INTRODUCTION

1.0 OVERVIEW

This chapter is about the introduction to the project background of design and development of solar powered aeration system. Problem statements are identified based on the project background and the objectives are discussed. The scope and the limitations is described in term of k-chart. The chapter outline is also illustrated.

1.1 INTRODUCTION

Aquaculture farming has started in Malaysia in year 1950 majoring in the production of fish and crustaceans. Since then, there has been a tremendous increment in aquaculture demand from year to year as recorded in FAO Fishery Statistic, reported by the Fisheries and Aquaculture Department, Food and Agriculture Organization of the United Nation as shown in Figure 1.1 [1]

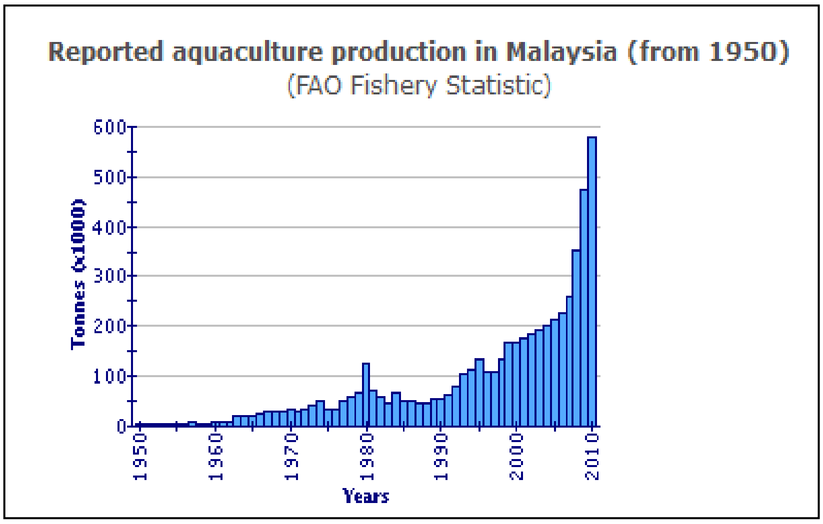


Figure 1.1: FAO Fishery Statistic. [1]

In aquaculture farming, aeration system is used to ensure the water and air circulation of the ponds. There are many types of aeration system such as vertical pump, pump sprayer, propeller-aspirator pumps, paddle wheels, and diffused air that have different level of efficiency[2] that is measured in term of Standard Oxygen Transfer Rate (SOTR) which is the amount of oxygen added oxygen added in 1 hour under standard condition [3]. Table below shows the types of aerator with their average efficiency.

Aerator Type	Average SAE (lbs O_2/hp-hr)	SAE Range (lbs O_2/hp-hr)
Vertical pump	2.3	1.1 – 3.0
Pump sprayer	2.1	1.5 – 3.1
Propeller-aspirator pumps	2.6	2.1 – 3.0
Paddle wheels	3.6	1.8 – 4.9
Diffused air	1.5	1.1 – 2.0

Figure 1.2: Measured Aerator Efficiency.[3]

Despite of the types of aerator available, the production of high quality aquaculture products still at a low level and this has been a concern for most of the aquaculture farmers. This is because the current aeration system technology is inadequate due to no monitoring feature is equipped to ensure ideal condition for aquaculture growth. The monitoring system is very important to maintain the ideal factors that affect the growth of aquaculture products.

The three main factors are pH level, temperature of water and concentration level of dissolved oxygen. Therefore, a good aeration system that can monitor these conditions will be able to produce high quality products which bring higher Return of Investment (ROI) [4].

This thesis is based on the basic of theoretical study of the aquaculture water quality and hardware design and development of aeration system to investigate the monitoring system designed and the ability of the system to sustain ideal pond condition for the aquaculture farming. The results from the developed hardware are collected and analysed to ensure system ability to monitor and control ideal temperature level, pH level and concentration level of dissolved oxygen.

1.2 PROBLEM STATEMENT

Based on the conducted ground survey in a tiger prawn aquaculture farm known as Agrobest Sdn Bhd situated in Tanjung Batu, Pekan, the three factors mentioned are confirmed to be the key factors in producing high quality aquaculture products. As in current practice of the farm, manual processes such as taking water temperature samples and measuring dissolved oxygen level are still being applied in aquaculture farming. These reduce the work efficiency and accuracy that affect the end result. With the monitoring process on the aeration system, all the data can be monitored to ensure and maintain the ideal state of the pond. Therefore, this project has incorporate the use of intelligent controller, Arduino YUN and UNO and three sensors which are the temperature sensor, pH sensor, and dissolve oxygen sensor to be designed as the monitoring unit for the aeration system equipped with solar powered oxygenator pump as underwater aeration system for control purposes.

1.3 OBJECTIVE

The three (3) main objectives of the project are:

i. To investigate the fundamental issues related to aquaculture farming.

ii. To design and incorporate several sensors to ensure high concentration of dissolved oxygen level in aquaculture farming.

iii. To develop a complete prototype of aeration system powered by solar energy.

1.4 SCOPES OF THE PROJECT

Several scopes for the project which are:

i. To design a monitoring and control system using Arduino YUN, temperature sensor, pH sensor and dissolved oxygen sensor.

ii. To integrate solar stand-alone system as power source for the aeration system.

iii. To do analysis on the data collected from the sensors and execute automatic control mechanism i.e. the water mill to control ideal pond condition.

iv. To investigate the impacts of proposed system on the aquaculture farming.

The K-Chart of the project is shown in Figure 1.3. In this K-Chart, it explains about the research gap with the main research topic starting with aquaculture. It is then broken down into three types of aquaculture product that is differentiated by the type of water. For this project, it is about freshwater fish and crustaceans. In freshwater, there are four different aquaculture segmentation and this project is focusing on aquaculture farming. There are two types of aquaculture farming which artificial is the focus on this project. Outdoor aquaculture farming is chosen as it is the category where the problem is identified. For outdoor aquaculture farming, aeration and water quality are the aspects that being explored. Only the three factors proven by ground survey are selected to be investigating as these factors are proven to affect the growth rate and quality of aquaculture product.

Figure 1.3: K Chart

1.5 CHAPTER OUTLINE

This thesis consists of five chapters and all the chapter are summarised as shown as below:

Chapter 1: It consists of five (5) elements which includes introduction, problem statement, objectives, scope of work and thesis outline. For introduction, it explains about the general information of this thesis and topic. Problem statement is stated in this section. Objectives that are required to achieve at the end of this project are stated. Whereas for scope of work, it states all the tasks that are needed to be accomplished in order to complete this project. Overall topics' scope is explained in thesis outline.

Chapter 2: It consists of the outlines the background researches and external sources that related to this project that have been explained based on the few researches paper, journal, articles and the existing management of aqua-farming system.

Chapter 3: It describes the scope of work in details. The justification of the works' scope, verification of main task, explanation of tools and resources usage and the flow of the overall project are discussed in this section.

Chapter 4: It covers result and discussion for this project. It explains the results obtained through experiments conducted on the designed and developed prototype to carry out functionality check of the input sensors to achieve the desired results. Discussions for the results are given according to the results.

Chapter 5: It summarizes the overall project where the conclusion is made on the discovered, analysis and overall project. Few recommendations are proposed as future development. At the end of the chapter, total budget of this project is presented.

CHAPTER 2

LITERATURE REVIEW

2.0 OVERVIEW

In this chapter, the background research and literature reviews on various journals, articles, researches paper and others as well as the existing aquaculture aeration system will be explained.

2.1 AERATION SYSTEM IN AQUACULTURE INDUSTRY

One of the most important aspect that is taken into consideration before planning the outline of the project would be understanding the current aeration system available in market and the effect on the growth of fishes and crustaceans. As known, aeration system is a type of mechanism that recirculates the water in aquaculture pond by rotating water mill to create movement of water [5]. Conventional aeration system is powered by electrical supply from grid and is widely used in the aquaculture industry in Malaysia.

Figure 2.1: Aeration Systems Used in AgroBest Farm, Tanjung Batu.

There are various types of aeration system that are available in the market i.e. surface aeration and subsurface aeration that can easily be purchased through online platform or vendors.

However, it is found that the conventional aeration system is not equipped with the water quality monitoring system that can provide useful water quality data to the aquaculture farmers in order to help them increase their harvest quality. Quoting from Patrick O'Rourke [4], a good aeration system ensures high quality and good production of harvest which means better Return of Investment to the aquaculture farmers. Therefore, investigation carried out at AgroBest Farm located in Tanjung Batu; Pekan concluded that the missing piece is the current aeration system is not providing monitoring features that allows farmers to understand the water quality of their ponds especially for large scale aquaculture farms.

A short market research is carried out to support the fact of conventional aeration system is not equipped with monitoring systems and Table 2.1 is showing the comparison of selected sample of product that is commonly used by aquaculture farmers.

Table 2.1: Comparison of Conventional Aeration System.

Specification @ Products				
Brand	**Jinhu Jieda Machinery**	**Zhengzhou Known Imp**	**Sun Mines Electrics Co**	**L'Obel Solar**
Solar powered	**No**	**No**	**No**	Yes
Monitoring & Control	**No**	**No**	**No**	**No**
Horsepower	2hp	3hp	2hp	1hp
Wheel Structures	2 paddles	3 paddles	3 wheels	No
Price	RM 1320	RM2499	RM1526	RM2196

It is noted that in Table 2.1, most conventional aeration systems are not equipped with monitoring system and only one out of the four models is found to be using solar powered electricity. Therefore, this is a gap in term of technology of aeration system whereby improvement and implementations of innovation can be done to create a better aeration system addressing to the concern of aquaculture farmers.

2.2 FACTORS AFFECTING AQUACULTURE PRODUCT QUALITY.

Based on the ground survey conducted on 13th March 2016 in an aquaculture farm known as AgroBest Sdn. Bhd located in Tanjung Batu, Pekan, there are three main factors that affect the aquaculture products quality which are stated as below:

i. Temperature of water

ii. Concentration level of dissolved oxygen

iii. pH level of water

According to the farm officer, Mr Ramesh, the quality of their products are totally depending on maintaining and controlling the three factors to create an ideal condition for the fish and crustacean growth however lacking on water quality data is what preventing them to optimize the process of identifying contaminated ponds as the farms consist of 461 ponds in total.

2.2.1 Water Temperature and the Concentration Level of Dissolved Oxygen.

Based on Karen A.Saffran and Anne-Marie Anderson[6], it has been found that there is a close relationship between temperature of water and concentration level of dissolved oxygen where when the temperature increases, the level of concentration of dissolved oxygen will decrease [7].

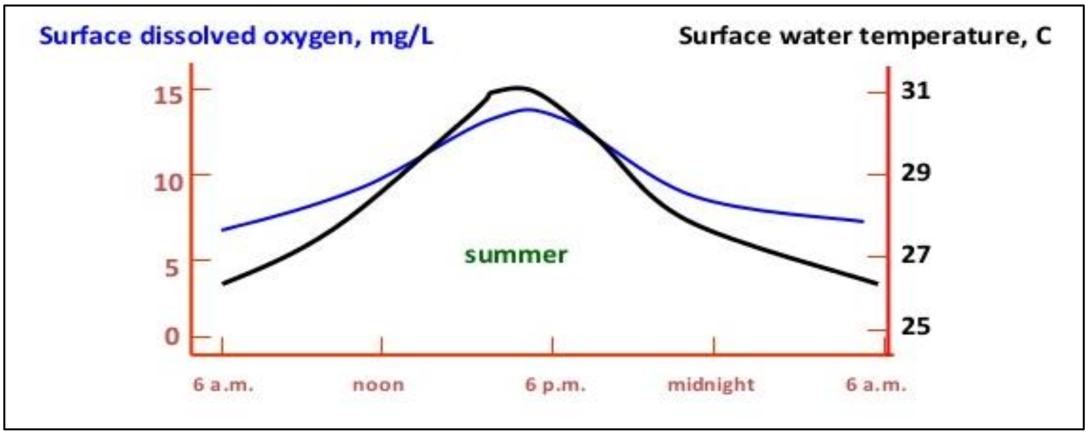


Figure 2.2: Relationship between Temperature of Water and Level of Concentration of Dissolved Oxygen in the Pond.

The relationship between water temperature and the level of dissolved oxygen in Figure 2.2 shows that the amount of dissolved oxygen measured in mg/L will vary based on the increment and decrement in water temperature. This factor is very important in aquaculture industry because every mg/L of dissolved oxygen differences will affect the growth of fishes and crustaceans [8].

The aquaculture pond will also experience different water temperature at different depth due to its exposure to sunlight and its average depth of 8 feet for a pond less than 2 acres [9]. This results in the formation of the phenomena known as stratification where water temperature varies at different depth of pond and affecting the level of concentration of dissolved oxygen level. For instance, at the surface of the pond, high water temperature in the afternoon reduces the amount of dissolved oxygen level. However as it goes deeper into the bottom of the pond, water temperature reduces and the dissolved oxygen level will increase[10].

In Figure 2.3, it shows the regions that are formed during stratification in a pond.

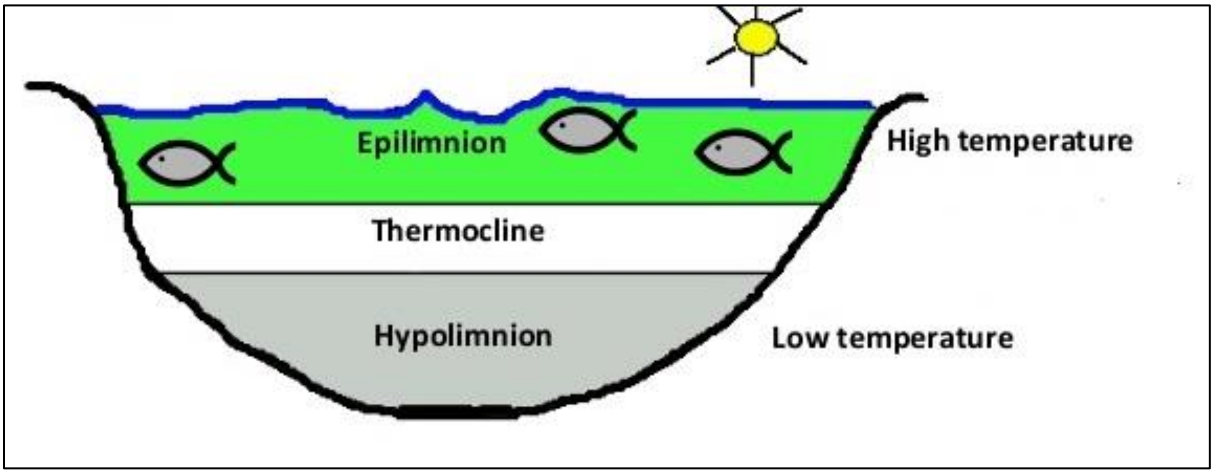


Figure 2.3: Stratification Regions in Aquaculture Pond.

Based on Figure 2.3, the basic regions formed by stratification are stated as below:

i. Epilimnion region

ii. Thermocline region

iii. Hypolimnion region

All these three regions happened in the same pond, the hypolimnion region which is the deepest region in the pond will have lower water temperature thus containing more dissolved oxygen[11]. This region is usually where the fishes and crustaceans tend to stay longer compared to the regions in epilimnion and thermoclines which contain less dissolved oxygen with higher water temperature[12].

However, according to Bertram Boehrer and Martin Schultze [13], the hypolimnion region needs to be exposed to good air circulation or else the level of dissolved oxygen supply will deplete and eventually causes anoxic condition. Anoxic condition is defined as those with dissolved oxygen less than 5 milligrams per litre (mg/L) which is equivalent to 5.005 parts per million (ppm)[14].

According to D.C Dowling and M.J Wiley [15], anoxic condition is not good for the growth of fishes and crustaceans and the effect on them based on dissolved oxygen concentration can be summarized as in Table 2.2:

Table 2.2: Effect on Aquaculture Products Based on Concentration of Dissolved Oxygen.

Level of concentration of dissolved oxygen	Effect on fishes and crustacean
0 to 2 ppm	●Small fish may survive for short exposure but lethal if prolonged. ●Lethal for larger fish.
2 to 5 ppm	●Most fish survive, but the growth is slower if prolonged due to stressful water condition.
More than 5 ppm	●Most desirable condition for all.

Therefore, it is very important to monitor the dissolved oxygen concentration of water to avoid the effects that will happen on fishes and crustaceans. A difference of 1 mg/L of dissolved oxygen can create different environment that causes stressful water condition for the fishes and crustaceans. [16]

Recommended by Yovita John Mallya [16], the recommended minimum dissolved oxygen requirements for are as follow:

i) Cold water fish – 6 mg/L

ii) Tropical freshwater and marine fish – 5mg/L

By maintaining the minimum requirement, the fishes and crustaceans' growth and quality will be improved[17].

