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IOT-BASED MONITORING OF AQUACULTURE SYSTEM

Omar Abdulhaleem Nasir
University Putra Malaysia (UPM), Malaysia
omar.abdulhalem592@gmail.com

Sharifah Mumtazah
University Putra Malaysia (UPM), Malaysia
s_mumtazah@upm.edu.my

Abstract

Aquaculture is considered to be a station of interest in many different countries, including Malaysia, which has started on developing its aquaculture system since the 1920s. The two main reasons behind this interest are the great food source for locals and a very good source of income that can help in amazingly increasing the economy of a country, so aquaculture should be well-taken care of, especially, in terms of water quality. Therefore, the main focus and goal of this paper are measuring the water quality parameters that can suit many types of aquacultural living species, especially the fish species. Five sensors are positioned in a one-tone fish tank to measure and monitor the water parameters' fluctuations, especially during the feeding time. These smart sensors are a waterproof temperature sensor, water PH sensor, water turbidity sensor, air temperature sensor, and light sensor. These sensors are connected to an Arduino board, which sends the collected data from sensors to the GSM and then to Thing speak cloud, which is an easy way to monitor data fluctuations 24 hours a day. As a result, the collected data of water parameters seem to be slightly fluctuating which does not affect the health of the fish in the tank. The reason of choosing these sensors is to also illustrate the statistical correlation between air temperature and water temperature, light intensity and turbidity, turbidity and PH, especially during feeding time. These IoT sensors are very cheap to *be bought and easy to be installed and monitored on the cloud. Therefore, this could be very cost-effective for many farmers who want to keep their aquacultural species safe and reproducing.*

Keywords

Water Temperature, Water PH, Water Turbidity, Air Temperature, Ambient Light Sensor

1. Introduction

IoT, which stands for Internet of Things, is playing a great role in facilitating many life aspects, including the aquaculture farming aspect. Since IoT is known as a collection of many different smart sensors that can help in doing the tasks and functions we need to do with a much lower costs and more accurate performance.

Aquaculture is considered to be playing a vital role for thousands of people, whom they consider as their main source to survive because it is considered to be their main job to gain money from. Let's take Malaysia as one of the most countries that considers its aquaculture industry as its main source for survival and economic growth. Basically, thousands of Malaysian local people depend on fishing as their source of income. Not only that, aquaculture is also considered to be the main key in increasing the economy of Malaysia because as long as the population is increasing, the demand for fish is also increasing which obviously mean that more fish would be bought and consumed by those who live in this blessed country (A. Yusoff, 2015). The demand for fish in increasing because it is considered to be the main healthy source for surviving, especially for those who live in the country side where fish is available all the time and can easily be fished and eaten as a health animal protein. Furthermore, statistically, it is been estimated that the fish demand would amazingly be increased to about 1.9 million tons by 2020 (A. Yusoff, 2015). Therefore, we can see and notice that fish is one of the main food sources to Malaysians, and without any exaggeration, we can say that Malaysian's are considering fish as almost their everyday food. Basically, Malaysians spend about 20% of their expenditure on fish food which is quite a lot (A. Yusoff, 2015). Therefore, statistically, Malaysians are considered to be the most fish consumers in the world, so we can see how aquaculture, especially fish matters to the Malaysians. Moreover, fish mainly comes from the sea that surrounds Malaysia, so there is a huge amount that can cover the locals' needs, and a small portion can be used for exchange as well. There are lots of fish types that are valuable, such as shrimp, grouper, and snapper, so these would be breed domestically which could help in increasing the total income of Malaysian's economy. Fish farming is a very common occupation in Malaysia, and it used and still is helping in participating to boost the income by addingRM 992million approximately. Those people who breed fish in ponds, tanks, cages, and pools are playing a vital role in increasing the aquaculture commodities, and those people are called culturists. This below table clearly shows the systems that culturists use to produce aquaculture commodities (A. Yusoff, 2015).

Table 1: *Malaysian Aquaculture Production Systems (A. Yusoff, 2015)*

Brackishwater	Area	Culturists (No.)	Freshwater	Area	Culturists (No.)
Ponds (ha)	7,525.43	1,174	Ponds (ha)	5,642.31	18,875
Cages (m_2x 1000)	2,374.8	1,984	Cages (m_2x 1000)	404.0	1,357
Bottom culture (ha)	10,740.2	1,004	Ex-mining pools	1,794.34	211
Raft culture (m_2x 1000)	65.4	793	Raft culture (m_2x 1000)	430.5	1,845
Long line (ha)	1259	12,896.8	Long line (ha)	28.36	205

Aquaculture is one of the most important food source and cash crop in many countries, including Malaysia, so here comes the role of another aspect that we need to be focusing on which is water quality. Water quality is one of the most important elements that governments and culturists have to be careful of because water has to be clean enough to help the fish to reproduce more and more number of fish; otherwise, fish would not be able to reproduce because poor water quality could lead to significantly affect the fish health. As a result, it could lead to several diseases that could lead to the death of fish. Once fish get diseased, it would eventually lead to severely affect the humans' health, especially those countries that consider fish as one of their main meals like Malaysia (A. B. Dauda, 2018).

One of the most commonly adopted and cultured fish type in Malaysia is the catfish. Catfish is one of the African fish species that was adopted and farmed by many different courtiers, including Malaysia, which became one of the major countries who adopted this type of fish and became the major type of fish that Malaysian farmers cultured. Catfish did not only help in increasing the income of Nigerian economy, but it also helped in incredibly increasing the food source of the Malaysian locals and became a cash crop for them as well.

