A Proposed Model of Fishpond Water Quality Measurement and Monitoring System based on Internet of Things (IoT)

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Abstract. Aquaculture in Malaysia is now being promoted as an important engine of growth and eventually becoming the pillar of the economy of the nation. However, healthy fish production requires intensive care, and to ensure a stable and healthy production environment inside the fishpond is a challenging task. While cultivating aquatic organisms, water quality is a critical factor. It depends mainly on various parameters such as dissolved oxygen, ammonia, pH, temperature, salt, nitrates, carbonates, etc. In most places, this testing is performed by fishpond farmers manually or by researchers through laboratory testing, where there is no real-time monitoring. Today, with the advancement of the Internet of Things (IoT) and sensors, the technology is reaching the ground level with its application uses in agriculture and aquaculture. It is highly desirable to have an IoT-based automated system that can continuously measure and monitor fishpond with optimum utilization of resources. This paper proposes a model for real-time measurement and monitoring system based on IoT technology for measuring and monitoring the water parameters in the fishpond. We used a qualitative method to investigate perceptions, experiences, and ideas of fishpond farmers in order to propose the model. With the help of the proposed model, the quality of water can be continuously measured and monitored to ensure the growth and survival of fish in the pond. As a result, preventive action can be taken in a timely manner to minimize losses and increase productivity.

1. Introduction
Global meat consumption has increased dramatically to fourfold over the last 50 years, reported by the Food and Agriculture Organization (FAO) of the United Nations. With the current population growth rate, it will require at least 70 percent more protein in 2100 as there will be about 4 billion more people on earth (total 11 billion) [1]. In the recent past, the aquaculture industry has seen tremendous growth throughout the world. A vital factor promoting aquaculture is that fish farming is considered one of the most profitable investment firms. Aquaculture in Malaysia is now being promoted as an essential engine of growth and eventually becoming the pillar of the economy of the nation.
An aquaculture is a promising option for sustainable fish meat, and it will allow a significant increase in fish consumption by 2050 [2]. It is the best available agricultural options we have today, but it has its own challenges. The widespread use of chemical substances has resulted in significant harmful effects on the ecosystem and the environment. Antibiotic resistance is attributed to the excessive use of chemicals in our food, including fish. Poor management of fish farms results in diseases causing significant losses in aquaculture from the emergence of fish viruses. According to the Sustainable Fisheries Partnership (SFP) Foundation report, 42% of fisheries are poorly managed and produce unhealthy virus-infected foods [1]. Fish are quite sensitive to water pollutants compared to land-based crops and animal production; hence, aquaculture production is vulnerable to water quality deterioration. Moreover, the widespread use of chemicals has had a significant harmful impact on ecosystems and the environment. Some researchers suggested that prolonged exposure to high concentrations of unionized ammonia would have an adverse effect on the well-being of fish [3]. Unreasonable management of fish farming will result in the development of viral diseases in fish and lead to significant losses in aquaculture [1].

The management of fisheries relies entirely on the monitoring of water quality for fish diseases that are very frequent and give impact directly to the harvesting yield [4]. Low water quality can also have an impact on fish growth and delay the harvest. Therefore, it is important to measure and monitor the parameters of water quality in fishponds. While cultivating aquatic organisms, water quality is a critical factor for optimum fish production [5]. It depends mainly on various parameters such as dissolved oxygen, ammonia, pH, temperature, salt, nitrates, and carbonates. Amongst them, the most critical are temperature, dissolved oxygen, and pH [6]. In most places, this testing is performed by fishpond farmers manually or by researchers through laboratory testing, where there is no real-time monitoring [7].

Today, with the advancement of the Internet of Things (IoT) and sensors, the technology is reaching the ground level with its application in agriculture and aquaculture. It is highly desirable to have an IoT-based automated system that can continuously measure and monitor fishponds with optimum utilization of resources. [8] define IoT as “a comprehensive network of smart objects that capable of auto-organizing, sharing information, data, and resources, reacting and acting in the face of situations and changes in the environment.” [9] explain that the IoT is the combination of two words: The Internet and things. The Internet means connectivity, and things mean electronic devices, including living things and non-living things.

The IoT empowers researchers in technology to develop smaller and more affordable wireless systems that consume less power and can be integrated into almost any device [10]. There are three components in IoT that allow for seamless connections, which are hardware, middleware, and presentation [11].