2.2.2 pH Level of Water

According to the pH Requirement of Freshwater Aquatic Life, safety levels as no deleterious effects for the freshwater aquatic system is between the pH range of 6.5 to 8.5 by Robertson-Bryan Inc [18]. Water changes can be performed to normalize the pH as suggested by H. Roberts and B. S. Palmeiro [19]. The optimal growth performance and survival rate for Grass Carp is between ranges of 7 to 8 as stated by C. B. Tiwary, V. S. Pandey, F. Ali and S. Kumar [20]. Hence, pH level of water is an essential factor to be concerned and look upon for aquaculture farming[21].

Since the controlled experiment is carried out in university, a simple investigation has been done to investigate the water quality of different water samples in the radius of 50km around the university. Three water samples are collected from:

i. Universiti Malaysia Pahang Lake

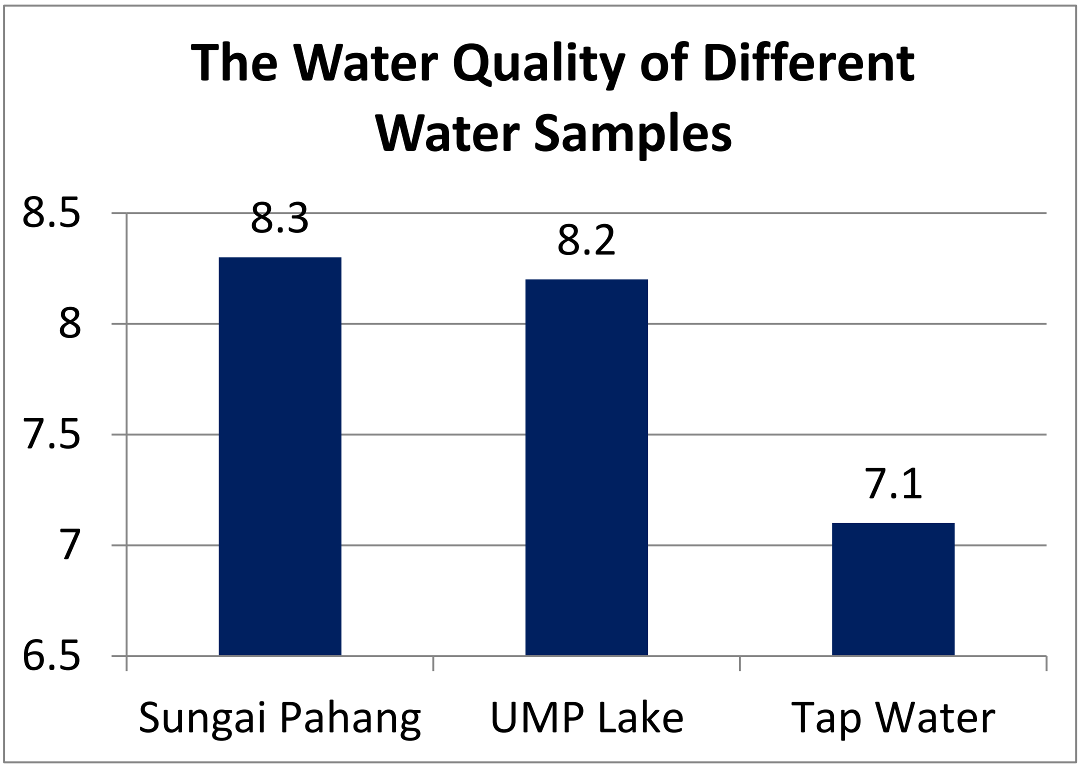
ii. Pahang River

iii. Tap water in campus

The equipment used in the investigation is the pH meter to measure the level of pH in the samples of water.

Figure 2.4: pH Meter

These three samples are analysed and the result is shown as below:



By average of the result, the three samples are found suitable for fishes and crustaceans, proving the ideal range of pH suitable for aquaculture products.

2.3 Solar Stand Alone System

The development of solar stand-alone system is very important to act as the main electricity supply for the aeration systems. According to Damien Toner and Mo Mathies [22], aquaculture industry is growing and the location of aquaculture operations in remote areas may lend it to renewable energy usage far easier than other small and medium sized enterprises. Although the cost benefits are still marginal, renewable energy being environmentally friendly[23] is an important factor in improving the image of aquaculture. A few recorded cases also have proven that solar energy is more energy cost saving[24] i.e. one of the cases in Canada, the solar water heating at salmon hatchery has helped the farm to save €11,500 per year with payback time of 6 years [22]

Based on the case study at Pacific Oyster Farm, a typical 75W panel can provide up to 70kWh per annum[22]. In Malaysia, solar energy has a very high potential and suitability to be used as source of electricity[25].

According to Nasrudin Abd Rahim and Md. Hasanuzzaman [26], the average of solar radiation is 400 to 600 Mj/m^2 in Malaysia and it has a promising potential to establish large scale solar power installation. Besides that, Malaysian government is also very supportive and keen to develop solar energy as one of the significant sources of energy in the country [26].

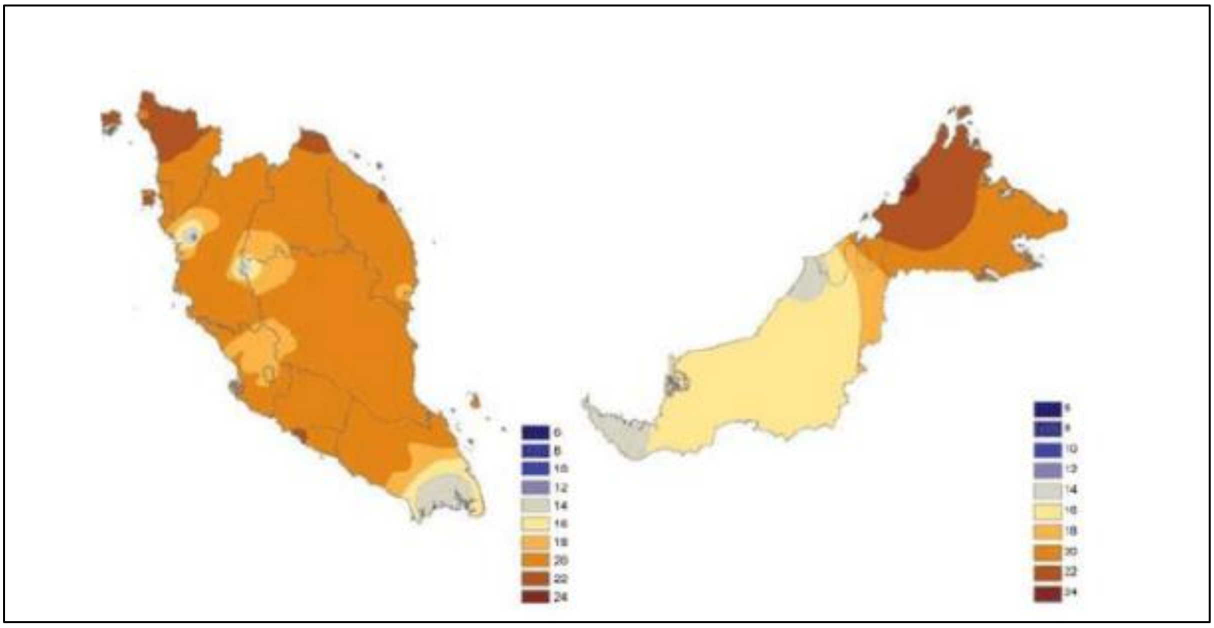


Figure 2.5: Annual Average Solar Radiation in Malaysia [27]

It is also found that the north and north east part of Malaysia has the highest value of solar radiation.

Table 2.3: Annual Solar Radiations in Different Cities in Malaysia [26].

Region	Annual average value (kWh/m^2)
Kuchung	1470
Bangi	1487
Kuala Lumpur	1571
Petaling Jaya	1571
Seremban	1572
Kuantan	1601
Johor Bahru	1625
Senai	1629
Kota Baru	1705
Ipoh	1739
Taiping	1768
George Town	1785
Bayan Lepas	1809
Kota Kitabalu	1900

There are also many literatures reported the application of renewable energy in remote area which located away from power lines. Mozes et al [28] demonstrate an aeration system, using a paddle wheel, powered by a photovoltaic power supply. The study was carried out on the coastal area in the centre of Israel. Meah et al [29] show the design, installation, site selection and performance monitoring of solar system for small-scale remote water pumping application. Noroozi et al [30] show the hybrid power system to supply electrical and thermal energy in Shahdad village in Chahabar, south east of Iran using HOMER (Hybrid Optimization Model for Electric Renewables) as a software tools for electric power system design.

Based on the above named papers, the research work on renewable energy for aquaculture industry is further continued on the focus on designing solar off-grid system to support the electrical demand of aeration system for aquaculture farm.

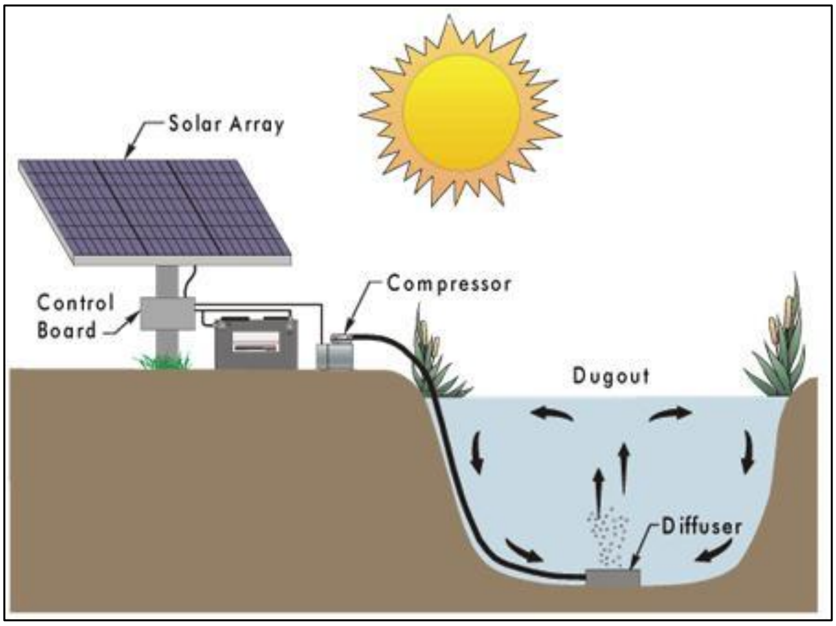


Figure 2.6: Illustration of Solar Powered Aeration System [31].

2.4 CHAPTER CONCLUSION

This chapter has discussed the literatures on the importance of water quality for the growth and quality of fishes and crustaceans. The three main factors; water temperature, dissolved oxygen level has been studied and proven that each factor will affect the production of aquaculture products. It is found that despite the fundamental understanding on the importance of these factors, the development of monitoring system to provide water quality data to the aquaculture farmer is still explorable. It is because with the monitoring system, the water quality data can be accessed easily by the farmers to perform control execution. The solar energy potential to be used as electricity for aeration system in aquaculture also has been studied and the potential of solar stand-alone system is high based on the geographical aspect and amount of solar irradiation that are received annually. Thus, strengthening the project ideation to build a solar powered aeration system with water quality monitoring system to improve the growth rate and quality of aquaculture products.

CHAPTER 3

METHODOLOGY

3.0 OVERVIEW

In this chapter, the processes and steps to complete the project is explained. The designing and developing stages of solar powered aeration system will be shown.

3.1 SYSTEM OVERVIEW

3.1.1 Design Specification

The design and development of the solar powered aeration system is the most important phase of the project. A lot of discussions are done with supervisor including system flow of project, selection of components, and hardware design and demonstration strategy of the overall prototype. It is then be decided to use 60 gallon water tank to represent the pond, 10 fishes and underwater oxygenator pump with 10W solar stand-alone system to represent the aquaculture pond. It is a simpler and practical prototype for demonstration purposes.

The monitoring system of the solar powered aeration system consists of a waterproof temperature sensor, a dissolved oxygen sensor and a pH sensor as the inputs. Temperature sensor is used to detect the water temperature, while the dissolved oxygen sensor is used to determine the level of dissolved oxygen concentration in measurement of mg/L. Based on the literatures, the water temperature and dissolved oxygen level is related to each other. Therefore, both inputs will be sent into Microsoft Excel through Arduino as the controller and is compared in the form of line graph.

The pH sensor detects the pH level of the water: acidic, alkaline and neutral level in the scale ranging from 1 to 9. The data is then also sent to Microsoft Excel via Arduino Controller. A 2 x 16 LCD display is also connected to Arduino to display the temperature of water in degree Celsius.

For the solar stand-alone system design, a 10W monocrystalline solar panel is connected to the solar charge controller. A 5AH lithium battery is used to store energy supply and an underwater oxygenator is used as underwater aeration for water circulation and increasing dissolved oxygen concentration in the water.

The overall design of the solar powered aeration system with the monitoring function block diagram is designed as shown in Figure 3.1. It should be noted that the prototype is demonstrating the pond in aquaculture farm.

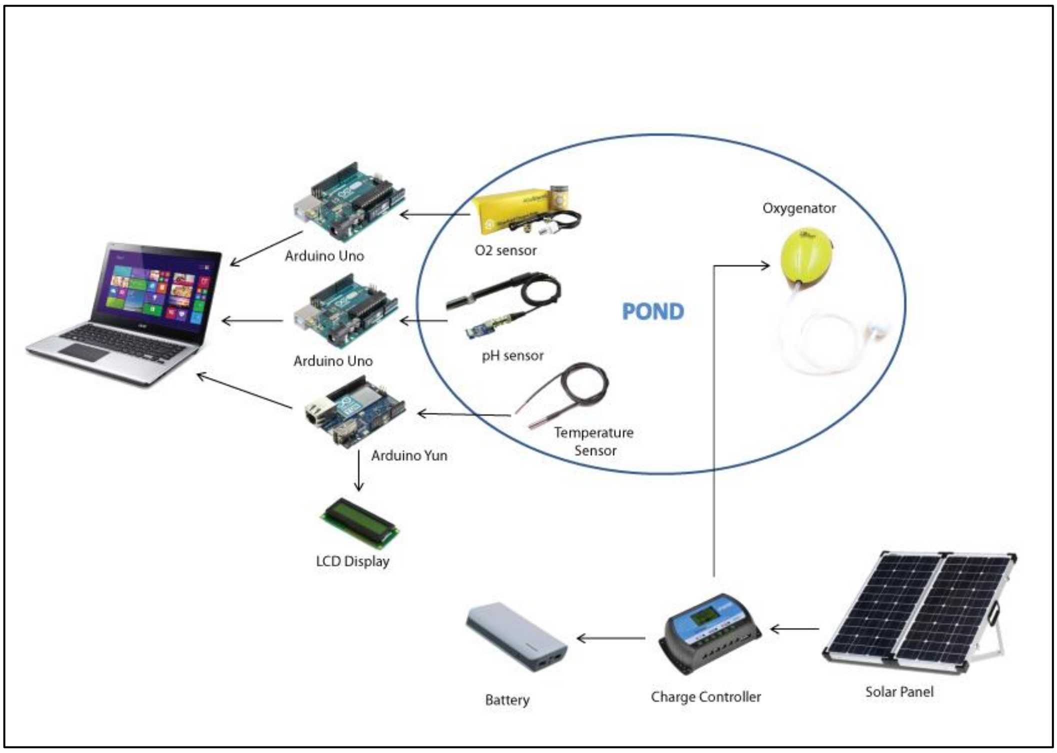


Figure 3.1: Solar Powered Aeration System Block Diagram.

The components list of the designed prototype is shown as below where the components used are divided into few parts: sensors, controllers, electronics components, hardware, and software.

Table 3.1 shows the sensors that are chosen for the project to measure the three factors affecting the water quality i.e. water temperature, dissolved oxygen level and pH level of the water. The quantity for each sensor is one as in this project only one prototype of monitoring system is developed.

Table 3.1: List of Sensor Components

SENSOR COMPONENTS	
DETAILS	**QUANTITY**
DISSOLVED OXYGEN SENSOR	1
TEMPERATURE SENSOR	1
pH SENSOR	1

Table 3.2 shows the hardware components that are used in the project. The 60 gallon water tank is used to demonstrate the aquaculture pond. Water pipe is used to fill up water from the water source into the water tank. The fish net is used to transfer fishes into water tank for experiments. Laptop is required as all the data from microcontrollers are transferred into Microsoft Excel via serial port. All items are required in one unit as only one prototype of aquaculture pond is developed.