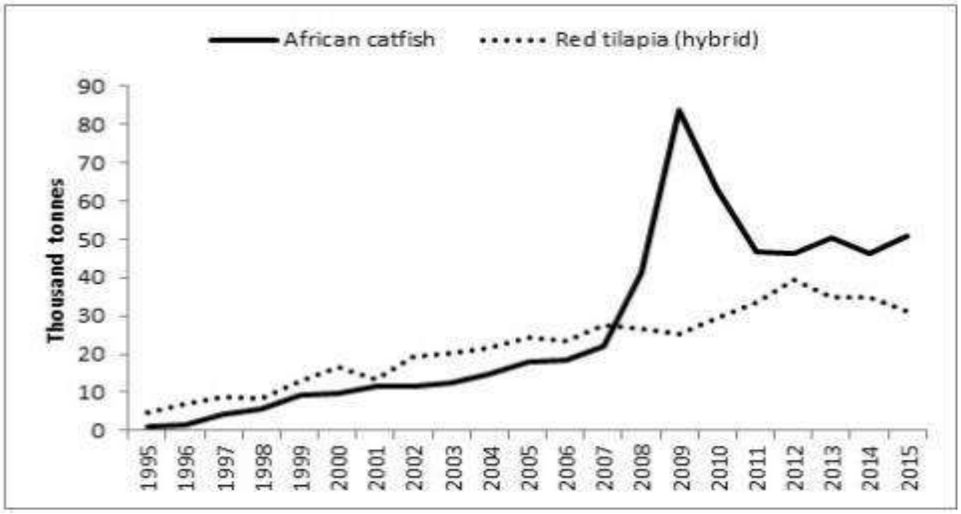

Figure 1: *Aquaculture Production of Catfish in Malaysia (A. B. Dauda, 2018)*

Therefore, this above figure clearly shows how aquaculture production was exponentially increasing in Malaysia, and these data were collected from the fisheries themselves. We can obviously notice and compare how aquaculture was not given any attention before the 1990s, but we can notice how it became a major interest by Malaysian farmers to increase their economy income and meet the locals' needs at the same time. Actually, the fish production number started to be highly increasing with the emergence of the new techniques that helped the farmers to learn how to meet the needed requirements of fish nutrients, and then the percentage of fish industries started to grow up since the 1980s (A. B. Dauda, 2018).

As a result, we can tell how aquaculture is playing a key role in working as a food supply for Malaysians' population. It also plays a vital role in providing more business employment for locals, and this aquaculture helped in amazingly increasing the cash income, which reached up to RM268.970mil (N. Vaghefi, 2020). We can notice this increase from the below statistical figure.

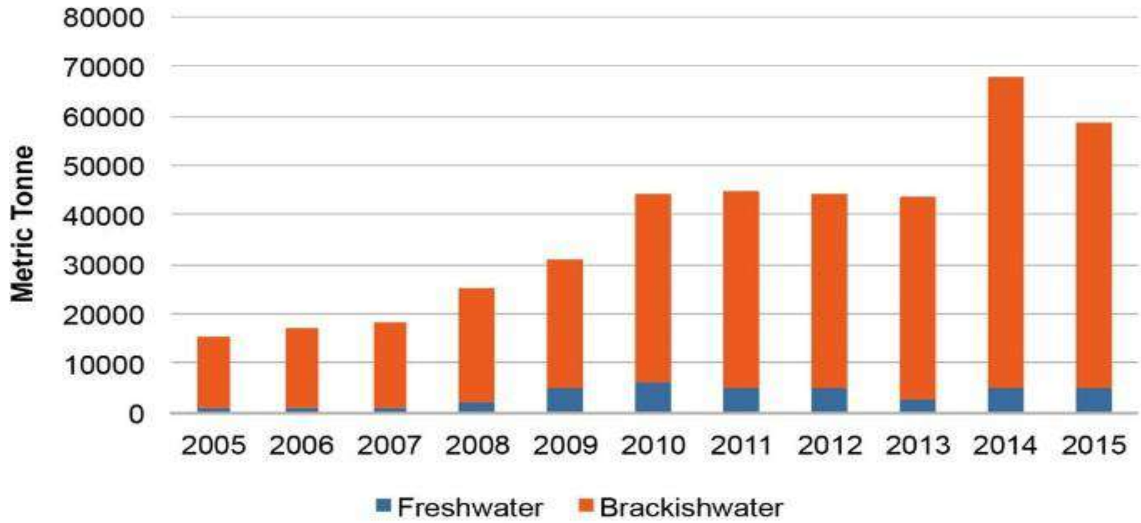

Figure 2: *Statistics on Aquaculture Production in Malaysia (N. Vaghefi, 2020)*

Therefore, we can tell what role aquaculture is playing in Malaysia, and besides that, aquaculture became a necessary food source to meet the needs of the 30.75 million inhabitants (N. Vaghefi, 2020). This above figure demonstrates the statistics of one type of fish production of only one city in Malaysia, which is Penang, so we can imagine how aquaculture farming could be beneficial for all Malaysians once other cities produce such an amount of aquacultural species.

Water quality is a very significant issue that governments need to be taking into consideration, not only to save the life of aquaculture, but to also save the life of humans who consider water as the main source of survival. Unfortunately, there are statistics claim that there are about 5 million people die annually because of the poor water quality that spreads diseases to people who most of the time cannot handle those waterborne diseases which lead them to die (S. Geetha, K. Mezgebe). The death of these people is basically because of water pollution that is made by the people themselves by throwing their trash nearby water, or even by industries that ship oil or gasoline to the nearby regions via ships which leak some amount of these transferred commodities, so these are the most catastrophic factors that could significantly lead to water contamination. Therefore, water quality needs to be carefully considered to save humans' life as well as aquaculture life. Thankfully, we are living in an age of technology where there are several sensors and tools that could help in monitoring the conditions of water. Besides, even though there is a widely accepted standard that is also being applied in Malaysia which is named as myGAP. MyGap stand for Malaysian Good Agricultural Practice, and it is responsible for emphasizing on environmental, economic, and social facilities to ensure that all products are safe and ready to be used, so MyGap plays a great role in safeguarding farms from almost every kind of disease. Also, it is the one that is responsible for allowing large farming industries to export their commodities overseas. Therefore, such large farming industries have to get the approval from myGAP in order to be able to export their livestock, and this can be very difficult to be done with the farmers who own small farming lands because it would cost them a lot of money, so here comes the role of this paper's suggestion ("Aquarium Fish Aggression", 2019).

This paper mainly would be presenting the significance of water quality to save the life of aquaculture, especially the life of fish, and the monitoring would be IoT based, and some observations would be done in order to check what parameters that can affect the quality of water. The suggested IoT tools would be inexpensive to apply, and it would also be easy to implement. The needed tools are: (Arduino microcontroller, water temperature sensor, water PH sensor, and water turbidity sensor). Off course, there are many other parameters that can badly affect the quality of water as they would be mentioned in the below table 2, but these three parameters are chosen to be enough for controlling water quality and inexpensive to be applied.