Several authors propose different systems for water quality monitoring. Water quality monitoring is crucial for improving the efficiency of aquaculture. In recent years, IoT has already demonstrated a tremendous number of application domains [7]. However, not so many fish farms are currently equipped with smart devices with real-time and connected water monitoring capabilities [7]. There are many examples where IoT might help farmers in fishponds to improve their working conditions. Some fishponds, for example, are far from the land, and using IoT to monitor water quality at a distance might reduce their costs. Another example is that the changes in water quality can occur very quickly and at any time, so real-time monitoring of water with alerts can help fishpond farmer to avoid missing any event.

An IoT implementation has also been conducted in the fish farming sector as it was reaching in agriculture and aquaculture. In a study by [13], they determined the applicability of ZigBee wireless sensor network technology to aquaculture recirculation systems. They also developed low-cost modules and wireless sensor network based on the ZigBee standard in order to monitor a recirculating aquaculture system. The setup system included temperature, dissolved oxygen, water pressure, and electrical current...
sensors. The modules were installed to transmit sensor data to the network coordinator in a recirculating aquaculture system.

The fishpond management system has been studied by several researchers [12], [14]–[20]; however, their studies have not discussed the implementation of the system with Raspberry Pi microcontroller in a rural area. In this study, we want to propose a model for real-time measurement and monitoring system based on IoT technology for measuring and monitoring the water parameters in fishpond by using Raspberry Pi microcontroller in a rural area, which is expected to solve the problems of fishpond farmers to monitor and measure water quality in fishponds. The proposed model could perceive any changed of information from a microcontroller, triggering the alarm of notifications to a connected personal computer or smartphone. The monitoring of the fishpond could be carried out via smartphone applications for convenience use and subsequently provide time savings and reduces labor costs. The cost is up to 50 times lower than the conventional water monitoring system, and the lifetime of the sensor with 24/7 operation will be up to 2 years, thus reducing the maintenance costs [12].

2. Methodology

We compiled all existing information on the IoT and sensor technologies in aquaculture by reviewing available literature and gather some basic information related to these technologies. In this process, we used a keyword-based search for conference papers and articles from the scientific databases such as IEEE Xplore, ScienceDirect, EmeraldInsight, and as well as from the Google Scholar. For search keywords, we used the query “Internet of Things” OR “IOT” AND [“Aquaculture” OR “Fishpond”].

Next, we used a qualitative method to investigate perceptions, experiences, and ideas of fish farmers [21], [22]. The qualitative method was also useful for gathering a consensus opinion not found in the literature, an effort that would not be feasible with quantitative or mixed-method approaches [23]. Interview data included in-depth interviews with ten (10) respondents, It is common for data in the content analysis study to be based on 1 to 30 respondents [24], they are four (4) fishpond farmers (P1,P2,P3,P4) which are small fishpond farmers that have more than five years of experience, Chairman of Bintulu Fishermen’s Association (P5) that responsible for promoting the economic and social interests or wellbeing of its members, two (2) fishpond researchers (P6,P7) that have extensive research in the fishpond, UPM Bintulu campus’ ICT manager (P8) who knows ICT infrastructure in UPM Bintulu campus and two (2) Local Internet service provider (ISP) representatives (P9,P10) that provide the internet services in Bintulu.

In this study, participants were classified as P1 to P10. In other words, participant one was labeled as P1. Participant two was labeled as P2. This was applied to all ten (10) participants. Finally, we combined data from literature and qualitative to construct a model of fishpond water quality measurement and monitoring system based on IoT technology.

3. Results and Discussion

This section lists the themes related to the business process, architecture, and equipment of fishpond use for fishpond production. We wanted to understand the business process of fish farming and identify the devices needed in order to develop a real-time measurement and monitoring system for fishpond, such as IoT microcontrollers, sensors, and water quality parameters for freshwater fish.