Table 3.2: List of Hardware Components

HARDWARE COMPONENTS	
DETAILS	**QUANTITY**
60 GALLON WATER TANK	1
WATER PIPE	1
FISH NET	1
LAPTOP	1

Table 3.3 shows the electrical components used in the project. It is mostly consist of the components to design and develop solar stand-alone system. The oxygenator pump is used to demonstrate underwater aeration system. The solar module is used to convert sunlight into electrical energy. Solar charge controller is used to control charging of battery while battery is used to store electricity for autonomy. The DC cable with MC4 connector is used to connect solar module with the solar charge controller and the crocodile clip is used to connect battery with solar charge controller. All items are required in one unit as only one prototype is developed for the project.

Table 3.3: List of Electrical Components

ELECTRICAL COMPONENTS	
DETAILS	**QUANTITY**
10 WATT MONOCRYSTALLINE SOLAR MODULE	1
OXYGENATOR	1
SOLAR CHARGE CONTROLLER	1
5 AH LITHIUM BATTERY	1
DC CABLE	1
CROCODILE CLIP	1
MC4 (IN PAIR)	2

Table 3.4 shows the list of electronics components for the project. One unit of Arduino Yun is used to connect to the temperature sensor while two unit of Arduino Uno are used to connect with the dissolved oxygen sensor and pH sensor. The reason why 3 Arduino are used is because one pair of Arduino consist of one pair of transmits and receives port that are required by each sensor. Therefore three sensors require three controllers. The 2x16 LCD display is used to display the temperature data. All components are required in one unit because only one prototype is built for the project.

Table 3.4: List of Electronics Components

ELECTRONICS COMPONENTS	
DETAILS	**QUANTITY**
ARDUINO YUN	1
ARDUINO UNO	2
2 X 16 LCD DISPLAY	1

Table 3.5 shows the list of software components used in the project. Microsoft Excel is used to record the data collected from the sensors, normalization of data and develop graphs. While PLX-DAQ software is used to connect Arduino and allow data transmission via serial port. All software are required in one unit as only one prototype is developed for the project.

Table 3.5: List of Software Components

SOFTWARE COMPONENTS	
DETAILS	**QUANTITY**
MICROSOFT EXCEL	1
PLX-DAQ	1

3.2 HARDWARE IMPLEMENTATION

In hardware implementation, it is divided into few parts which are microcontroller, sensor selection, electrical and electronics components and software used. The prototype of solar powered aeration system is very crucial to develop and demonstrate the project operation specifically.

3.2.1 Microcontroller Selection

Arduino YUN controller is the main control system of this project as it functions as the brain to control input and output processes. Arduino YUN is one of the types in its ARDUINO family as it is integrated with microprocessor as well as wireless technology to allow wireless transfer of data and programming in and out of the controller itself. In this project, Arduino YUN will be used to receive data from sensors and execute output processes based on the input data. Besides that, it will also be connected to the internet which allows live feed of input data from sensors directly to the designed webpage. Therefore this controller is very important to ensure the functionality of this project prototype.

For this project, an Arduino YUN is purchased online from Cytron Technology. However, it came with openwrt source that runs Linux Operating System. Therefore, it is quite different in term of setting up the wifi hotspot of the Arduino YUN in order to allow programming transfer wirelessly. Many resources has been referred via Arduino official website, forums and Youtube Channels, and it is found that there are two different models of Arduino YUN that came from different manufacturers i.e. Arduino.cc and Arduino.org. Therefore the setup of both models is different.

Based on discussion in the Arduino Forum, it is possible to change the setting by changing openwrt source to openwrt-yun source. There are some opinions saying that oepnwrt source allows more exploration in Arduino YUN however it is not user friendly compared to openwrt-yun which is more convenient and have a lot of references. The steps to change from openwrt to openwrt-yun are as below:

i) Download the files from Arduino.cc website and put into a SD Card.

ii) Insert the SD Card containing the files into the slot on the Arduino YUN.

iii) Reset the system and try to connect to the wifi hotspot.

After following the steps, the Arduino YUN openwrt system is successfully changed to oepnwrt-YUN. Since it runs on the openwrt-YUN, the setup is done based on the tutorial provided and a simple project is done to check the functionality of the controllers. A simple program is written and transferred wirelessly to the Arduino YUN. Then a simple circuit is constructed using LDR as input sensor, 2x16 LCD Display, and a led. The simple project is successful and further exploration on Arduino YUN is conducted.

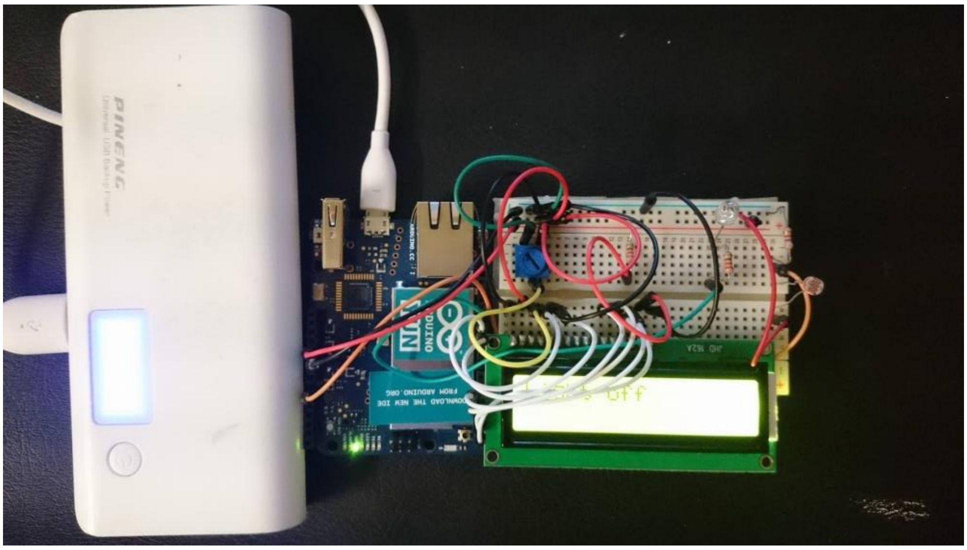


Figure 3.2: A Simple Project to Test the Arduino YUN Controller.

Arduino Uno is also used in this project to connect to the dissolved oxygen sensor and pH sensor that requires transmits and receives terminals for data transfer and receives purposes. Arduino Uno is relatively cheap compared to other available microcontroller in the market. Based on Figure 3.3, it has 6 pins for analogue inputs, 16 MHz crystal oscillator, 14 digital I/O pins which 6 of them can be used as Pulse Width Modulation (PWM) outputs, USB connection port, power jack and others.

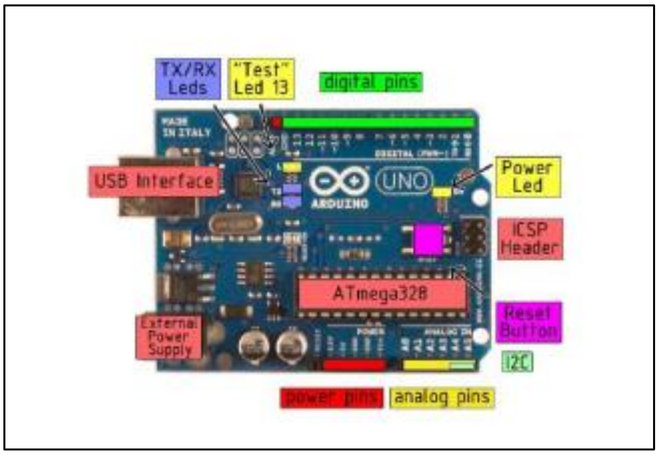


Figure 3.3: Arduino Uno Microcontroller with Specification Label.

Arduino Uno is adequate for this project as it is able to connect to both dissolved oxygen sensor and pH sensor via Tx/Rx pins which will then transmit the data from sensors into Microsoft Excel. Using the C++ Programming, it is very simple and easy to understand the programming language and its application. More Arduino Uno specification is also mentioned in Table 3.6.

Table 3.6: Arduino Uno Specifications

Microcontroller	Atmega328
Operating Voltage	5V
Input Voltage	7 to 12V
Input Voltage (limits)	6 to 20V
Digital I/O Pins	14 (6 pins are keep for PWM output)
Digital Current per I/O Pin	40mA
DC Current for 3.3V	50mA
Analog Input Pin	6
Flash Memory	32 KB
SRAM	2 KB
EEPROM	1KB
Clock Speed	16 MHz

To program the Arduino Uno and YUN, the Arduino Software (IDE) is used. With the correct serial port that is selected and changeable under Tools, the programming that is done can be compiled and uploaded. The program is then sent and saved as non-volatile memory. Arduino programming is very user friendly compared to other microcontroller however it will be limited in term of memory consumption.

3.2.2 Selection of Sensors

The most essential part in design and development of the monitoring system of solar powered aeration system is the selection of sensors. The sensors are used to detect the water condition for the system. In this project, 3 sensors are used which consists of temperature sensor, pH sensor and dissolved oxygen sensor.

Firstly is the temperature sensor that is used to measure the water temperature in order to identify temperature differences that will affect the concentration of dissolved oxygen. This sensor is connected to Arduino YUN and is able to measure and transmit data into Microsoft Excel. This water temperature sensor is a sealed digital temperature probe that allows precise measurement of water temperature using the 1-Wire interface. The sensor model, DS18B20 provides 9 to 12 bit temperature readings over the 1-Wire interface where it requires only one wire (and ground) to be connected from the central of microcontroller.

Figure 3.4: Temperature Sensor DS18B20.

The specifications of the temperature sensor are described in Table 3.7. It should be noted that any input that exceed the specification will result in component damage.

Table 3.7: Temperature Sensor Specifications

Model	DS18B20
Input Voltage	3.0 – 5.5V
Type	Waterproof sealed with stainless steel
Temperature Range	-55°C to +125°C
Accuracy	± 0.5°C
Interface	1 Wire
Wire Colour Code	Red = Vcc, White = Data, Black = GND

Secondly is the pH sensor that is used to measure the pH level of water and transfer the data to Microsoft Excel via Arduino Uno. The pH electrode is a passive device that detects a current generated from hydrogen ion activity. This current which can be positive or negative is very weak and is impossible to be measured by multimeter, or an analogue to digital converter. Since the weak electrical signal is easily interrupted, therefore it is important to use proper connectors and cables.

The equation that is used to predict the current that is generated from the hydrogen ion activity is as below in Eq. (3.1)

$$E = E^0 + \frac{RT}{F}\ln(\alpha H +) = E^0 - \frac{2.303RT}{F}pH \qquad (3.1).$$

Where;

R = ideal gas constant

T= temperature in kelvin

F = Faraday constant

The pH sensor measured in mV that is then converted into pH scale. It is a combination of electrode that contains both measuring and reference electrode in a single unit. Electrolyte solution is required to be refilled because the lifespan is determined by usage or storage. It has a BNC connector that connects to the EZO pH circuit before connecting to Arduino Uno. This scientific pH sensor is very accurate and reliable to provide practical momentary reading for measurement compared to the use of litmus paper that only provide approximate value and colour changes based on chart. The pH sensor that is used in this project is shown in Figure 3.5.

Figure 3.5: pH Sensor

Table 3.8 shows the specification of the pH sensor. It is stated that any pH value more than 12.3 will be read as error due to component limitation. The max pressure is stated at 690kPa and any pressure higher than stated will damage the component.

Table 3.8: pH Sensor Specifications

Model	Atlas Scientific pH Sensor
pH Range	0 -14 (Na+ error at > 12.3pH)
Temperature Range	1°C to 99°C
Max Pressure	690 kPa
Dimensions	12 mm X 150 mm
Resolution	Limited by only device reading it.
Plug	BNC

The pH sensor probe can be fully submerged in fresh water or salt water, up to the BNC connector. There is also no specific set of schedule for recalibration of the sensor however required simple cleaning to prevent coating of the pH bulb that can lead to erroneous readings including shortened span (slope).

Thirdly is the dissolved oxygen sensor that is used for measuring the dissolved oxygen level of water. This galvanic dissolved oxygen sensor is a passive device that generates a small voltage from 0mV to 47mV on the oxygen saturation of the HDPE sensing membrane. Using multimeter, the voltage can easily be measured. The zinc rod (anode) in the tube is submerged in an electrolyte where the sensing element, HDPE sensing membranes compressed against a silver disk (cathode).

The measurement for the dissolved oxygen is expressed in mg/L. When reading dissolved oxygen, factors such as salinity and temperature are examples of factors that need to be taken into account. In determining the dissolved oxygen percentage as compared to atmospheric oxygen, the equation is as stated as in Eq. (3.2).

$$\% \text{ saturation} = (\text{mV in water} / \text{mV in air}) \times 100 \qquad (3.2).$$

Since the determining of dissolved oxygen in mg/L from the probes output voltage is very complex, therefore the EXO dissolved oxygen circuit is designed to derive the oxygen saturation in mg/L. The dissolved oxygen sensor reacts with oxygen in the water and the more it reacts the more depletion of the electrolyte solution. It is recommended to change the solution and membrane every 2 years. Figure 3.6 shows the dissolved oxygen sensor used in the project.

Figure 3.6: Dissolved Oxygen Sensor.

3.2.3 Oxygenator Pump

For the underwater aeration system, it is represented in the prototype using the AD-606 oxygenator pump. This oxygenator pump is suitable for water measurement up to 55 gallons. It has 3m of airline and 1 air stone that is connected to the air pump. Since the pond prototype is represented by a 60 gallons water tank, this oxygenator pump is the best choice to represent the underwater aeration. Figure 3.7 shows the oxygenator pump used in this project.

Figure 3.7: AD-606 Oxygenator Pump.

This oxygenator pump has a USB connector point for charging purposes therefore in the design of solar stand-alone system, a 5V output is required to power up this oxygenator pump. Its power rating is rated at 1.5W and maximum pressure is 0.021 Mpa.

3.2.4 10W Solar Stand Alone System

The solar stand-alone system designed and developed for this project consists of the following components:

i) 10W monocrystalline solar module

ii) Solar charge controller

iii) 5Ah lithium battery

iv) MC4 and DC cables

v) Crocodile clips.

The 10W monocrystalline solar module with charging output of 22V/0.6A and efficiency of 15 – 20% is used in this project. In the designing stage, the total power estimated to be generated is calculated as below.

Assume 5 PSH (Peak Sun Hour) (10am to 3pm);

0.6 A x 5 PSH = 3 amp-hours/day

3 x 12 V = 30 watt-hour / day

It is estimated that the solar module is able to produce up to 30watt-hour a day given good weather with 5 hours of full sunlight. Figure 3.8 shows the solar module used in the project.

Figure 3.8: 10W Monocrystalline Solar Module.

The solar module is then connected to the charge controller PV inputs using the DC cable with MC4 connectors. The cable and MC4 connectors are shown as in Figure 3.9.

Figure 3.9: DC Cable with MC4 Connectors.

The solar charge controller model is GAMMA 3.0 USB functions is to regulate the voltage from solar module and control the charging process of battery. The charge controller 12V output is connected to 5Ah lithium battery using DC cables. Figure 3.10 shows the GAMMA 3.0 USB charge controller.

Figure 3.10: GAMMA 3.0 USB Charge Controller.

This model of charge controller is able to prevents the 12 V battery from over-charging and also provide a 5 V USB output for conveniences. It requires a minimum of 6V to powe up the solar charge controller and can operate in 12 V and 24 V systems.

The battery model is 5Ah 12V lithium battery that is connected to the solar charge controller by using crocodile clip. This battery is chosen after detailed calculation to sustain the oxygenator operation for more than 20 hours. The calculation is shown as below.

Oxygenator pump power rating: 1.5W (from manufacturer)

Duration operated depending on battery = 30 watt-hour / 1.5 W = 20 hours

20 hours is sufficiently enough to run the pump for a day considering rainy days and night time. Figure 3.11 shows the battery and figure 3.12 shows the crocodile clips used in this project.

Figure 3.11: 5 Ah 12 V Lithium Battery.

Figure 3.12: Crocodile Clips.