Table 2: *Water Quality Parameters ("Aquarium Fish Aggression", 2019)*

Parameters	Sources	Potential Health Effects	Fresh Water Guideline mg/L	Cost (RM)
PH	Due to different dissolved gasses and solid.	Bitter test, corrosion, affect mucus membrane	EDWQ, 2010 -WHO, 2008 6.5-8.5 6.5-8.5	70-80
Temp.	Due to chemical reaction, hot waste water.	Influence chemical, biochemical, biological of aquatic system.	- -	10-15
EC	Due to different dissolved solid.	High conductivity increases corrosive nature of water.	- 500 S/cm	87-90
Turbidity	Soil runoff	Higher level causing bacteria.	7 NTU 5 NTU	88-90
TDS	From the presence	Undesirable taste	1000 1000	70

1.1 Research Problems

In fact, there are two major problems that grabbed the attention to propose and focus to do some study regarding this topic. The first problem is the environmental problem, which is mostly related to the water quality, which has a very terrible effect on the fish health and production. The second issue is the lack of monitoring. In the past, it was very difficult to keep track with the changes of water conditions because the needed tools for measuring water quality elements were not existed yet. However, nowadays, it is becoming much easier to keep track or maintain the water quality conditions by deploying the newly invented smart devices that can enable us to get an updated status of water quality conditions. Therefore, with the availability of these cost-effective smart sensors, people would be eligible to monitor and measure the water quality conditions. Actually, the main reasons that prevent farmers from monitoring the daily conditions of water quality is the cost, which forces them to ignore the fact that water conditions should be carefully monitored because they cannot afford the prices that they have to pay to get a suitable water conditions that can keep their farmed fish alive and reproduce. For example, MyGAP is one of the standards that can certifies farmers to continue farming their fish because they are the ones who can make sure that the water environment of the farmers are clean and suitable, but at the same time, it can cost farmers thousands of Ringgits, which is a very high cost for the farmers to afford. Therefore, this report proposes cost-effective tool that can help in monitoring the water quality. Plus air temperature sensor and light sensor would also be added outside the fish tank. The reason for adding these two sensors is to make sure whether the air temperature has any effect on the water temperature, and to also check if the light sensor is added, would there be any effect on water turbidity with and without the presence of light.

1.2 Research Aims and Objectives

The main aim of this research is to design, develop and study the effectiveness of inexpensive IoT solution to monitor water quality (water temperature, pH and turbidity) in aquaculture fish tanks:

The main aims can be divided into the following sub-objectives:

1. To investigate the impact of air temperature on water temperature in fish tanks.
2. To investigate the effect of fish feeding on water pH and turbidity in fish tanks.
3. To investigate the impact of light ambient on water turbidity in fish tanks.

1.3 Research Scope

The scope of this project is limited to three main points as the following:

1. Water quality monitoring in terms of PH, temperature, and turbidity, so the sensors of these three aspects would be implemented in a one- tone fish tank.
2. Air temperature sensor and light sensor would be placed outside the one-tone fish tank in order to check if there is a correlation between water temperature and air temperature, and also to check if the light ambient has any impact on the water turbidity values.

2. Methodology

2.1 Introduction

This paper is presenting and applying the types of sensors that are used to check and monitor the water quality of aquaculture. There are five sensors that would be installed in one-tone fish tank, and these sensors are: Waterproof Temperature sensor, water PH sensor, water Turbidity sensor, Air temperature sensor, and Light sensor. The type of fish that are in the one-tone tank is called Lemon Barb. These five sensors are installed in a fish farming environment, and this environmental fish farming is created for the purpose of giving UPM students to explore and analyze many different aspects of fish and water quality.

2.2 Water Temperature

Starting with the temperature sensor, it is a sensor used to measure the hotness and coolness of a solution, which is water in our case. The chosen type of this sensor is DS18B20, which is able to accurately read digital data. This below figure shows how temperature sensor looks like.

Figure3: *Temperature Sensor (Daigavane, 2017)*

2.3 Water PH

For the PH sensor, its role is to measure the alkalinity or acidity of a solution, and it ranges from 0-14. If the PH ranges are less than 7, they indicate that the solution is acidic, and if they are above 7, they indicate that the solution is alkaline, and if it reads 7, it means that the solution is neutral. The power supply that this sensor works on should be 5V, and the normal range that this sensor reads is from 6 to 8.5. The PH figure is mentioned in figure 4.

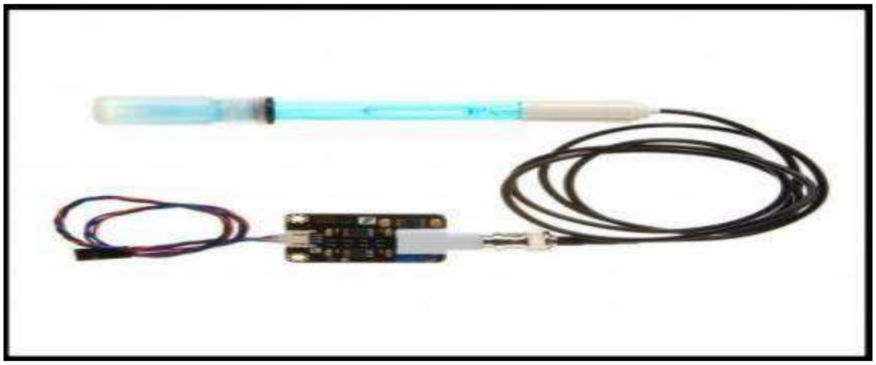

Figure 4: *PH Sensor (Daigavane, 2017)*

2.4 Water Turbidity

In terms of the turbidity sensor, its main role is measuring water transparency, so it is responsible for indicating the level or degree that water loses its transparency and this below figure shows how the sensor looks like. Basically, it measures the water clearness, so the readings we get from this sensor represent the level of water clearness, and its measuring unit is NTU. This water turbidity sensor is clearly illustrated in the below figure, which is figure 5.

Figure 5: *Turbidity Sensor (Daigavane, 2017)*

2.5 Air Temperature

The forth sensor, which is the air temperature and humidity, is responsible for measuring the outside temperature and humidity of the environment. This sensor is installed in order to prove that the outside temperature can play a role in affecting and changing the water temperature of the fish tank (Z. Slobodova, 1993) . This below figure shows how this sensors looks like.

Figure 6: *Air Temperature and Humidity (Nichani, 2017)*

2.6 Light Sensor

The last sensor that would also be installed in the one-tone fish tank is the light sensor, which is also known as the LDR (Light Detector Resistor). The main purpose of choosing this type of sensor is to be able to predict the value of turbidity with and without the presence of light. Meaning that the purpose of this sensor is to make sure if the light has any role in affecting the water turbidity values or not.

Figure 7: *Light Sensor(LDR) ("Light Dependent Resistor",2019)*

2.7 MCU Node ESP8266

To enable all of these above sensors to send their collected data to cloud, we need to add a device that has the WiFi feature because Arduino micro controller does not have a WiFifeature, so we chose to have the MCU Node ESP8266. MCU Node ESP8266 is an open source board that can help in sending the readings of these five sensors to cloud by sending them to the GSM and then to cloud. Here is how this board looks like in the previous figure, which is demonstrated in the below figure.