Participants were asked related to themes, as shown in Table 1 (Simplified themes). The first theme is defined as a business process and need. The second theme is identified fishpond architecture and its components, and the third theme is identified tools and equipment fish farmers used. All participants responded by providing their business processes, their current pond architectures, and tools and equipment they have used in order to elicit the requirements for the proposed model.
Table 1. Simplified themes for questions

| Simplified Themes                        | Participants       |
|------------------------------------------|--------------------|
| Defined business process and need        | P1, P2, P3, P4 & P5|
| Identify fishpond architecture and its components | P1, P2, P3, P4, P6 & P7 |
| Identify tools and equipment             | P6, P7, P8, P9 & P10|

3.1. Business process and need

Respondents mentioned that fish diseases often occur when conditions of rearing deteriorate, such as poor maintenance of the pond, the incidence of pollution, too high densities of stocking, etc. They knew good maintenance of fishponds would significantly reduce the risk of disease and incidence. There are many types of fish diseases that occur, such as bacterial, parasitic, or viral. Fish farmers will obtain expert advice such as from government agencies and take rapid action to control and reduce fish diseases. When ponds are infected, many fishpond farmers lose their income throughout the year. Because most fish diseases cannot yet be effectively treated. Fish farmers knew good management of water quality helps to avoid poor quality conditions in the fishpond that favor the spread of fish diseases. Fish diseases can often be avoided by maintaining an environment in high quality and reducing the stress of fish. Antibiotics and other pharmaceuticals were used in treatment in some cases.

The quality of water used for fishpond farming is one of the major factors affecting fish yield. For optimum production of species being cultured, good quality of water must neither be too acidic or alkaline, contain enough dissolved oxygen, not to muddy or turbid, not have offensive color, in a suitable temperature, salinity, and color, be free from pathogens as well as pollutants (e.g., oil films, petrochemicals, detergents, agrochemicals). It is, therefore very important for the fishpond farmers to maintain a good quality of water for desirable fish culture.

3.2. Fishpond architecture and its components

![Figure 1. An Idea Fishpond Design (Source: [1])]()

Fish farmers can build fishponds as large as the space permits but should be a manageable size. A good size of the fishpond start with is 6 m by 4 m. Then, fish farmers can build a bigger fishpond later once they have had a good experience with a smaller one.

Figure 1 illustrates an ideal fishpond design. Fish farmers can follow the following guidelines when constructing fishponds: (1) the walls of the fishpond must slope, with the bottom having one deep end to drain. (2) during construction, slopes and the bottom of the fishpond should be well packed by beating the ground with timber. This design to avoid erosion and leakage. (3) the depth of the fishpond at the shallow end should be 0.5-1.0 m, sloping at the drainage end to 1.5-2.0 m. (4) at the deeper drainage end, fishpond farmers can construct a collection pit for water collection before flowing out. A collection pit is also useful when fishpond farmers drain the fishpond to harvest the fish.
Fishpond farmers should also consider how high the fishpond walls should be built. The walls of fishpond should be high enough to prevent water from flooding across the edges. If the fishpond overflows, fish can escape. The walls should be high enough to prevent fish from escaping. However, the walls should not be too high. If they are too high, the walls will slowly get eroded and will fall into the pond.

3.3. Tools and equipment
Fish farmers encountered a problem where their fish died with a large quantity, and then they asked the Department of Fisheries (DOF) to investigate. They lose a lot of fish, and it took a few days to know the problem. There are many technologies that could help fishpond farmers to improve their working conditions. For example, for fishpond farmers that have fishponds at the far away from their houses and using IoT technology to monitor water quality at a distance could reduce their cost. By using real-time measurement and monitoring for water quality, this problem can be solved.

The fishpond farmers wanted a real-time monitoring system for their fishpond as it would lessen their burden of manual testing of water parameters. They wanted a system to alert them for any adverse condition well in advance to avoid heavy losses. This is because the changes in water quality can happen very quickly and at any time, so monitoring water quality in real-time with alerts can help fishpond farmers to not miss any event.

Fishpond farmers want a system that can monitor and identify the cause of water quality degradation. The fish farmers would like to monitor their fishponds water quality parameters include water temperature, pH, and dissolved oxygen. This is confirmed to the study of [12] many other parameters can also be monitored, but they generally directly influence by these three main parameters. Monitoring and measuring these parameters are, therefore, the basis for good water quality. In addition, real-time monitoring and measurement will provide a faster reaction time. Fishpond farmers really like to have a system that can detect a water temperature, pH, and dissolved oxygen. It can reduce the cost of labor, such as the cost of traveling to the fishpond sides.

3.4 Proposed model
In general, the proposed model consists of components as depicted in figure 2. The components included in the proposed model are (1) Microcontroller, (2) Sensors, (3) Database Server, (4) Network, (5) Software. Then, the price of the components to develop this system will be shown.
3.4.1. Microcontroller

Some papers use Arduino as a microcontroller to monitor the ponds [19][1], but Raspberry Pi is more advanced than Arduino because it has a built-in Wi-Fi module, so it can continuously collect the information sent by sensor nodes via the internet [25], [26]. Raspberry Pi is an inexpensive microcontroller with an easily affordable price, and anyone can grab a piece of Raspberry Pi for themselves from teenagers to computer enthusiasts. Raspberry Pi has the size of a credit card. Usually, the smaller is better, as we all know with technology. Raspberry Pi can be hidden nearly anywhere, behind TV sets, inside walls, or even in your wallet. Figure 3. shows the picture of Raspberry Pi.