3.3 PROJECT FLOW

The flow chart for the monitoring system is shown in Figure 3.13. When the monitoring system starts, the sensors will check the water quality aspects which are water temperature, dissolved oxygen level and pH level of water. The user then will run the PLX-DAQ software and select the serial port that is desired. If the port for dissolved oxygen is selected, the data from dissolved oxygen sensor will be transmitted into Microsoft Excel. If the port for water temperature is selected, the data from temperature sensor will be transmitted into Microsoft Excel and if the port for pH level is selected, the data from pH sensor will be transmitted in Microsoft Excel. For the water temperature, the data from sensor is also being displayed at the 2x16 LCD display without requiring user to select serial port. If no serial port is selected, the sensors will keep measuring the water quality until the whole system is switched off.

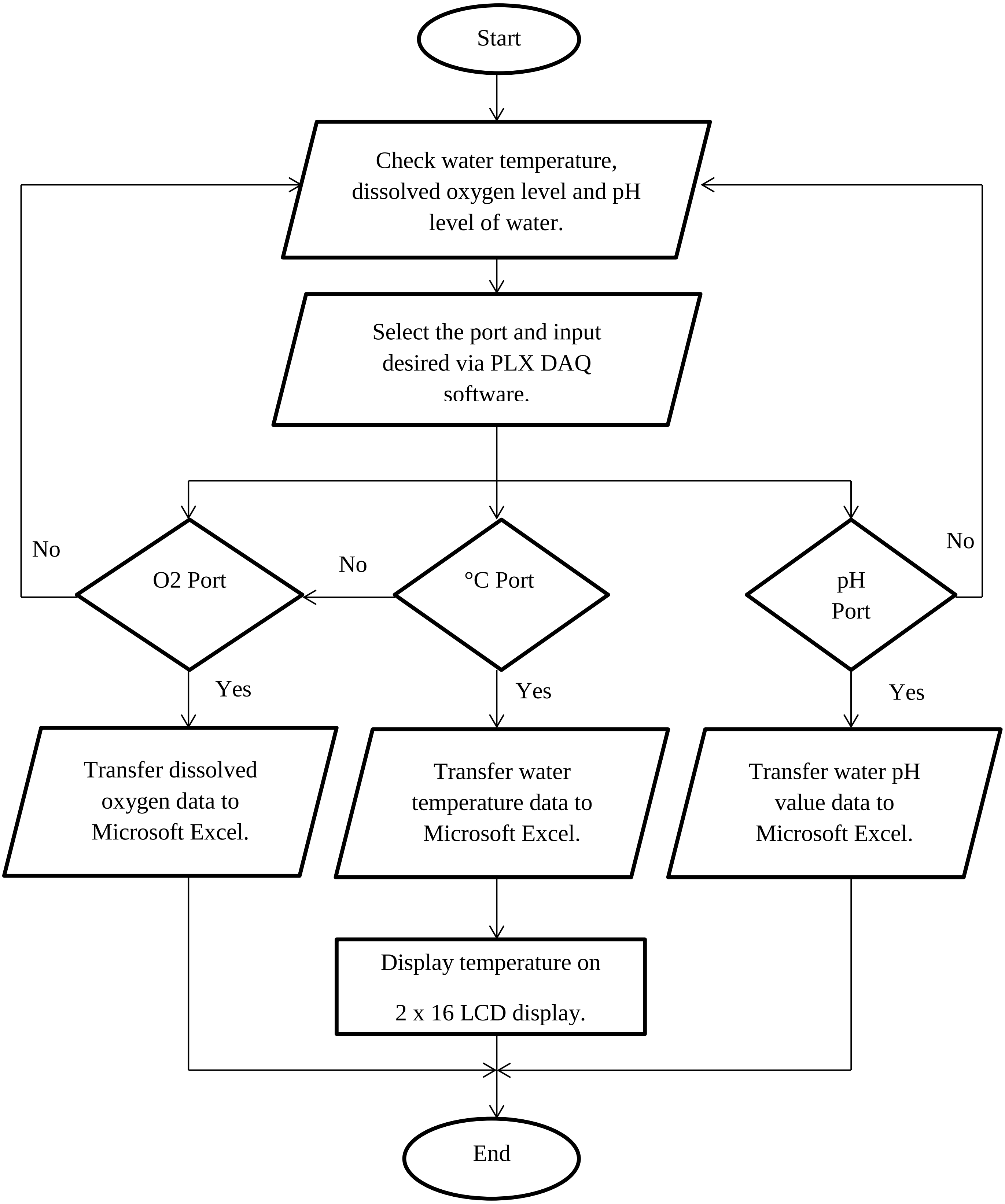


Figure 3.13: Monitoring System Flow Chart.

3.4 CIRCUIT ASSEMBLY

This project consists of 3 circuit diagrams where the dissolved oxygen sensor and pH sensor are connected with Arduino Uno while the temperature sensor is connected with Arduino YUN. The overall circuit diagrams are shown as below.

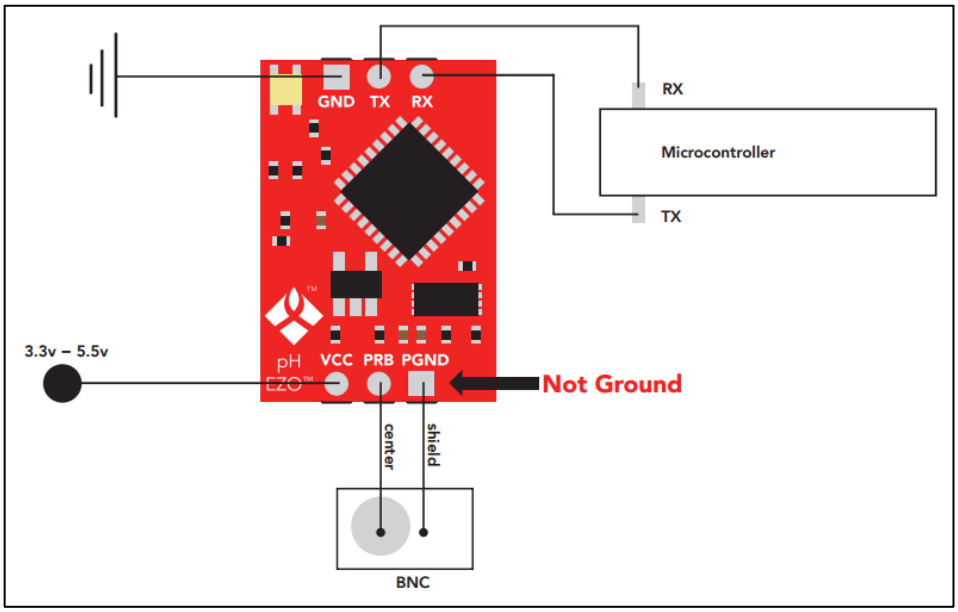


Figure 3.14: Circuit Diagram for pH Sensor.

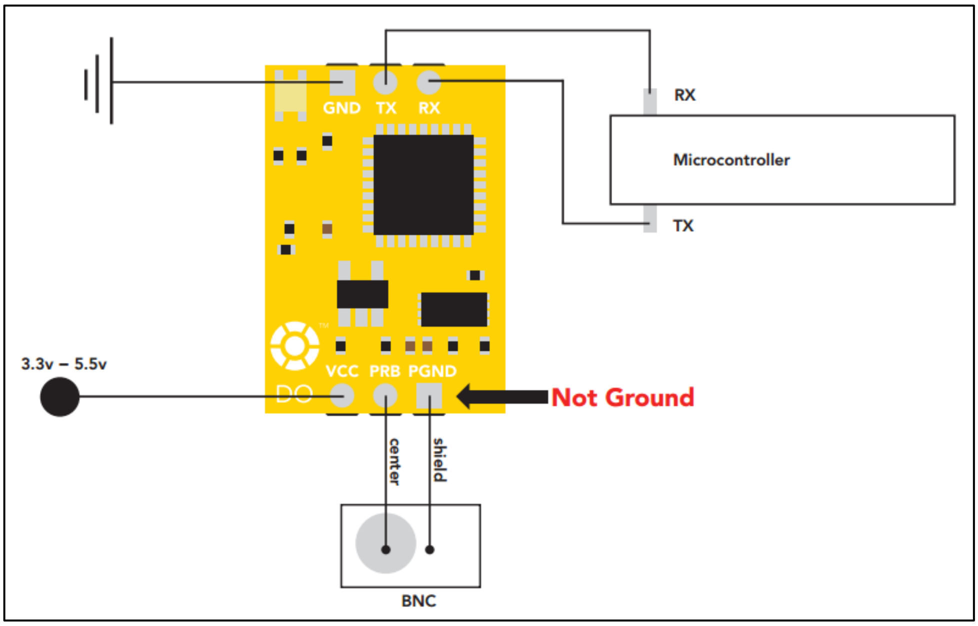


Figure 3.15: Circuit Diagram for Dissolved Oxygen Sensor.

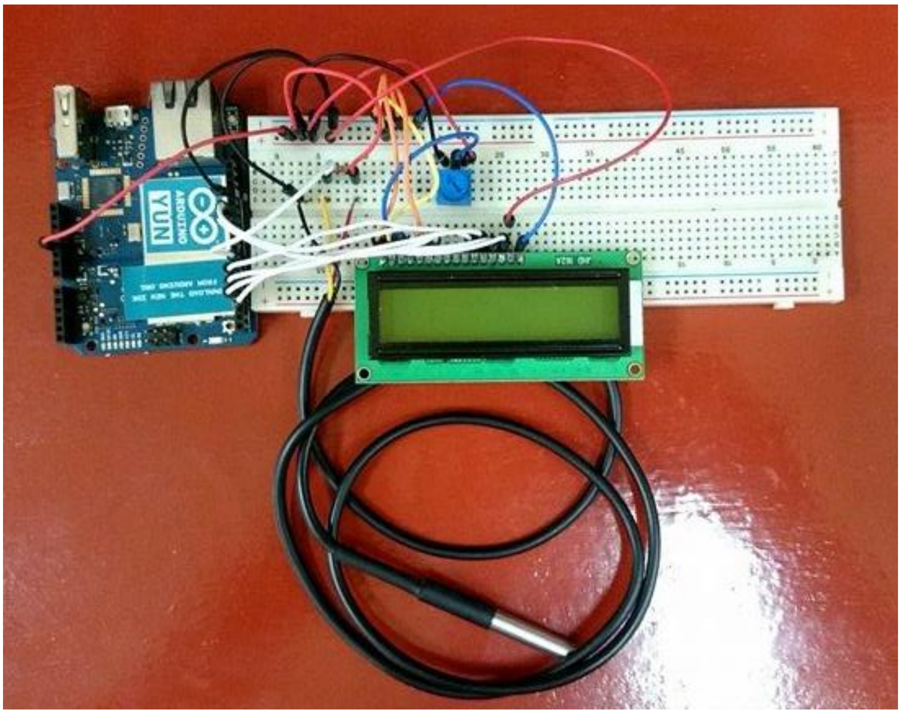


Figure 3.16: Circuit Diagram for Temperature Sensor and LCD Display.

3.5 CHAPTER CONCLUSION

This chapter has discussed the methodology of the project with the beginning where the system block diagram is created. It is then continued with implementation of hardware where microcontrollers and sensors are chosen based on required specifications. The solar stand-alone system design and development is also discussed with each components are explained specifically. Finally, the project flow of monitoring system and the circuit assembly are shown at the end of the topic.

CHAPTER 4

RESULTS AND DISCUSSION

4.0 OVERVIEW

This chapter explains about the experimental conducted using designed system and the results collected are analysed and discussed at the end of the chapter.

4.1 PROTOTYPE EXPERIMENT

When the prototype of the solar powered aeration system with monitoring function is completely developed, it is then used to conduct experiments to ensure the prototype achieves the objectives. For the monitoring system experiments, 12 experiments are carried out with different pond condition at different weather. The aim is to prove the literatures concept of the relationship between water temperature and dissolved oxygen can be determined by the monitoring system designed and how underwater aeration can be applied in the scenarios. The solar module tilt angle is also investigated to find out the ideal tilt angle for maximum generation of electricity. The charge controller charging characteristic is also analysed to understand the charging process of the GAMMA 3.0 Solar Charge Controller.

In order to conduct comparative analysis of actual situation, water quality data is also collect from the Lake of University of Malaysia Pahang to prove the concept of the relationship of water temperature and dissolved oxygen level.

Each experiment is important to investigate the characteristic and relationship of the factors that affecting the fishes and crustaceans growth and quality in aquaculture industry. Therefore Table 4.1 shows the condition of pond and weather and the experiments that are carried out while Table 4.2 shows the conditions taken at Lake Of University of Malaysia Pahang.

Table 4.1: Experiment Conditions

Condition	**Afternoon**	**Night**	**Raining**
Pond	Experiment 1	Experiment 5	Experiment 9
Pond + Fish	Experiment 2	Experiment 6	Experiment 10
Pond + Aeration	Experiment 3	Experiment 7	Experiment 11
Pond + Fish +Aeration	Experiment 4	Experiment 8	Experiment 12

Table 4.2: Experiment Conditions at UMP Lake

Condition	**Morning**	**Afternoon**	**Night**
UMP Lake		Experiment 13	

Figure 4.1 and 4.2 shows the examples of setup of the prototype when collecting experimental data.

Figure 4.1: Experimental Setup of Designed Prototype during Day Time.

Figure 4.2: Experimental Setup of Designed Prototype during Night Time.

4.2 RESULTS AND ANALYSIS FOR MONITORING SYSTEM

For the experiments conducted using the monitoring system, the main determined data is the increment and decrement of dissolved oxygen level in every 5 minutes comparing to the temperature changes. The data stated and plotted are after normalization due to huge difference in range for dissolved oxygen level which starts from 1 to 10 mg/L while for temperature, it ranges around 25°C to 40°C. Therefore using normalization, the pattern of the changes can be compared equally and demonstrated in the form of line graphs. Table 4.3 shows the summarize results for the experiment conducted on relationship between water temperature and dissolved oxygen level.

Table 4.3: Summarize Results of Experiments

Conditions	**Differences of Average Dissolved Oxygen Level (mg/L) for every 5 minutes. (Normalized data)**		
	Raining	**Afternoon**	**Night**
Pond	0.0129	-0.0873	0.07417
Pond + Fish	-0.0638	-0.102	-0.0077
Pond + Aeration	0.0935	0.0627	0.1192
Pond + Fish + Aeration	0.0285	0.0192	0.0046

Based on Table 4.3, it can be seen that in raining weather, the dissolved oxygen level increases but as much as it increases at night time. This is due to the factor of raining causes movement of water and temperature reduces that contributed to more dissolved oxygen being produced in the water. However, the increment due to raining and fall of temperature at night time still could not cater to the oxygen requirement of fishes. Therefore, based on these results, it shows that no matter the temperature is decreasing, yet aeration is required to compensate to the oxygen requirement of the fishes. That is why when aeration is included in the system, the dissolved oxygen level increases although fishes are consuming oxygen at the same time. Meanwhile in the afternoon, temperature increases and thus causing the decrement in dissolved oxygen level. This is a critical situation that requires high concern because water containing less than 5 mg/L of dissolved oxygen is consider anoxic, causing stressful condition that affect the growth and quality of fishes and crustaceans.

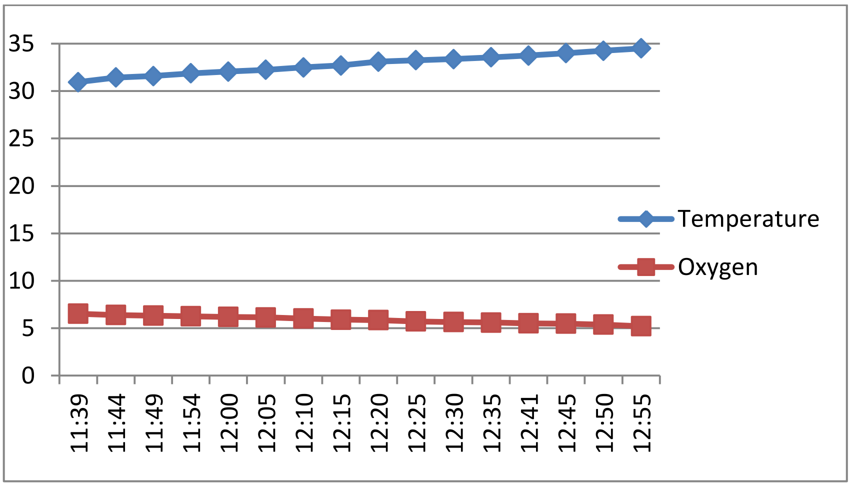
There is also a situation that has been brought into discussion with supervisor regarding a situation where during night time, the farmer needs to constantly hit the water surface to ensure enough dissolved oxygen for the fishes although it is found out that during night time, temperature decreases and dissolved oxygen increase. In this case, as in literatures, the depth of aquaculture pond creates stratification where water temperature only reduces at the surface and dissolved oxygen is generated at the surface while fishes tend to stay in the lowest region of the pond which has no water circulation. That is why the farmer still requires to create water movement to ensure the dissolved oxygen in the surface to circulate into the lowest region of the pond.