Figure 8: *MCU Node ESP 8266*

2.8 Tools Pricing Table

Table 3: *Sensors' Pricing Table*

Sensor Type	Price
Waterproof Temperature Sensor (DS18b20)	RM 48.00
PH sensor	RM 147.00
Turbidity sensor	RM 55.00
Air Temperature Sensor (DHT11)	RM 9.00
Light Sensor (LDR)	RM 5.00
MCU Node ESP8266	RM 20.00
Jumper Wires (3 sets)	RM 3.00 per set

We can tell how cheap the prices are of these seven tools, and they can be easily affordable by the farmers rather than paying a lot of money to get their water environment clean and maintained every short period of time.

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2.9 The General Architecture of the Proposed System

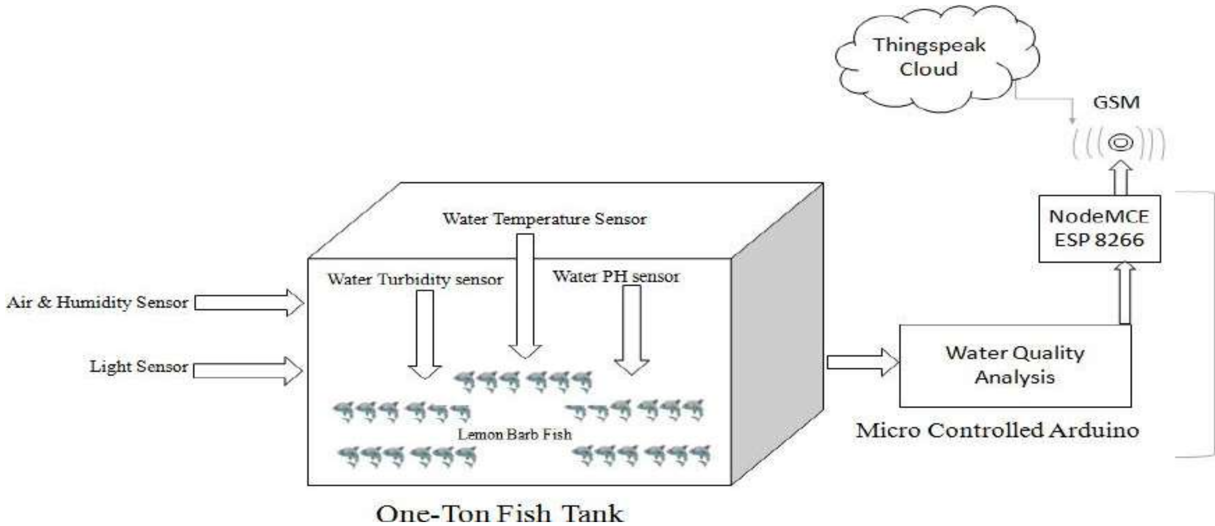

Figure 9: *Block Diagram (2.1) of the Proposed System*

The above diagram is showing all of these five sensors that would be installed in a fish tank, and all of these five sensors are connected to an Arduino board. Three of these sensors would be placed inside the tank, and they are the waterproof temperature sensor, water PH sensor, and water turbidity sensor. While the other two sensors, which are the air temperature and the light sensor are positioned outside the tank. After connecting these five sensors to Arduino and Node MCU ESP 8266, data of these sensors can easily be sent to GSM and immediately to the Thingspeak cloud so that we can monitor the sensors' readings on the cloud. Therefore, we can visualize the sensor is impacting the other. For example, by monitoring the readings of all five sensors, we can check if the air temperature is affecting the water temperature or not, or we can also check if the feeding of Lemon Barb fish is impacting the water PH and water turbidity or not. At the same time, we can also check if the light has any role of affecting the tank's water turbidity values or not. These types of impacts would be realized in the results section by comparing the graphs of the collected data of each sensor.

2.10 Thingspeak Cloud

There are some steps that need to be done in order to be able to send sensors' readings to Thingspeak cloud:

Step 1: A user needs to be signing up on this website: www.thinspeak.com, and then that user have to create own user name and password.

<u>Step 2</u>: After creating the account and signing in, the user has to create a channel through which he/she can send data to as it is illustrated in the below figure.

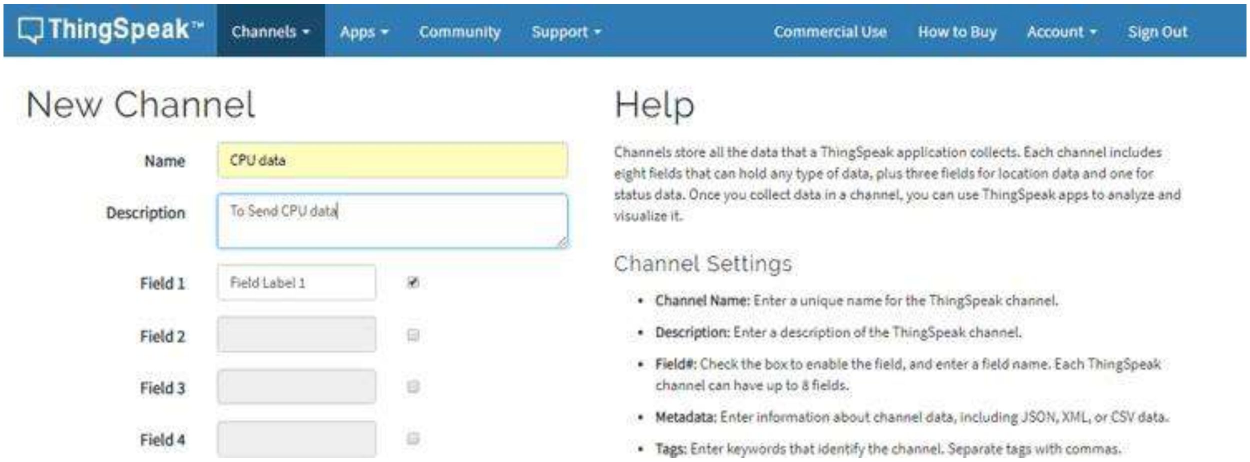

Figure 10: *Creating a Channel on Thingspeak ("How to Send Data to …. ", 2019)*

After creating a new channel, the user is required to name that created channel, for example, in our case, the name of the channel is Water Quality. Then the user should realize that these fields are the positions on which data will be stored. The user should know how many sensors he or she has so that each sensor would be occupying a field. Then after ticking the number of fields, the user can click on the save channel **button.**

<u>Step3:</u> Acquiring an API key from Thingspeak

In order for the user to be able to send his collected data to Thingspeak, he has to get the API key, which can be found in the channels column as it is demonstrated in the below figure.