The low price and small size of Raspberry Pi do not necessarily indicate low performance. Although we will not be able to play the latest 3D hardcore games on our machine, Raspberry Pi allows video streaming of high definition (HD) and other basic computer functions such as word processing and web browsing. Initially, it was designed as a programming platform for beginners, Raspberry Pi is versatile, powerful, all-rounder [27].
Figure 3. Raspberry Pi 3 board microcontroller (Source [28])

The comparative study done by [29] shows how microcontrollers promote the growth of IoT by using the specific board as per the intended application. The detailed analysis shows that, in terms of storage and computing speed, a Raspberry Pi-3 has higher performance compared to other boards like Arduino and ESP8266, but it’s a quite higher price. Equipped with built-in Wi-Fi and Bluetooth, Raspberry Pi provides an easy way to connect to the internet and push data to cloud servers when needed for further processing. Therefore, compared to other microcontroller boards, it clearly has great advantages.

Hence, in the proposed model, we decided to use Raspberry Pi B+, the latest version of the Raspberry Pi microcontroller. Raspberry Pi B+ will use as a core controller. It is a small computer board run on LINUX operating system that can connect to a computer monitor, keyboard, and mouse. The temperature sensor, dissolved oxygen sensor, and pH sensor can be read directly from the Raspberry Pi by using a Python program in order to access all the sensor terminals.[25], [29].

3.4.2. Sensors

Term of sensor widely used to refer to the sensing element such as heat, light, sound, pressure, or magnetism. A sensor is a device that measures and converts a physical quantity into a signal that an observer or an instrument can read [30]. Sensors are capable of converting one input parameter such as light, temperature, pH, or speed and convert it into an electronic signal such as voltage, resistance, frequency. They are in small size, low power consumption, and high-density operations. In this study, we will use three basic sensors to measure the water quality parameters in the fishpond. It is a water temperature sensor, pH sensor, and dissolved oxygen sensor. Next, we will discuss these sensors in more detail.
Table 2. Acceptable conditions for fish production in selected countries.

| Water Quality Parameters | Malaysia [16] | The Philippines [31] | Australia [31] | India [32] |
|--------------------------|---------------|---------------------|----------------|-----------|
| Temperature (°C)         | Normal + 2 °C | -                   | -              | 21 - 33   |
| Dissolved Oxygen (DO) ppm| 3.0 – 7.0     | 5.0                 | > 5.0          | 4 - 10    |
| pH (index 0-14) ppm      | 7.5-8.5       | 6.5 - 8.5           | 5.0 - 9.0      | 7.5 - 8.5 |

The oxygen concentration is measured in terms of parts per million (ppm) or in terms milligram per litter (mg/L), both units of measure are the same [31].

- **Temperature sensor**
  Water temperature affects not only the dissolved oxygen in the water but also the breeding of fish. Fish are poikilothermic animals that change their body temperature as the temperature of the ambient water changes. The change in the temperature can cause the death of fish or disease. The temperature range suitable for fish to live is between 25~32°C for tropical fish culture [33], but in Malaysia, the water temperature range is normal +2 °C [16] (see Table 2). For temperature measurement, we will use I-wire digital temperature sensor DS18B20 made by Dallas. DS18B20 measures temperature range from -55 to +125°C and in the range of -10 to +85°C, the accuracy is ±0.5°C. It can connect to any GPIO port due to its digital output capabilities.

- **Dissolved oxygen (DO) sensor**
  Dissolved oxygen is an important condition for a living of aquatic organisms. Low oxygen dissolved can cause the death of fish. There are two dissolved oxygen sources: oxygen in the air and oxygen generated by algal photosynthesis. Therefore, it’s necessary to detect dissolved oxygen in the fishpond. This study will use the Atlas Scientific DO sensor; it will sense on dissolved oxygen expressed in mg/L (oxygen weight over water volume) or its equivalent, parts per million (ppm). It can measure a wide range of oxygen 0-35 mg/L. Generally, all countries have an average DO level ranging from 5.0 to 9.0 in freshwater and 6.5 to 9.0 in marine, all within optimum fish production limits. [31].