For this scenario, underwater aeration i.e. oxygenator pump is the best to use because the pump creates water circulation from the bottom of the pond and at the same time helping the dissolved oxygen on the surface to circulate around the pond thus creating an environment that is rich in oxygen and able to support better growth of fishes. This is why understanding on the water data is very important to the farmers because by using the monitoring system, they are able to always identify the water quality for their fishes and crustaceans.

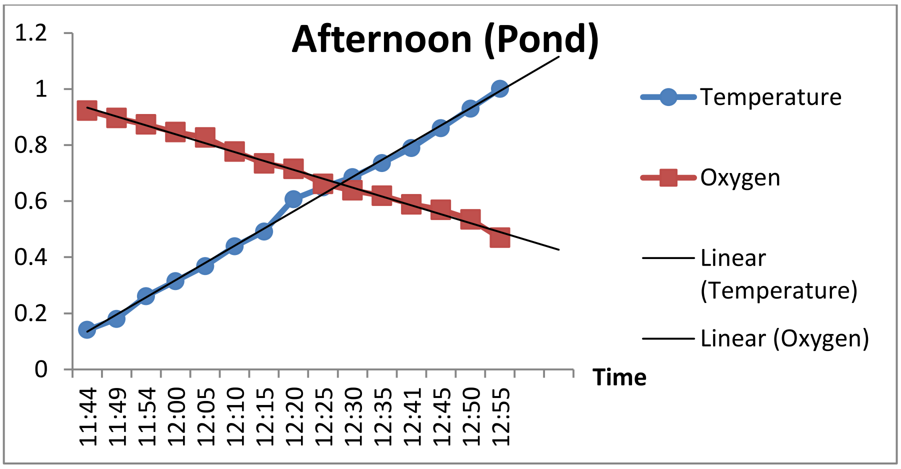
4.2.1 EXPERIMENT RESULTS AND ANALYSIS

Experiment 1: Water tank filled up with water under hot sun in the afternoon.

Graph 4.1 shows the comparison of water temperature and dissolved oxygen data for pond in the afternoon. Graph 4.2 shows the normalized water temperature and dissolved oxygen data for pond in the afternoon.



Graph 4.1: Water Temperature and Dissolved Oxygen Data for Pond in the Afternoon.

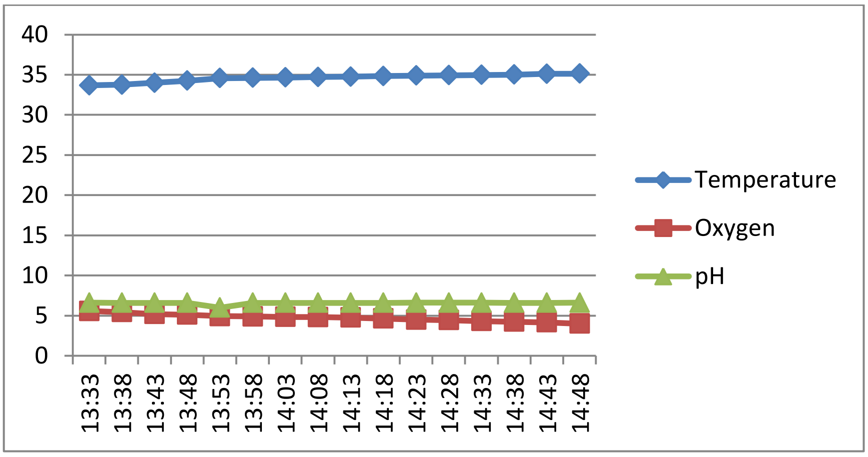


Graph 4.2: Normalized Water Temperature and Dissolved Oxygen Data for Pond in the Afternoon.

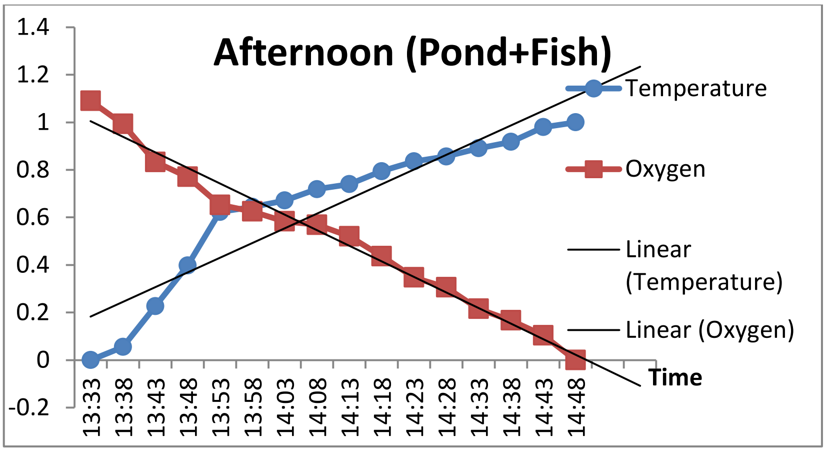
Based on the Graph 4.1 and 4.2 above, it is clearly shown that for pond in the afternoon, when the water temperatures increases the dissolved oxygen level decreases. The normalized data Graph 4.2 illustrated the relationship between the two factors thus proving the theory of the relationship as mentioned in literatures. From this data, it is highly recommended not to rear any fishes and crustaceans in the pond without having aeration system to support the decrement of dissolved oxygen in the water. However, if fishes and crustaceans are still being rear in this condition, the growth of the fish will be slowed and the quality will be lowered due to stressful environment created by dissolved oxygen level less than 5 mg/L. The average normalized dissolved oxygen decrement for every 5 minutes is calculated at -0.0873.

Experiment 2: Water tank filled up with water and fish under hot sun in the afternoon.

Graph 4.3 shows the comparison of water temperature and dissolved oxygen data for pond with fishes in the afternoon. Graph 4.4 shows the normalized water temperature and dissolved oxygen data for pond with fishes in the afternoon.



Graph 4.3: Water Temperature, pH and Dissolved Oxygen Data for Pond with Fishes in the Afternoon.

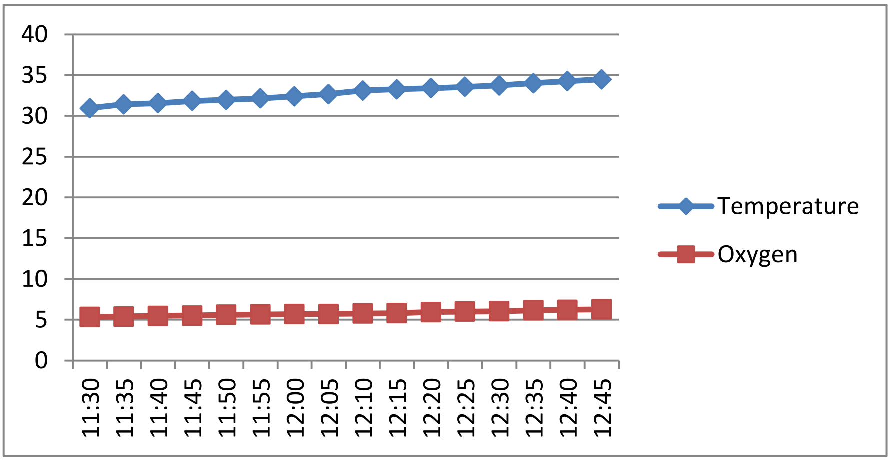


Graph 4.4: Normalized Water Temperature and Dissolved Oxygen Data for Pond with Fishes in the Afternoon.

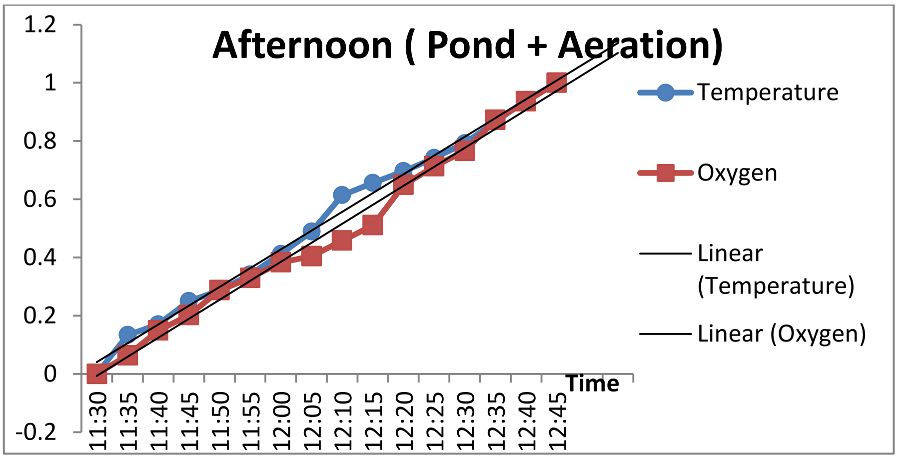
Based on the Graph 4.3 and 4.4 above, it shows a higher decrement of dissolved oxygen level when fishes are added into the pond and measurements were taken under hot sun in the afternoon. The average normalized decrement of dissolved oxygen level is calculated at -0.1020 which is higher than the decrement experienced when no fishes are added. This is because the decrement is contributed even more when fishes consumed oxygen in the water thus causing higher decrement of dissolved oxygen in the afternoon. Conversely if aeration system is fixed for the pond to supply oxygen and provide water circulation, the water condition will be better. Therefore, it is clear that aeration system is required the most during high temperature and presence of fishes. In term of pH measurement, there are no significant changes due to less effect of waste from the fishes.

Experiment 3: Water tank filled up with water plus oxygenator pump under hot sun in the afternoon.

Graph 4.5 shows the comparison of water temperature and dissolved oxygen data for pond plus oxygenator pump in the afternoon. Graph 4.6 shows the normalized water temperature and dissolved oxygen data for pond plus oxygen pump in the afternoon.



Graph 4.5: Water Temperature and Dissolved Oxygen Data for Pond plus Oxygenator Pump in the Afternoon.

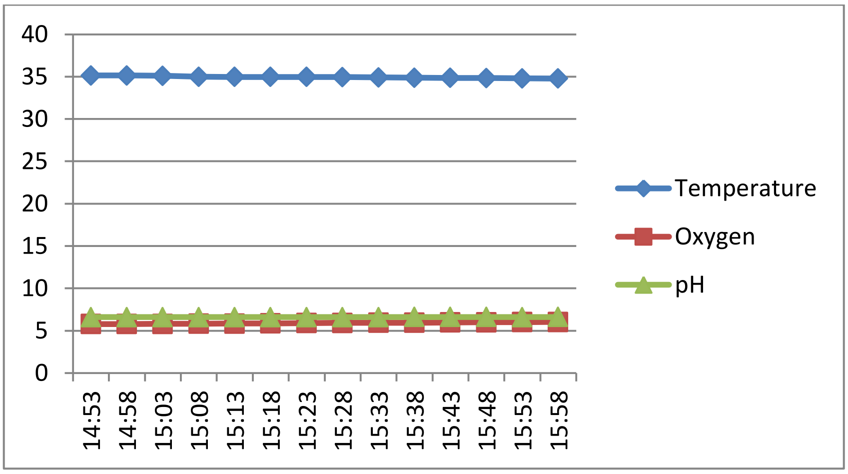


Graph 4.6: Normalized Water Temperature and Dissolved Oxygen Data for Pond plus Oxygenator Pump in the Afternoon.

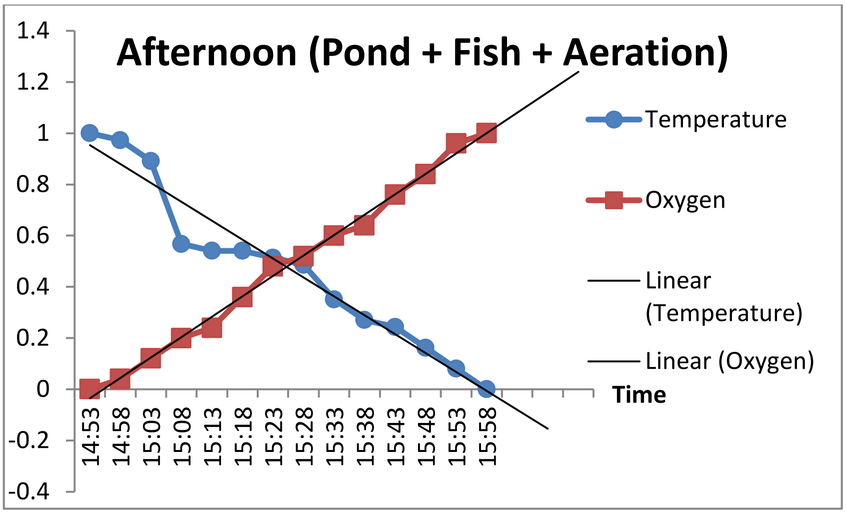
Based on Graph 4.5 and 4.6, experiment is to investigate the contribution of oxygenator pump to overcome the decrement of dissolved oxygen level in pond under the hot afternoon sun. It is clearly illustrated that when aeration system is fixed, the level of dissolved oxygen increases despite of temperature increment. The average normalized dissolved oxygen increment is calculated at 0.0627. This is because the oxygenator pump acts as the underwater aeration that not only creates effective water circulation that breaks the stratification in the water, it also reduces the effect of temperature of water by pumping in air into the water constantly thus creating a very oxygenated environment. Nonetheless, the dissolved oxygen increment might vary based on the changes in surrounding temperature.

Experiment 4: Water tank filled up with water and fishes plus oxygenator pump under hot sun in the afternoon.

Graph 4.7 shows the comparison of water temperature, pH and dissolved oxygen data for pond with fishes plus oxygenator pump in the afternoon. Graph 4.8 shows the normalized water temperature, pH and dissolved oxygen data for pond with fishes plus oxygen pump in the afternoon.



Graph 4.7: Water Temperature, pH and Dissolved Oxygen Data for Pond and Fishes plus Oxygenator Pump in the Afternoon.

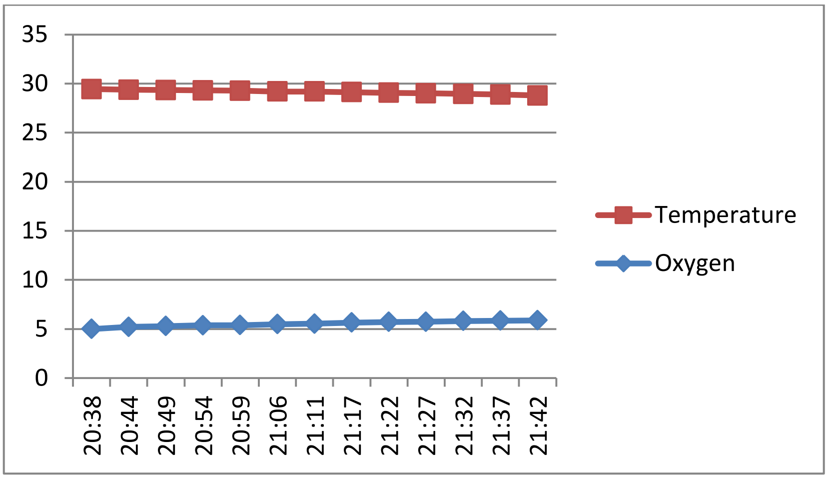


Graph 4.8: Normalized Water Temperature and Dissolved Oxygen Data for Pond and Fishes plus Oxygenator Pump in the Afternoon.