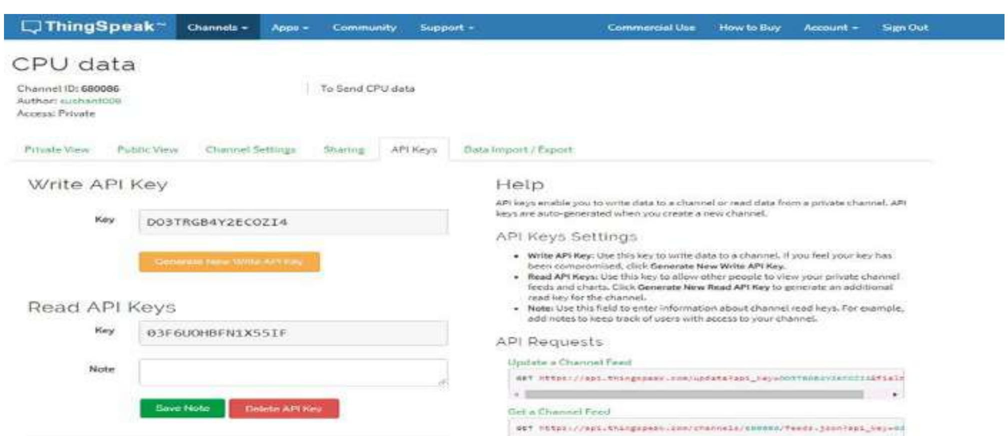

Figure 11: *Getting API Key on Thingspeak ("How to Send Data to …. ", 2019)*

The API key that the user needs is only the **Write API Key**. This key is unique, and it is a key element that helps in sending data to the specified fields on Thingspeak. These steps would make much more sense if you read the code of all five sensors, including the method of transferring data to Thingspeak, which is written at the very end of the paper.

2.11 Fish Farming Site

After collecting all of the mentioned five sensors, we were able to reserve a fish tank in the fish farming site Puchong, and its capacity is one tone. The below figure shows how this site looks like.

Figure 12: *Fish Farming Site*

2.12 Sensors' Installations

The below figure shows the one ton fish tank that we installed our sensors in. As it is illustrated in figure 14, the sensors are all placed inside the fish tank except the air temperature sensor and the light sensor, which were placed outside the fish tank in order to get the air temperature and light sensor values and compare them with the readings of the inside water three sensors.

Figure 13: *One-Tone Fish Tank*

3. Results and Discussion

3.1 Air Temperature and Water Temperature Values

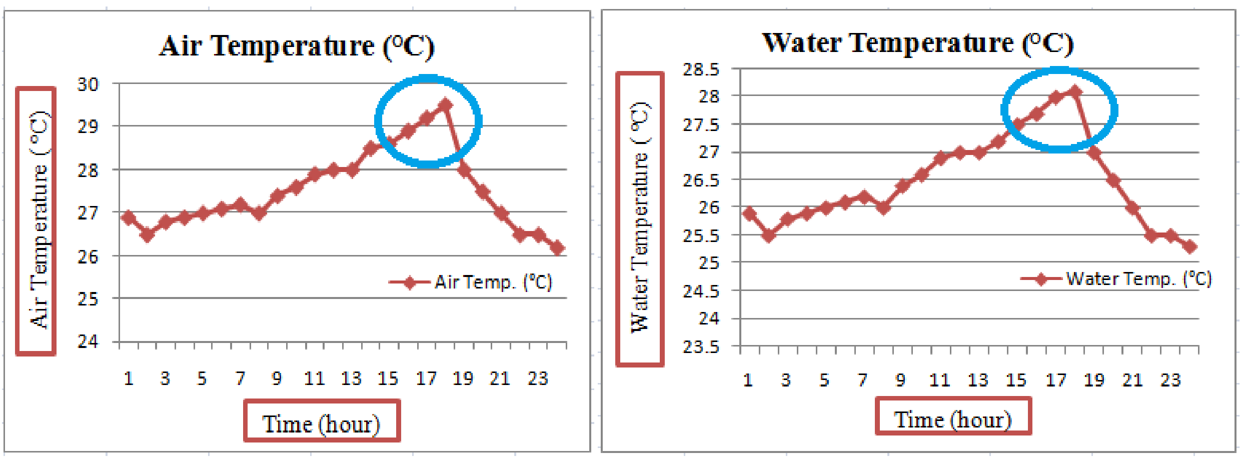

Figure 14: *Air Temperature & Water Temperature(°C) for Day 1*

Table 4: *Water and Air Temperature Statistics*

Day	Standard Deviation of Water Temp. (°C)	Average of Water Temp. (°C)	Standard Deviation of Air Temp. (°C)	Average of Air Temp. (°C)	Statistical Correlation (r) between (Water Temp. & Air Temp.)
1	0.81	26.61	2.64	27.56	0.85
2	0.63	26.71	2.58	27.61	0.86
3	0.59	26.76	2.54	27.66	0.85
4	0.59	26.81	2.52	27.69	0.92
5	0.59	26.88	2.46	27.76	0.93
6	0.56	26.91	2.40	27.81	0.91
7	0.46	27.01	2.37	27.83	0.95

Figures 14 shows the water temperature and air temperature of the fish tank starting from about 25°C till about 27°C. These water temperature values are within the range of the temperature values that can help in keeping fish survive. The point of providing these hourly collected data of water and air temperature is to prove that air temperature is greatly affecting the water temperature, and we can clearly visualize that once the air temperature increases, the water temperature gets affected and increases as well. Thankfully, Malaysia is luckily located in a geographical location where its weather is kind of stable; otherwise, it would be very difficult to control the air temperature.

Actually, temperature differs from one fish species to another, but the temperature range of this type of fish should be surrounded between (24°C-27°C); otherwise, this type of fish cannot survive in other temperature degrees. Off course, there are other types of fish that can live in much cooler water temperature like Golden Fish, but for this type of fish, it should be living within the specified range of temperature (S. Sharpe, 2019). In fact, most of the fish species prefer living within this range. This is why we have calculated the average, mean, and the standard deviation of the collected values of temperature.