- **pH sensor**
  pH refers to the concentration or how acidic or alkaline of water is. Water is acidic when pH is below seven, and seven is neutral. Water is considered alkaline when the pH is above 7. The recommended pH range for aquaculture is 7.5 to 9.0 in Malaysia (see Table 2). The acidic and alkaline death points of fish are approximately pH below four and pH above 11, respectively. In this study, we will use the pH Meter Kit SKU: SEN0169, it has the capability to measure the entire range of acidity to alkalinity. It can work continuously in turbid, strongly acid, and alkali solutions for months.

- **Database server**
  In the proposed model, we will design the database using MySQL that is installed on the server. MySQL is a popular web application database. MySQL is the relational management of databases system (RDBMS). It is open-source software. The database will store the information of the water parameters that a sensor node sends in real-time. It can provide the information to the web page for monitoring the fishpond remotely.

- **Network**
  Raspberry Pi equipped with inbuilt Wi-Fi and Bluetooth is an easy way to connect to the internet and to transfer the data to the cloud servers if necessary, for further processing [34]. 2.4GHz 802.11n wireless LAN is a self-contained SOC with integrated TCP/IP protocol that gives Raspberry PI microcontroller access to your Wi-Fi network. Local network system consists of
router and modem, which can receive the Internet from local ISP and work for sending and receiving data packets either from sensors to server/cloud server or from server/cloud server to farmer’s smartphone or desktop computer.

- **Software**
  Several software dependencies must be installed before writing the system code. These dependencies add more functionality to the Raspberry PI by using the Python programming language and facilitate the process of software design. Some dependencies, for example, allow Python to use the interfaces or interface of the Raspberry PI with its GPIO pins. Dependency installation requires an internet connection. To run the system, the code is needed and installed on the Raspberry PI.

As a final point, the price of the components to create this system for one pond is shown in Table 3. The price for Raspberry PI microcontroller is RM300, the price of all sensors is RM300.30, and the price of web hosting to host database and application is RM600 per year. The most expensive item is the Raspberry PI microcontroller, this microcontroller cost RM300, it expensive because it has higher performance in comparison with other boards [34]. The temperature sensor cost RM30, the DO sensor cost RM100, and the pH sensor cost RM200. To this price, some minor costs as boxes for the microcontroller or breadboard must be added. The cost of this system is appropriate because not only does the system increase production, save money, but it also reduced the time and intensity of labor of the farmer, reducing the frequency of farmers to get up at night and increasing the satisfaction of the farmers. The system is highly scalable, and only the components required must be purchased.

### Table 3. Cost of the proposed system.

| Item                          | Cost per unit (RM) | Units | Cost (RM) |
|------------------------------|--------------------|-------|-----------|
| Raspberry PI microcontroller | 300                | 1     | 300       |
| Temperature sensor           | 30                 | 1     | 30        |
| DO sensor                    | 100                | 1     | 100       |
| pH sensor                    | 200                | 1     | 200       |
| Web Hosting                  | 600                | Per year | 600  |
| Other (Breadboard, 40 Ways Male to Female Jumper Wire) | 50 | | 50 |

**Total** 1280

### 4. Conclusion

The model of fishpond monitoring and measurement system using an IoT is designed and proposed to assist fishpond farmers in monitoring the water quality of their ponds. This model is intended to alleviate the problems through manual monitoring, such as tedious testing and exhaustive inspection due to wet and spacious farming. Benefit from using the proposed model includes more effective monitoring of the fishpond as the system can monitor the quality of the water in a timely manner and alert the fish farmers to detect water quality degradation. In this model, three parameters can be monitored, which are water temperature, pH, and dissolved oxygen. With the help of the proposed model, the quality of water can be continuously measured and monitored to ensure the growth and survival of fish in ponds. As a result, preventive action can be taken in a timely manner to minimize losses and increase productivity.

The purpose of this study was to propose a model of fishpond water quality measurement and monitoring system based on the Internet of Things (IoT) in order for fishpond farmers to monitor the water quality of their ponds. Therefore, our future work will be to focus on the implementation of the system. Furthermore, the collected data can be analyzed using big data analytics, and preventive measures can be taken before the threshold range is crossed by the water quality parameter. It is possible to automate the fishpond system using the internet of things that reduce energy consumption and labor costs.
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