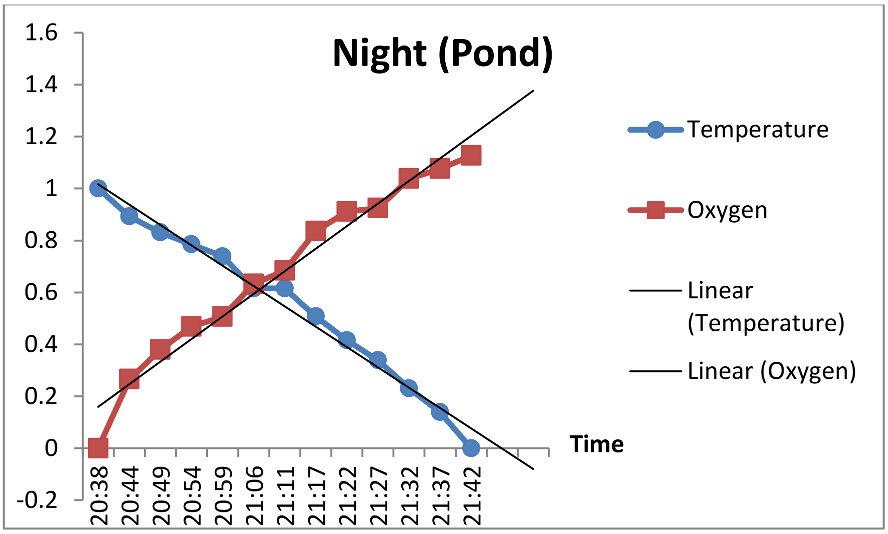
For this experiment, it is to investigate whether the aeration system is able to compensate to the amount of dissolved oxygen loss due to water temperature and fishes respiration. As shown in Graph 4.7 and 4.8, it is found that the oxygenator pump is able to create the amount of dissolved oxygen to overcome the losses due to water temperature and respiration of fishes. However, the amount on average normalized dissolved oxygen increment is measured at 0.0192 which is lesser to the increment without fishes. This is due to the consumption of oxygen by the fishes during respiration. The pH of water also does not shows any significant changes most probably due to low amount of fishes therefore not much effect on water pH.

Experiment 5: Water tank filled up with water during night time.

Graph 4.9 shows the comparison of water temperature and dissolved oxygen data for pond at night. Graph 4.10 shows the normalized water temperature and dissolved oxygen data for pond at night.



Graph 4.9: Water Temperature and Dissolved Oxygen Data for Pond at Night.

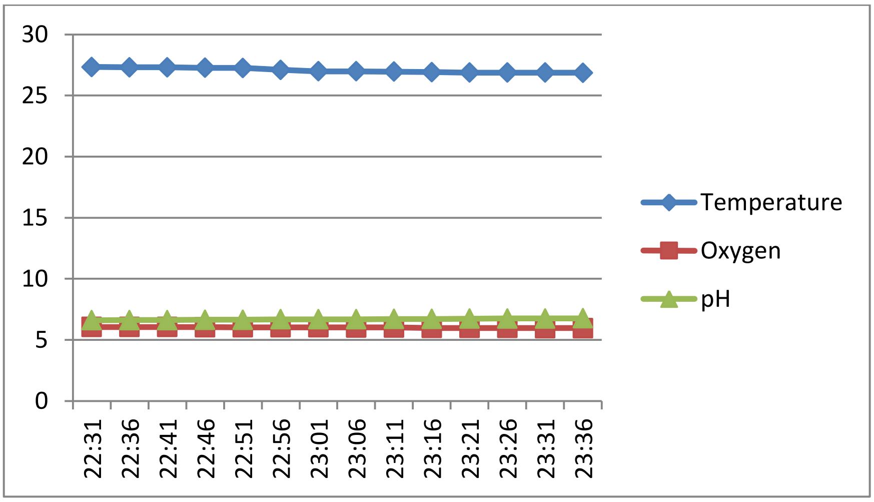


Graph 4.10: Normalized Water Temperature and Dissolved Oxygen Data for Pond at Night.

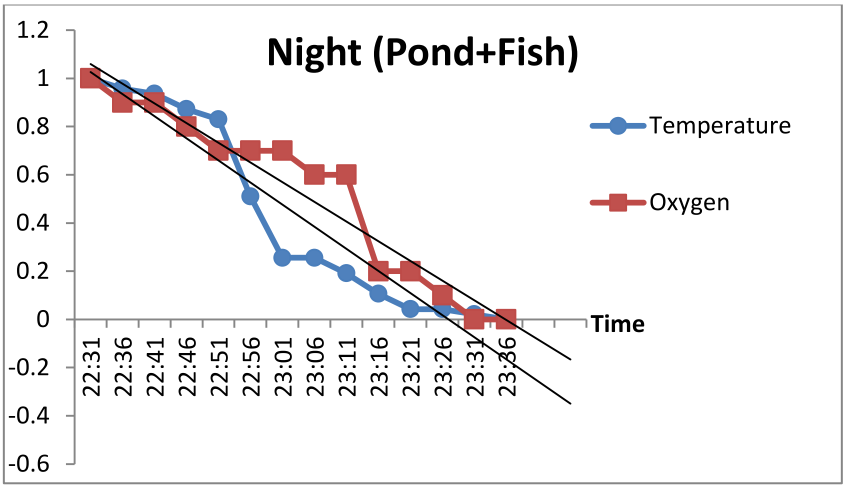
The experiment is to investigate the effect of water temperature decrement on the level of dissolved oxygen during night time. Based on the Graphs 4.9 and 4.10 above, it is clearly shown that during night time, the level of dissolved oxygen increases while water temperature decreases as stated previously in the relationship between the two factors in literatures. Therefore at night time, more oxygen content is in water which is a good condition for fishes. However, due to stratification, the bottom part of the pond in actual practice will still experiencing low dissolved oxygen because fishes and crustaceans tend to stay at the bottom of pond during night. Therefore, it is still recommended to install underwater aeration system to provide water circulation so that the high content of dissolved oxygen on the surface can be circulated to the whole pond. The average normalized dissolved oxygen increment is calculated at 0.07417.

Experiment 6: Water tank filled up with water and fish during night time.

Graph 4.11 shows the comparison of water temperature and dissolved oxygen data for pond with fishes at night. Graph 4.12 shows the normalized water temperature and dissolved oxygen data for pond with fishes at night.



Graph 4.11: Water Temperature, pH and Dissolved Oxygen Data for Pond with Fishes at Night.

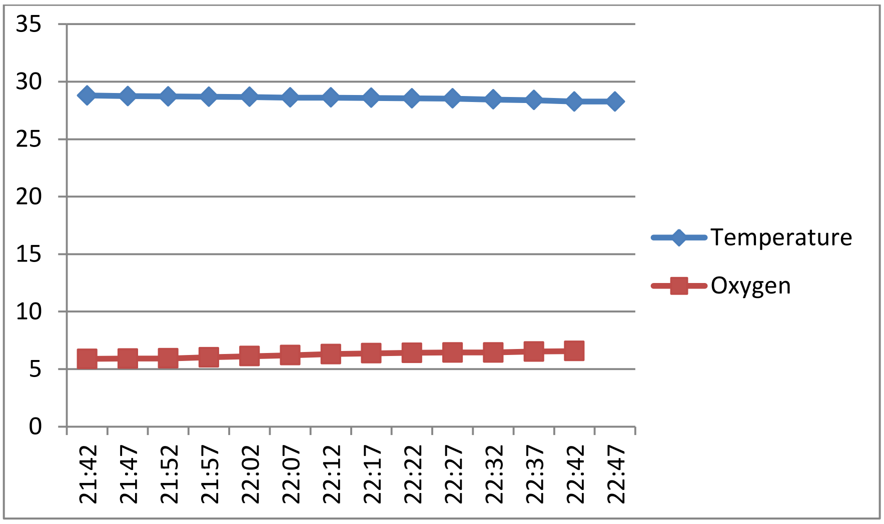


Graph 4.12: Normalized Water Temperature and Dissolved Oxygen Data for Pond with Fishes at Night.

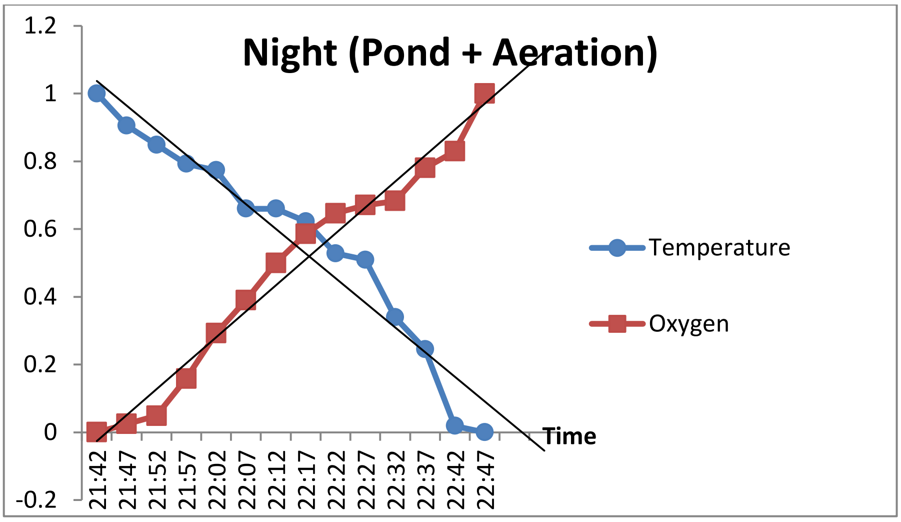
The experiment aims to investigate whether the increment of dissolved oxygen during night time is able to provide sufficient amount of dissolved oxygen level for the fishes. Based on the findings in Graph 4.11 and 4.12, it can be concluded that despite the increment of dissolved oxygen due to water temperature decrement, it still insufficient to provide enough oxygen for fish's respiration. Nevertheless, the amount of oxygen intake of fishes may be varied based on size and number of fishes in a pond. That is why the graphs show decrement of dissolved oxygen at night due to higher oxygen intake of the fishes. The pH of water does not show significant changes due to less number of fishes used in the experiment. The average normalized dissolved oxygen decrement is measured at -0.0077.

Experiment 7: Water tank filled up with water plus oxygenator pump during night time.

Graph 4.13 shows the comparison of water temperature and dissolved oxygen data for pond plus oxygenator pump at night. Graph 4.14 shows the normalized water temperature and dissolved oxygen data for pond plus oxygenator pump at night.



Graph 4.13: Water Temperature and Dissolved Oxygen Data for Pond plus Oxygenator Pump at Night.

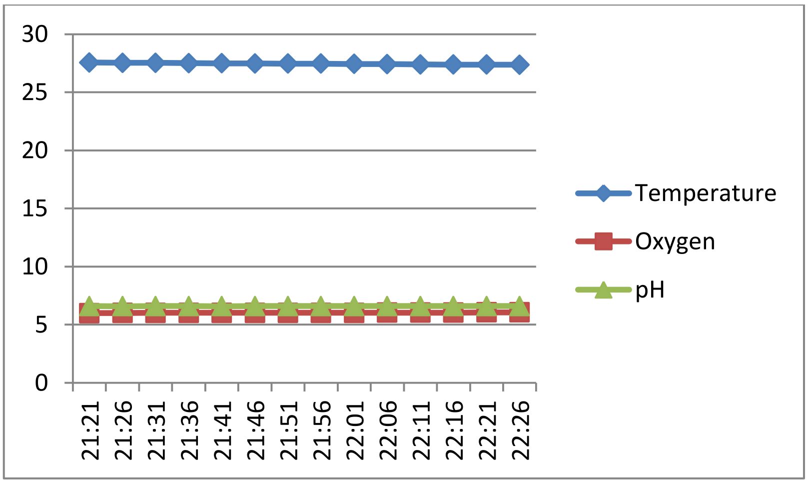


Graph 4.14: Normalized Water Temperature and Dissolved Oxygen Data for Pond plus Oxygenator Pump at Night.

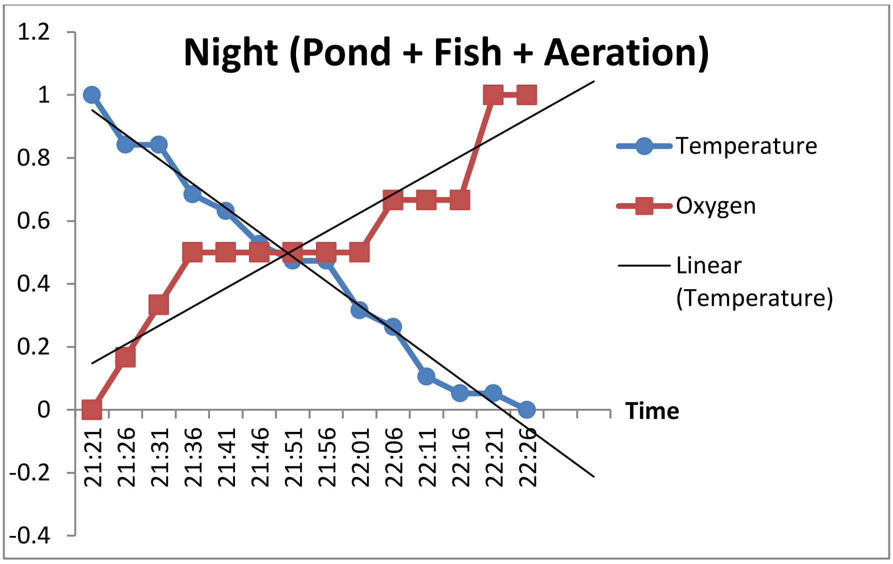
For this experiment, when oxygenator pump is installed, it is found that the increment of dissolved oxygen is enhanced as seen in Graph 4.13 and 4.14. The average normalized dissolved oxygen increment is calculated at 0.1192 which shows the best water condition for aquaculture farming. The oxygenator pump has increased the rate of dissolved oxygen increment up to 50% higher than the increment due to the drop in water temperature. Yet, the increment of the dissolved oxygen will be even higher if higher capacity oxygenator pump is used. Therefore, it is important to understand the oxygen intake by fishes and amount of dissolved oxygen increment at night to determine the optimum size of oxygenator pump to avoid over-design and over-engineering of aeration system.

Experiment 8: Water tank filled up with water and fishes plus oxygenator pump during night time.

Graph 4.15 shows the comparison of water temperature, pH and dissolved oxygen data for pond and fishes plus oxygenator pump at night. Graph 4.16 shows the normalized water temperature, pH and dissolved oxygen data for pond and fishes plus oxygenator pump at night.



Graph 4.15: Water Temperature, pH and Dissolved Oxygen Data for Pond and Fishes plus Oxygenator Pump at Night.

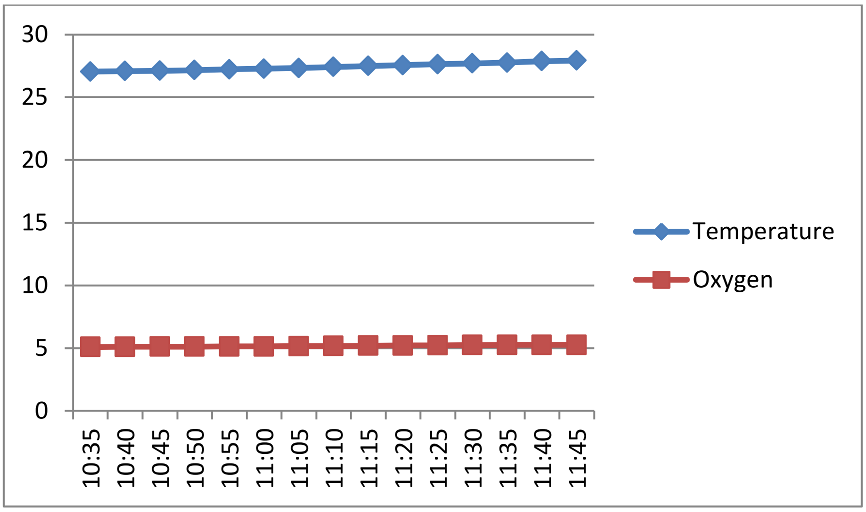


Graph 4.16: Normalized Water Temperature and Dissolved Oxygen Data for Pond and Fishes plus Oxygenator Pump at Night.

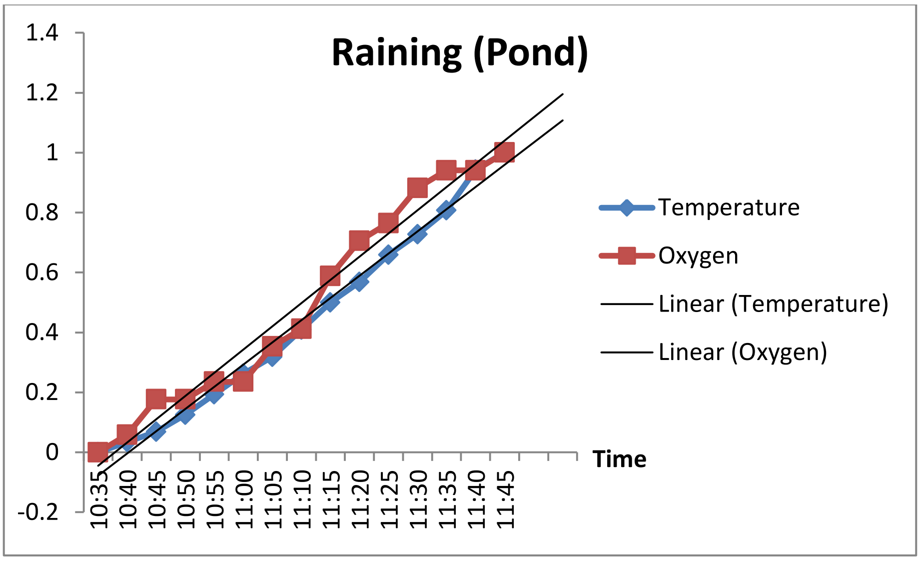
This experiment investigates whether the oxygenator pump is able to compensate to the oxygen intake of fishes during night time. Based on Graph 4.15 and 4.16, it is found that, despite of oxygen consumption of fishes, the decrement in temperature and presence of oxygenator are managed to ensure dissolved oxygen level to be maintained and increase from time to time. The average normalized dissolved oxygen increment is calculated at 0.0046. The pH of water does not show significant change due to fewer amounts of fishes used in the experiment. However, for different location, temperature changes at night might vary and this will cause the increment of dissolved oxygen to be different that the result obtained in the experiment.