If we want to analyze the two weeks data we collected from these two sensors, we can tell that they are proportional to each other. Once the air temperature increases, the water temperature also increases, so air temperature plays a great role in affecting the water temperature of the one-tone tank. These three days data that are presented in the above figures proves that aquaculture is very important to be placed or positioned in an environment where air temperature is suitable to keep the water temperature stable within the range between 25°C - 28 °C. It is obvious that water temperature should be set and controlled depending on the fish type, but the majority of fish types are kept within the previously mentioned range.

In terms of table 4, it presents the statistics of the collected values of 14 days of the water temperature and air temperature, including their statistical correlation, standard deviations, and overall average. Actually, the statistical correlation is mentioned in the above table to statistically prove that these two sensors are co-related to each other. Plus the standard deviation is mentioned in each day of each sensor in order to specify the allowable range of temperature values that can suit the fish temperature so that the fish species can keep living in their tanks which could perfectly lead to decrease the possibility of fish death, and increase the fish reproduction at the same time. In addition, the average of the daily collected data is mentioned in the last column of the above table to demonstrate the everyday temperature average of both water temperature and air temperature.

In terms of standard deviation and average calculation, they were made by using Excel program and utilizing the standard and average functions. The standard deviation data indicates the temperature ranges in Celsius degrees (°C), and if the temperature of the tank exceeds this degree range, it would not be good for fish to live in because it could cause the fish to die because once temperature gets higher, the metabolism of the fish will get increased, which will make the fish look for more dissolved oxygen in the water, and they cannot get the oxygen they need, they would die after a short while of time, and this could significantly affect the fish farming overall production (“Temperature Control”, 2017). For the statistical correlation, we can tell how these two sensors are highly correlated to each other by getting the value of (r), which is equal to 0.93 out of 1, which means that the likelihood that these two sensors are correlated is very high. Therefore, we can conclude that water temperature highly depends on air temperature, so to control the water temperature of a fish tank; we need to make sure that the fish tank is placed in a place where air temperature is controlled.

3.2 Water PH and Turbidity Sensors' Values

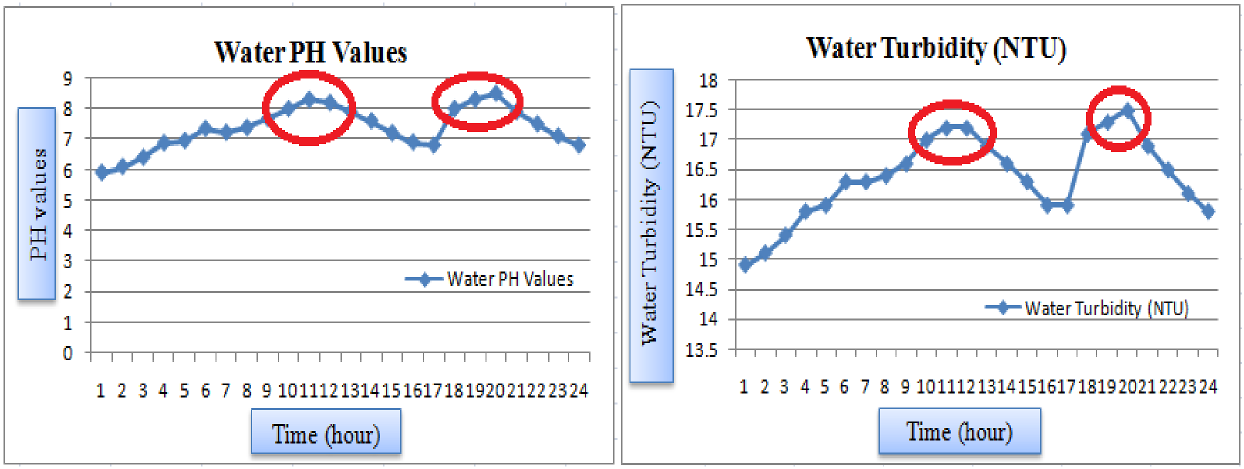

Figure 15: *Water PH and Turbidity (NTU) Values for Day 1*

If we want to have a closer look on how water PH and water turbidity are being affected during the feeding time, here are the results of day 1, but they were collected in minutes not in hours in order to be able to realize how water PH and water turbidity change every minute during the feeding time as they are mentioned in the below figure.

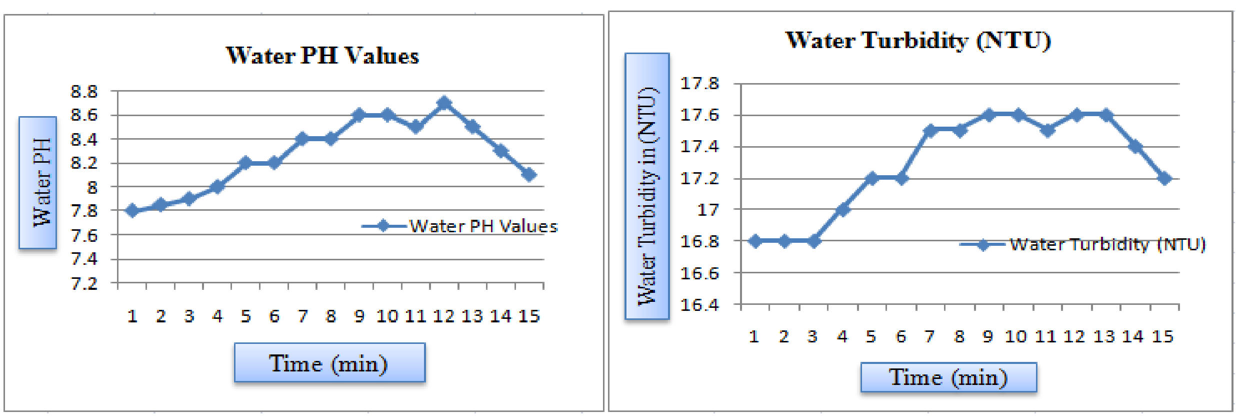

Figure 16: *Water PH and Turbidity (NTU) Valuesduring Feeding Time*

Table 5: *Water PH and Turbidity (NTU) Statistics*

Day	Standard Deviation of PH	Average of PH	Standard Deviation of Turbidity (NTU)	Average of Turbidity (NTU)	Statistical Correlation (r) between (PH & Turbidity)
1	0.86	7.42	1.29	17.19	0.97
2	0.88	7.39	1.33	17.16	0.97
3	0.84	7.42	1.30	17.19	0.97
4	0.81	7.46	1.22	17.24	0.97
5	0.77	7.50	1.20	17.26	0.97
6	0.74	7.55	1.18	17.31	0.98
7	0.73	7.58	1.17	17.33	0.98

PH sensor plays a great role in water quality measurements. Again, the range of PH values depends on the type of fish, but the majority of fish types can live in a PH range between 6 to 8.5 or 9 maximum (Shirlie, 2019). The PH values that were collected and sent to Thinkspeak Cloud show the range of PH values, which were from 6.5 to 8.6 as they are mentioned in figures 21 and 22. Again, these provided charts of PH and turbidity prove our second objective, which is the impact of feeding on water PH and water turbidity. Therefore, we can tell from these above figures, which were based on the data that were collected during fish feeding time, prove that the water PH and water turbidity values increase exponentially during feeding time, and both water PH and water turbidity are directly proportional to each other.