Experiment 9: Water tank filled up with water during raining time.

Graph 4.17 shows the comparison of water temperature and dissolved oxygen data for pond during raining. Graph 4.18 shows the normalized water temperature and dissolved oxygen data for pond during raining.



Graph 4.17: Water Temperature and Dissolved Oxygen Data for Pond during Raining.

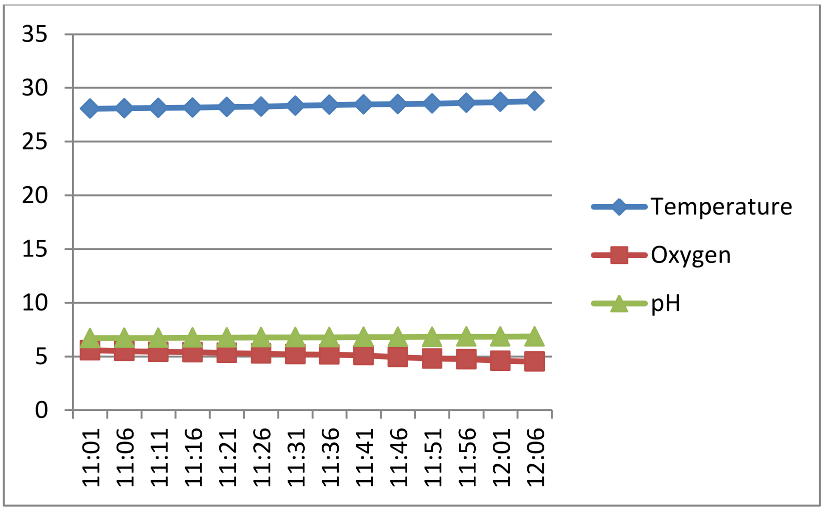


Graph 4.18: Normalized Water Temperature and Dissolved Oxygen Data for Pond during Raining.

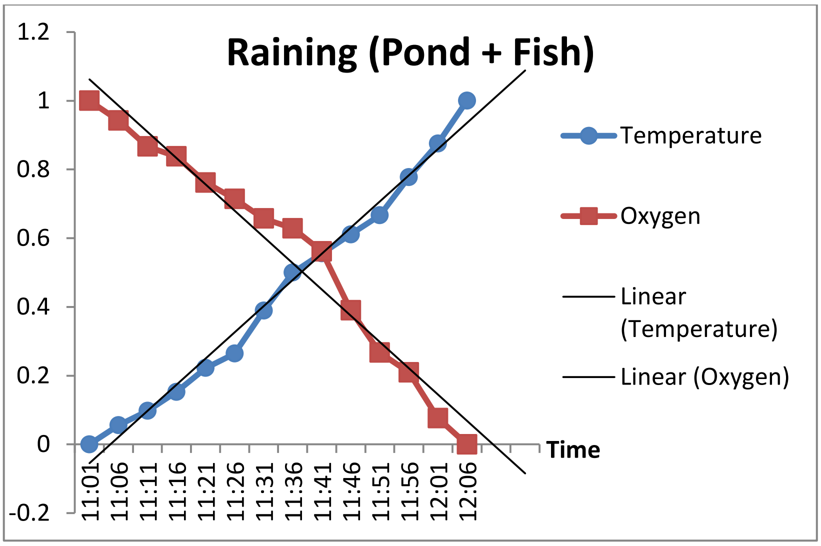
In this experiment, the effect of raining on the water temperature and dissolved oxygen level is investigated. Based on Graph 4.17 and 4.18, it is found that during raining, the water temperature reduces and the rain drops create movement on water surface. This condition increases the level of dissolved oxygen in the water. The average normalized dissolved oxygen increment is calculated at 0.0129. This means that raining helps to improve the level of dissolved oxygen in the water. Conversely, the increment of dissolved oxygen will vary if the factors such as size of rain drop, amount of rain and duration of rain. This is because bigger raindrop creates larger water movement, higher amount of rain will increased the amount of fresh water in the pond with higher content of dissolved oxygen and the longer the duration of rain, it will affect the temperature drop of water. All this factors will create different results but with the monitoring system, it is still able to provide the data and findings.

Experiment 10: Water tank filled up with water and fish during raining.

Graph 4.19 shows the comparison of water temperature, pH and dissolved oxygen data for pond with fishes during raining. Graph 4.20 shows the normalized water temperature, pH and dissolved oxygen data for pond with fishes during raining.



Graph 4.19: Water Temperature, pH and Dissolved Oxygen Data for Pond with Fishes at Night.

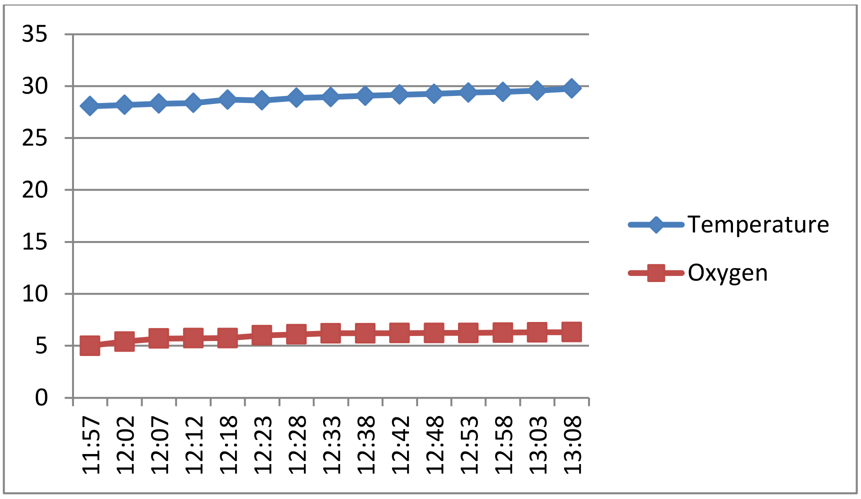


Graph 4.20: Normalized Water Temperature and Dissolved Oxygen Data for Pond with Fishes at Night.

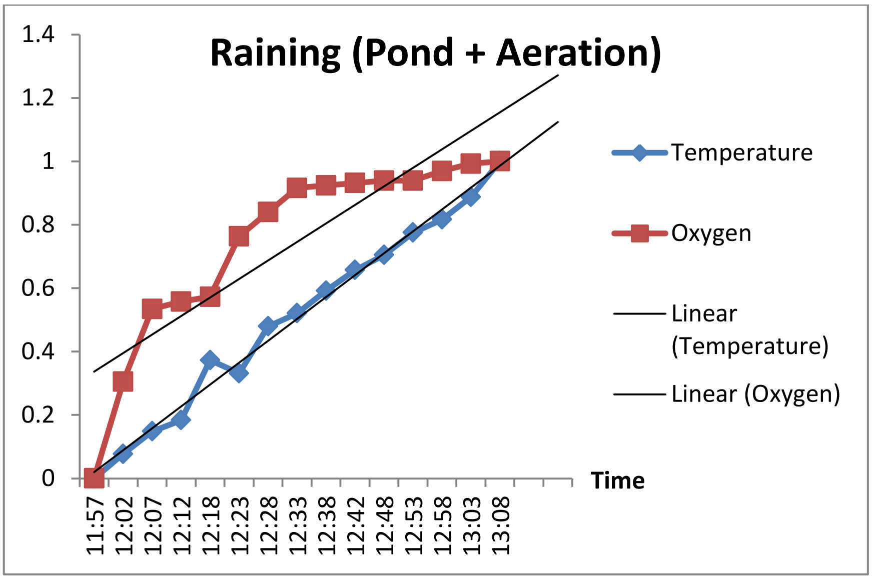
In this experiment, fishes are added into the pond during raining time to determine whether the increment of dissolved oxygen due to rain is able to compensate the oxygen intake by the fishes. Based on Graph 4.19 and 4.20, the results show that the raining itself is not enough to create sufficient dissolved oxygen for the fishes when the average normalized dissolved oxygen decrement is calculated at -0.0638. However, the raining condition during the experiment is only light raining with small rain drops. Different raining and rain drop sizes may produce different outcomes.

Experiment 11: Water tank filled up with water plus oxygenator pump during raining.

Graph 4.21 shows the comparison of water temperature and dissolved oxygen data for pond plus oxygenator during raining. Graph 4.22 shows the normalized water temperature and dissolved oxygen data for pond plus oxygenator during raining.



Graph 4.21: Water Temperature and Dissolved Oxygen Data for Pond plus Oxygenator Pump during Raining.

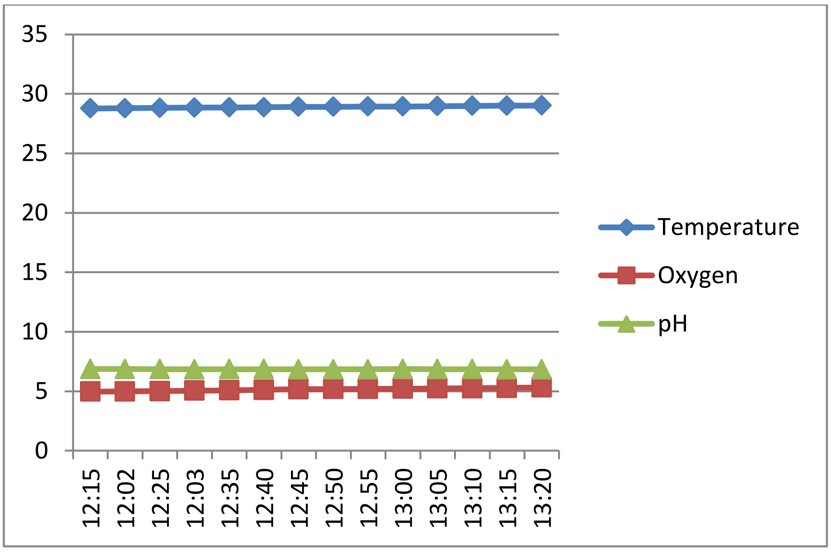


Graph 4.22: Normalized Water Temperature and Dissolved Oxygen Data for Pond plus Oxygenator Pump during Raining.

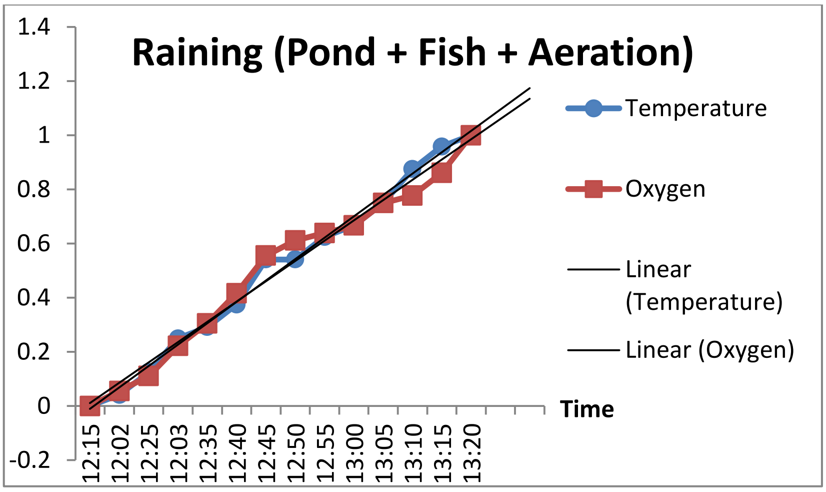
In this experiment, oxygenator pump is added to see the effect on the dissolved oxygen level during raining. Based on Graph 4.21 and 4.22, it is found that the oxygenator pump increases the increment of dissolved oxygen in the water by 50% and this condition is quite similar to night time. The average normalized dissolved oxygen increment is calculated at 0.0935. This shows that raining and aeration will create a better environment for growth of fishes compared to depending solely to the raining itself. However in actual condition, the incremental of dissolved oxygen will be vary because of different number of fishes, size of pond, capacity of oxygenator pump, different size of rain drop, duration of rain, and amount of rain.

Experiment 12: Water tank filled up with water and fishes plus oxygenator pump during raining.

Graph 4.23 shows the comparison of water temperature, pH and dissolved oxygen data for pond with fishes plus oxygenator during raining. Graph 4.24 shows the normalized water temperature, pH and dissolved oxygen data for pond with fishes plus oxygenator during raining.



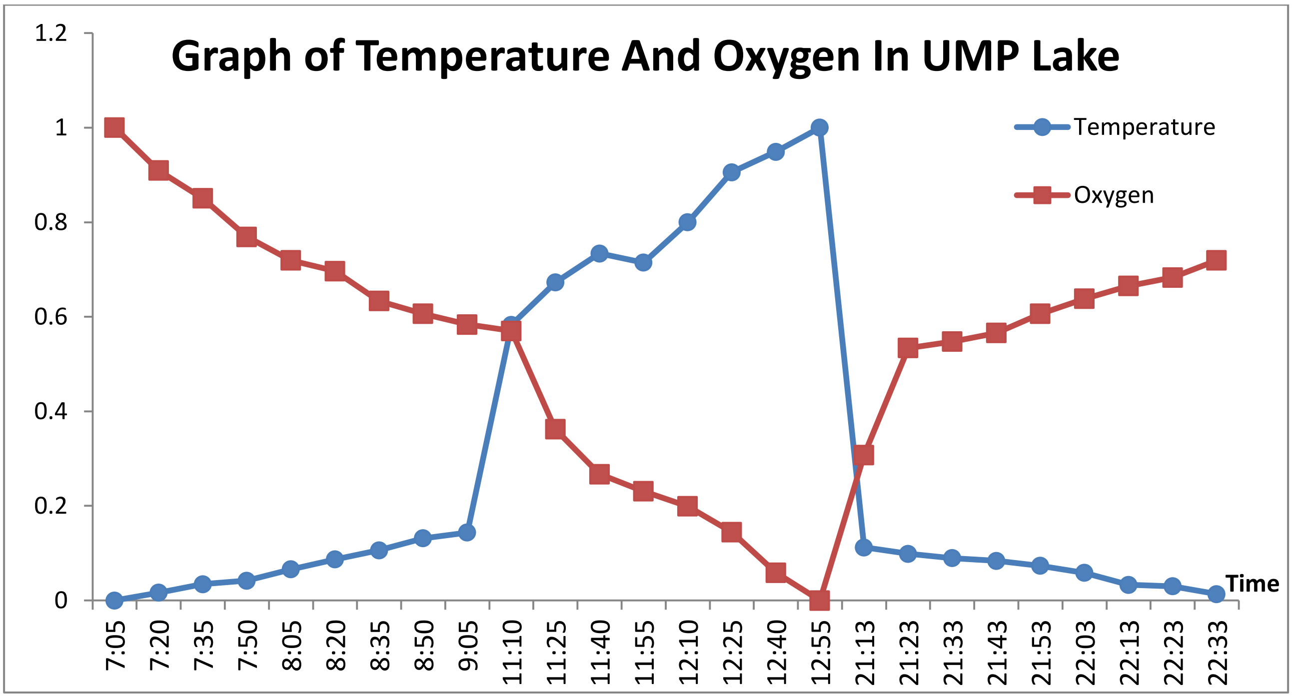
Graph 4.23: Water Temperature, pH and Dissolved Oxygen Data for Pond and Fishes plus Oxygenator Pump during Raining.



Graph 4.24: Normalized Water Temperature and Dissolved Oxygen Data for Pond and Fishes plus Oxygenator Pump during Raining.

In this experiment, fishes are added into the pond that is equipped with oxygenator pump during raining. Based on Graph 4.23 and 4.24, it is found that despite of the oxygen intake due to respiration of fishes, the amount of dissolved oxygen is sufficient enough to maintain an ideal condition of water with dissolved oxygen content being maintained at 5 mg/L. This shows that even during raining, aeration is still required to maintain the water quality for growth of fishes. The average normalized dissolved oxygen increment is calculated at 0.0285. With the monitoring system, the data of water quality can always be collected regardless of different conditions such as location, weather, size of pond and number of fishes.

4.2.2 UMP Lake Data Collection and Analysis



Graph 4.25: Water Temperature and Dissolved Oxygen Data in UMP Lake.

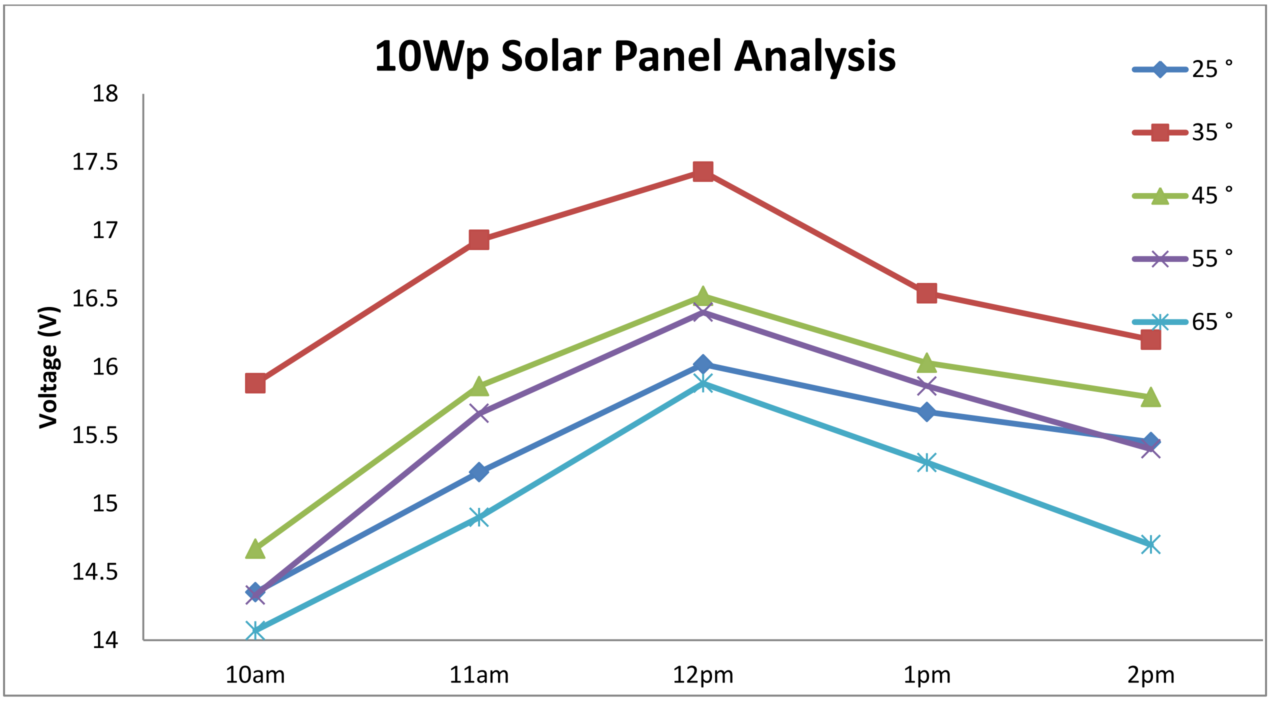
To further investigate and prove the relationship between water temperature and dissolved oxygen level as stated in literatures, it is important to conduct experiment and data collection at the actual lake by using the monitoring system designed. Therefore, an experiment has been carried out at the lake of University of Malaysia Pahang to find out the results. As shown in Graph 4.25, in the morning the water temperature of the lake increases and the decrement of the dissolved oxygen are recorded. This scenario continues towards the afternoon where temperature increment is more drastically resulting in higher decrement of dissolved oxygen level in the water. The experiment is continued until the night and it is when the water temperature starts to reduce and the effect of that is seen by the increment of dissolved oxygen level of the water. This proven that the results obtained through controlled experiment is the same as the one obtained in actual lake which further strengthen the fact that water temperature is the main factor affecting the level of dissolved oxygen level in water. It also proven that the monitoring system designed is able to monitor and produce real results which are beneficial to the aquaculture industries.

The results might be varying with different depth of water since the lake is more than 15 feet deep. Yet, the results obtained are still valid as stated in the literatures.

4.3 SOLAR STAND ALONE SYSTEM ANALYSIS

For the solar stand-alone system designed, the tilt angle of the solar module and the charge controller charging characteristic are studied and analysed.

4.3.1 Solar Module Tilt Angle Analysis

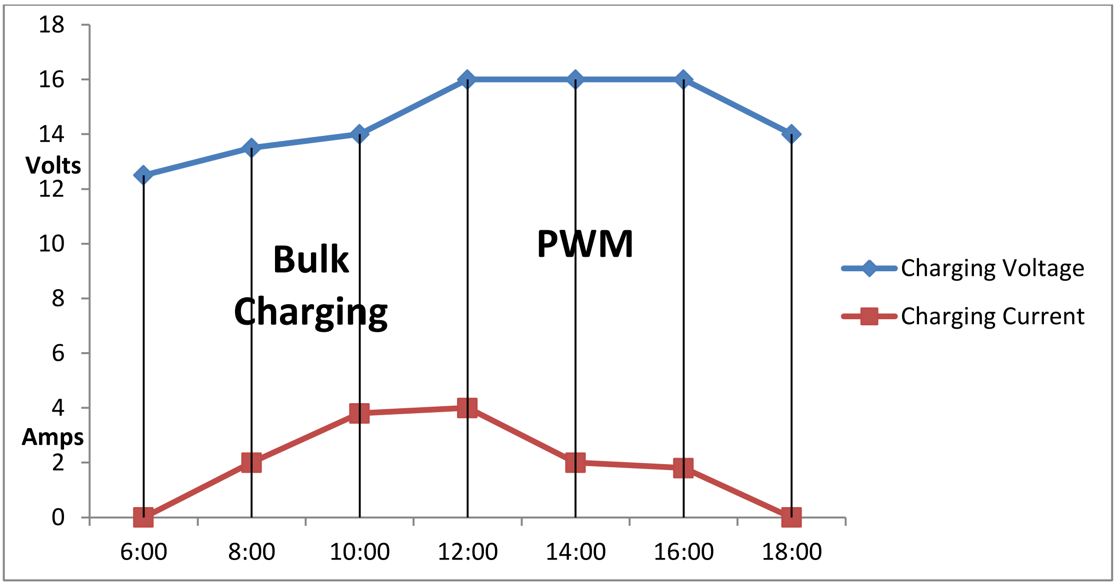


Graph 4.26: Solar Module Tilt Angle Analysis

In order to build the most efficient solar stand-alone system, the tilt angle of the solar module is the most important aspect as different angle will cause the module to receive different intensity of sunlight thus affecting the amount of electricity produced. Therefore, the experiment is conducted by changing different tilt angle at different time and the output voltages are measured using multimeter. Graph 4.26 shows the results of voltage outputs produced by tilt angles of 25°, 35°,45° , 55° and 65°. As illustrated, it is found that angle of 35° is the best tilt angle for the solar module as it enables the module to produce the highest voltage outputs compared to other angles at all time.

This experiment is carried out with the solar module facing 135° South East with no shading. Therefore, it can be concluded that in the installation, the best angle for the solar module would be 35°.

4.3.2 Solar Charge Controller Charging Characteristic.



Graph 4.27: Charging Characteristic of GAMMA 3.0 Solar Charge Controller.

Bulk charging is the state where 100% of available solar power is used to charge the battery because the battery voltage has not reached the boost voltage point. During the boost charge, also known as PWM charging, it is when the battery has been charged to the boost voltage point. To prevent overheating and excessive battery gas releases, constant-voltage regulation is applied. Before it is reduced to float charge, the boost stage is remained for 120 minutes. Finally in the float charge, the controller will reduce the voltage to a floating point where charging is conducted with smaller voltage and current. The purpose of float charging is to offset the power consumption caused by self-consumption and small loads in the whole system while maintaining the full battery storage capacity. If the loads continue to draw power from battery and sudden event where the load of system exceeded the solar charging current, the float set point would not be able to be maintained. Therefore, automatically, the controller will exit the float charging state and return to bulk charging.

4.4 CHAPTER CONCLUSION

The result collected by the monitoring system successfully proven the relationship of water temperature and dissolved oxygen level as in literatures. The most significant finding is that the rises in temperature for every five minutes will cause a decrement of 0.2% in dissolved oxygen level generally. While in raining and night condition, the drops of temperature for every 5 minutes shows the increment by average of 0.15% of dissolved oxygen content. However, both decrement and increment are still considered insufficient for respiration of fishes. Thus, when aeration system is installed, a significant 0.23% of dissolved oxygen increment is added on and with this, the ideal water condition can be maintained. The solar tilt angle and charging characteristic are also discovered that the most effective tilt angle is 35° with 135° South East with PWM Charging technology proven to be the best method for smart charging process. Therefore with these findings, it is concluded that the project successfully achieved the objective of developing a workable prototype.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATION

5.0 OVERVIEW

The chapter summarized the conclusion on the findings and analysis of the project. Project recommendation is also discussed for future development and improvement for commercialization purposes. The budget of the project is presented at the end of the chapter.

5.1 CONCLUSIONS

The fundamental studies on aquaculture industry have led to the finding of the three main factors affecting the water quality resulting to the effect on growth and quality of fishes and crustaceans. Through ground visit, the three factors were confirmed and led to the ideation of design and development of solar powered aeration system. Further researches are done to solve the problem of high electricity consumption by replacement with solar stand-alone system. The first objective is achieved when all the issues in aquaculture industry are successfully identified.

The second objective is to build a prototype of solar powered aeration system that is able to provide water quality data through the monitoring systems consisting of sensors and controllers. The prototype built is then used to carry out experiment on different weather and pond conditions to further proving the literature studies by experimental method. Based on the results obtained and discussed in Chapter 4, it is successfully shown that the sensors are able to send correct data to the Microsoft Excel via Arduino Controllers. The oxygenator pump used as the underwater aeration is also able to function with the solar stand-alone system that has been designed. The solar module tilt angle is also determined to find the best angle to produce the highest voltage outputs which successfully achieved the third objective which is to power the aeration system using solar stand-alone system.

Finally, the prototype overall performance and efficiency is considered high and suitable to be implemented for the aquaculture industry.

5.2 RECOMMENDATIONS

For the future improvement of the solar powered aeration system for commercialization purposes, there are some recommendations to improve the current prototype.

i) Wi-Fi system can be applied in the monitoring system to wirelessly transfer the data of water temperature, dissolved oxygen level and pH level of water directly to the main computer.

ii) Website should be used as well to replace Microsoft Excel as it increases accessibility for the farmers anytime and anywhere.

iii) Fewer microcontrollers can be used in the prototype for cost reduction by exploring the virtual transmits and receives port of the Arduino Uno.

5.3 BUDGET AND COMMERCIALISATION

Table 5.1: Estimation Cost of Prototype

No	Description	Unit	Price (RM)
1	Arduino YUN	1	350.00
2	Arduino Uno	2	100.00
3	Water Temperature Sensor	1	30.00
4	Dissolved Oxygen Sensor	1	1900.00
5	pH Sensor	1	900.00
6	Solar Module 10W	1	100.00
7	Oxygenator Pump	1	150.00
8	Charge Controller	1	100.00
9	Lithium Battery 5Ah	1	85.00
		Total Estimated Cost	**RM 3715.00**

Based on the cost estimation in Table 5.1, this project could be commercialized because there are improvement that can be done in term of reducing number of controllers and buying components in bulk that will reduce the cost of project overall. The most expensive component would be the dissolved oxygen sensor because for this prototype, it is specially ordered and purchased from New York, United State.

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}

APPENDIX A

PROGRAMMING

Dissolved Oxygen Sensor Arduino Programming

```
#include <SoftwareSerial.h>

#define rx 2

#define tx 3

SoftwareSerial myserial(rx, tx);

String inputstring = "";

String sensorstring = "";

boolean input_string_complete = false;

boolean sensor_string_complete = false;

float DO;

void setup() {

  Serial.begin(9600);

  Serial.println("CLEARDATA");

  Serial.println("Label,Current Time,Sensor Value");

  delay(1000);

  myserial.begin(9600);

  inputstring.reserve(10);

  sensorstring.reserve(30);

}
```

```
void serialEvent()
{
  inputstring = Serial.readStringUntil(13);
  input_string_complete = true;
}
void loop()
{
Serial.print("DATA, TIME");
Serial.println(sensorstring.toFloat());
delay(300000);
if (input_string_complete)
{
    myserial.print(inputstring);
    myserial.print('\r');
    inputstring = "";
    input_string_complete = false;
  }
 if (myserial.available() > 0)
{
    char inchar = (char)myserial.read();
    sensorstring += inchar;
    if (inchar == '\r')
{
```

```
 sensor_string_complete = true;
  }
  }
 if (sensor_string_complete== true)
{
   Serial.println(sensorstring);
   if (isdigit(sensorstring[0]))
 {
     DO = sensorstring.toFloat();
     if (DO >= 6.0)
{
       Serial.println("high");
 }
     if (DO <= 5.99)
{
       Serial.println("low");
}
}
   sensorstring = "";
   sensor_string_complete = false;
}
}
```

pH Sensor Arduino Programming

```
#include <SoftwareSerial.h>

#define rx 2

#define tx 3

SoftwareSerial myserial(rx, tx);

String inputstring = "";

String sensorstring = "";

boolean input_string_complete = false;

boolean sensor_string_complete = false;

float pH;

void setup()

{

Serial.begin(9600);

Serial.println("CLEARDATA");

 Serial.println("Label,Current Time,Sensor Value");

 delay(1000);

myserial.begin(9600);

inputstring.reserve(10);

sensorstring.reserve(30);

}

void serialEvent() {

inputstring = Serial.readStringUntil(13);

input_string_complete = true;
```

```
}
void loop() {
Serial.print("DATA, TIME");
Serial.println(sensorstring.toFloat());
delay(3000);
if (input_string_complete) {
myserial.print(inputstring);
myserial.print(inputstring);
inputstring = "";
input_string_complete = false;
}
if (myserial.available() > 0) {
char inchar = (char)myserial.read();
sensorstring += inchar;
if (inchar == '\r') {
sensor_string_complete = true;
}
}
if (sensor_string_complete == true) {
Serial.println(sensorstring);
if (isdigit(sensorstring[0])) {
pH = sensorstring.toFloat();
if (pH >= 7.0) {
```

```
Serial.println("high");
}
if (pH <= 6.999) {
Serial.println("low");
}
}
sensorstring = "";
sensor_string_complete = false;
}
}
```

Water Temperature Sensor Arduino Programming

```
#include <OneWire.h>

#include <DallasTemperature.h>

#include <LiquidCrystal.h>

#define ONE_WIRE_BUS 7

OneWire ourWire(ONE_WIRE_BUS);

DallasTemperature sensors(&ourWire);

LiquidCrystal lcd(12, 11, 5, 4, 3, 2);

void setup()

{

pinMode (ONE_WIRE_BUS, INPUT);

delay(1000);

Serial.begin(9600);

Serial.println("CLEARDATA");

Serial.println("Label, Current Time, Sensor Value");

delay(5000);

lcd.begin(16,4);

lcd.setCursor(0,0);

lcd.print("Dallas");

lcd.setCursor(0,1);

lcd.print("Temperature");

delay(3000);

lcd.clear();
```

```
sensors.begin();

}

void loop()

{

sensors.requestTemperatures();

Serial.print("DATA, TIME");

Serial.println(sensors.getTempCByIndex(0));

lcd.begin(1,1);

lcd.print (sensors.getTempCByIndex(0));

lcd.setCursor (6,1);

lcd.print (" C ");

delay(1000);

}
```

APPENDIX B

GANTT CHART

Project Activities	Semester II 2015/2016					Semester I 2016/2017			
	Feb	Mar	Apr	May	Jun	Sept	Oct	Nov	Dec
Topic Selection	1 day								
Literature Review				183 days					
Arduino Yun Coding		92 days							
Sensors Analysis		92 days							
3D drawing - Water Mill		7days							
PSM1 Seminar			1 day						
Hardware Development				152 days					
Monitoring System Experiments					91days				
Solar Stand-Alone Experiment							1day		
PSM2 Exhibition								1 day	
Thesis Submission									5days