For the turbidity sensor, this measures the water clearness in a fish tank. The clearer the water, the better for the fish to live longer because fish are in need to see light, so if the water was fully turbid, it will prevent the fish to see some light passing in the water, which can causes the fish to go blind. Therefore, it will lead the fish to get panicked and scared which can greatly harm the fish health. The measurement unit of turbidity is NTU, which stands for Nephelometric Turbidity Unit. The NTU for drinking water should not exceed 5NTU, but for the fish, the NTU amount should be reasonable enough to let the light come in to the fish tank [18]. Therefore, the turbidity values we get so far ranges between 14 to 18 NTU, which is considered to be good enough to allow some lightening get through water surface, but again, the lesser the NTU value the better chance for fish to get some light in because fish also need to have vision inside their water environment. Therefore, from the comparison that is provided in the above figures, we can tell that feeding plays a vital role in affecting the water PH and water turbidity, and as we can see that the values of water PH and water turbidity decrease after a few hours because the most of the allocated food would be eaten, so the water becomes clearer.

The standard deviation and average of PH values, which are mentioned in table 5, show the most suitable PH ranges that can keep the fish survive and reproduce in their tank.Table 5 also illustrates the standard deviation and average of turbidity sensor's values, which are surrounded from (14 to 18 NTU), show that these values are good enough to allow light passes through the water surface. What we are saying is that this range is reasonable enough because the NTU of milk is about 4000 and for Coca cola is ranged between (65-80 NTU), so we can tell that the ranges we have are transparent enough for allowing light to penetrate water surface (C. C. Myint, 2018). Let's not forget that the fish tank is positioned in a place, where it is not directly exposed to sun light in order to not increase the water temperature of the fish tank.

Therefore, we can easily compare and check from the results that both PH and turbidity sensors are statistically correlated to each other by getting the statistical correlation value (0.97r), which clarifies that there is a high correlation between both of them. This given number is out of 1, meaning that if the statistical value is 1, that means there is a 100% correlation between these two sensors, so (0.97r) is adequate enough to say that they are highly correlated.

4.3 Light and Water Turbidity Sensors' Values

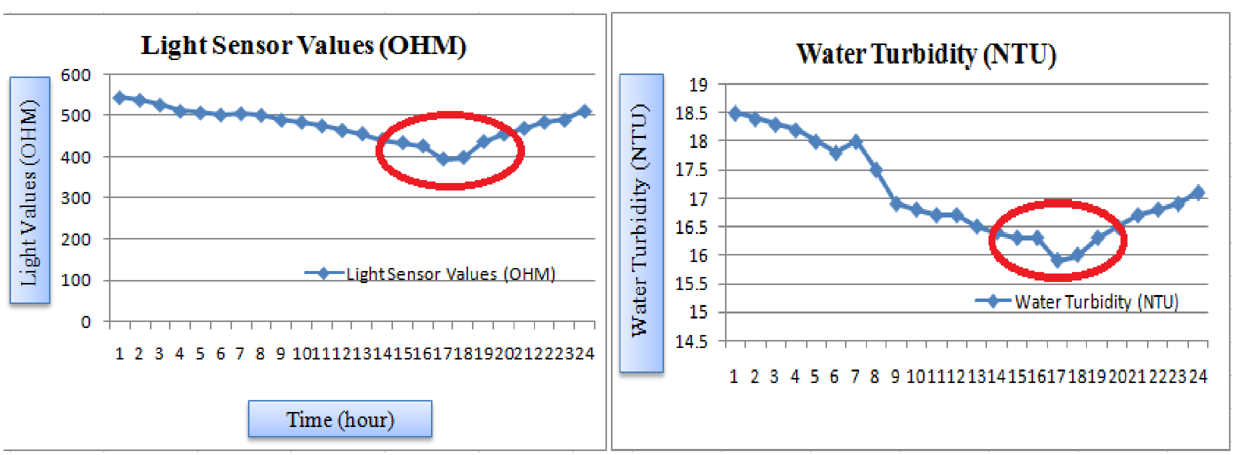

Figure 17: *Light and Water Turbidity (NTU) Data for Day 1*

Figure 17 illustrates the readings of the light sensor and the water turbidity sensor, and how light availability can help in decreasing the water turbidity values. These collected data show the data per-hour of day 1. Also, we can have a closer look of how ambient light affects the data readings of water turbidity during the day time by having a look at the below figure, which compares the per-minute collected data between the ambient light sensor and the water turbidity sensor.

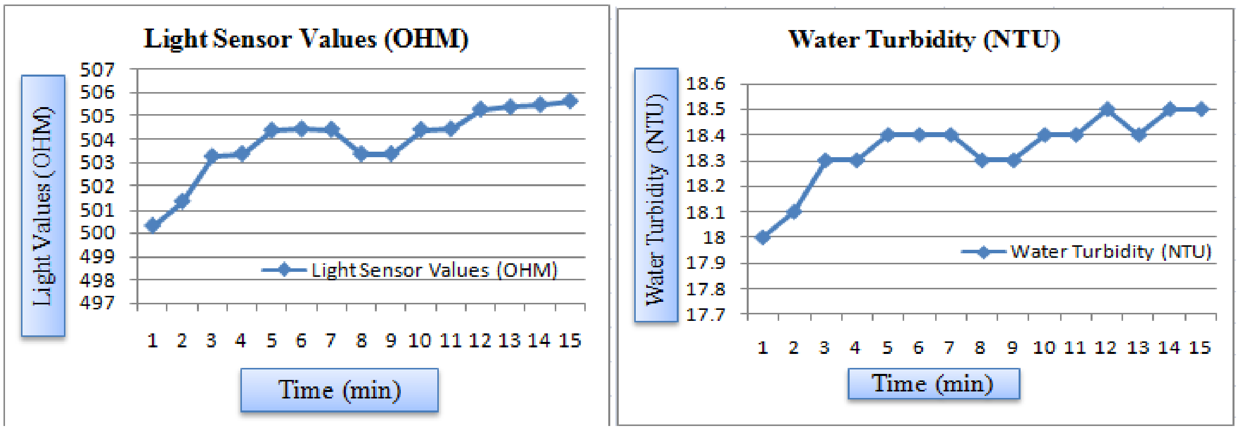

Figure 18: *One Hour Light and Water Turbidity (NTU) Data during Day Time*

Table 6: *Water Turbidity (NTU) and Light Sensor Statistics*

Day	Standard Deviation of Turbidity (NTU)	Average of Turbidity (NTU)	Standard Deviation of Light (OHM)	Average of Light (OHM)	Statistical Correlation (r) between (Turbidity & Light)
1	1.29	17.19	44.85	470	0.95
2	1.33	17.16	45.54	468.92	0.95
3	1.30	17.19	44.99	469.42	0.95
4	1.22	17.24	44.55	469.78	0.95
5	1.20	17.26	44.60	469.85	0.95
6	1.18	17.31	45.19	470.57	0.95
7	1.17	17.33	44.94	470.28	0.95

The last but not least is the light sensor, which is responsible for measuring the light intensity of the environment. Actually, light sensor is called a Photoresistor and known as LDR, which stands for Light Dependent Resistor, and its measuring unit is OHM. The higher the intensity of ambient light, the lower the resistance of LDR, so in our case, the values of LDR ranges from 390 to 550, which means that the ambient light intensity is not high, nor is it low. The reason that the ambient light intensity is not high is that the fish tank is positioned under a sunshade, which could provide some light to the fish tank, but at the same time, the sunlight is not directly shining on the fish tank. This is better for the living fish so that the amount of heat would be less, which could keep the water temperature stable: The value of LDR could reach a thousand if not more once the environment gets very dark, so the values we are getting prove that even at night, there is some light provided in order to keep the fish stable and healthy and prevent them from crashing one another. However, the reason for choosing such a sensor is because it is very cheap, and it responses to light intensity changes very fast (L. Parra, 2018). Not only that, this type of sensor is chosen to make sure if the ambient light of the fish environment affects the water turbidity values or not.

In terms of the statistical data that are provided in table 6, we can obviously notice that that standard deviation and average have been calculated from day 1 to day 7, and the values are almost the same because the everyday collected values are almost repetitive, so the standard deviation and the average of LDR are within the same range.

Another statistical calculation is the statistical correlation that has been made between LDR sensor and turbidity sensor, and the results were as expected to be which means that they are both highly correlated between each other, and their correlation rate is about (0.95 r) as the values are mentioned in table 4 on the second column from the left.

The coefficient (r), which is the statistical correlation unit, represents the strength of two types of data that are closely related to each other. Therefore, we can conclude that these two sensors are directly related to each other, and they are depending on each other indirectly, but they are highly needed once there is an IoT sensors set up, especially in conditions where there is water quality measurements.

5. Conclusion

Based on this paper's objectives, we can conclude that we were able to distinguish the effects of air temperature on water temperature as they are mentioned in figure 15, and these results' figures are 1 hour consecutive minutes of data readings. Plus the two weeks daily data is also added in tables 4, 5, and 6, and these tables were providing the standard deviation and average of each sensor, including the statistical correlation between each two compared sensors so that we can have a wider knowledge of how these sensors are working and affecting each other in different water, air, and light conditions. We were also able to realize that feeding is playing a vital role in affecting the water PH and water turbidity as their values exponentially increase during feeding time. The last objective is the role of ambient light on water turbidity values, and as we were clearly visualizing the demonstrated 17 and 18 figures, which show that once the turbidity values decrease, we can tell that the light intensity values are increasing. Meaning that when the light is available, the water turbidity values decreases, so the water turbidity sensor needs to be normalized prior application; otherwise, it will not be accurate during the day time.

These used sensors are widely and commonly available, so they are not difficult to be found and purchased. Also, let's not forget that the price of these sensors, including the MCU Node esp8266 are not expensive, so they can be easily bought with cheap prices that can be affordable by the farmers themselves instead of paying tremendous amount of money to follow MyGap standard water quality safety to keep their farmed fish alive and reproduce. MyGap is a very good standard that should be followed, but the main point of creating such a project is to minimize the needed money that has to be spent to make the water a suitable environment for the fish or aquaculture species in general. Therefore, instead of paying and spending thousands of Malaysian Ringgit to get a cleaned and well-conditioned parameters of water, farmers can get the same as these good conditioned water parameters with a few hundred of Malaysian Ringgit so that the farmers can afford these money to proceed working in farming occupation. Therefore, the number of unemployed people, especially those who could not afford to continue their studying journey, will be increased because the requirements and tools are cheap to be bought and easy to be installed, and they can have a 24 hours data, which could be monitored on the cloud, so farmers can use their smart phones to check the water conditions daily. The good thing about Malaysia is that it is located in a geographical location, where its weather is kind of stable, so it is also another opportunity for the farmers to have such a natural chance to raise their farmed fish without concerning about controlling water temperature. Water temperature is very hard to be controlled because farmers have to choose a suitable environment that its temperature and lightening are well-controlled, and again, this could be an additional cost for the farmers, who might not be able to afford its price.

5.1 Project's Contribution

This project has contributed in achieving many observable objectives, including:

1. Checking water parameters with very cheap smart sensors.

2. Farmers can infer how much the water temperature from the outside temperature, so the outside temperature can be a great indication to the farmers of how much the water temperature of their breeding environments.
3. Farmers should not worry about the high values they get of water PH and water turbidity during the feeding time because these two sensors get affected once the fish food is dispersed inside the fish tanks, and the readings of these two sensors will get back to normal after a few hours.
4. Water turbidity sensor has to be normalized because it can be easily affected by the ambient light.

5.2 Future Work

The first future aim is to publish a paper regarding this topic, and thankfully, it was successfully published in the "International Conference Science and Technology Research (Eurasia Research)", but my supervisor and I are still aiming on publishing this topic in a journal.

The future work would be developing this system further more by adding few more sensors that are responsible for monitoring the fish behavior, especially, if one of the water parameters or conditions changes. Besides the other sensors that would be added to monitor the fish behavior, a camera would also be added inside the fish tank in order to check how healthy the fish are by monitoring their swimming speed and their oxygen consumption because recent studies proved that once fish are healthy, they swim faster, and consume more oxygen because they keep being active during the day, so they obviously need to consume more oxygen.

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