A Flexible Water Monitoring System for Pond Aquaculture

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***Abstract*— Water quality is the most important factor for pond aquaculture. Farmers must be able to control a water quality to be within the appropriate range for each kind of aquatic animal, which needs both skill and knowledge. This work proposes a flexible water quality monitoring system for pond aquaculture, which can be configured to fit with a particular aquatic animal. Three types of sensors are applied to measure the water quality including pH, temperature, and dissolved oxygen sensors with 2 types of wireless connection, i.e., WiFi and NB-IoT. A microcontroller is used to processing these sensing signals and send data to a cloud server. The system monitors the water quality all the time. If the water quality is not within the controlled range, the alert message will be sent to the farmers. The dashboard is also provided for real-time system monitoring. Systems can be selected as three kinds of aquatic animals including white shrimp, white sea bass, and tilapia. The controlled range will be changed according to the type of aquatic animal that the user selected. As the result, we found that the proposed system can perform as desired and the accuracies of the prototype are 98.5%, 97.6%, and 95.1% for pH, temperature, and dissolved oxygen, respectively, when compared with the standard tools. The proposed system can support both connections, i.e., WiFi and NB-IoT.**

Keywords*— *water quality monitoring system, aquaculture, IoT, NB-IoT

I. INTRODUCTION

Aquatic products are an important food source for both domestic consumption and export market, which can be obtained from nature and aquaculture. However, according to the overfishing problem, fish stocks from nature were rapidly depleted. On the other hand, aquaculture tends to increase considerably. In general, aquaculture will look like a closed system. The water does not circulate. Climate and sludge directly affect the water quality, which has many risks to the quality of aquatic animals. Water is an important growth factor for aquaculture. If the water quality value is in the inappropriate range, the productivity of aquaculture will be decreased.

A water quality measurement system has been introduced to assist in the management of aquaculture. The information on water quality is gathered via several techniques and recorded in the database for further analysis. Moreover, these systems can manage the water quality remotely. Fig. 1 shows an overview of general water quality measurement systems. We can see that it consists of four mains parts including a water quality sensor, microcomputer unit (MCU), GSM module, and cloud server.

There are several factors of water quality that affect aquatic animals, such as pH, temperature, and dissolved oxygen. Different species of aquatic organisms require a different level of these parameters. Normally, farmers must have all of this knowledge to control the pond culture. Different configuration of water monitoring is needed for a different aquatic species.

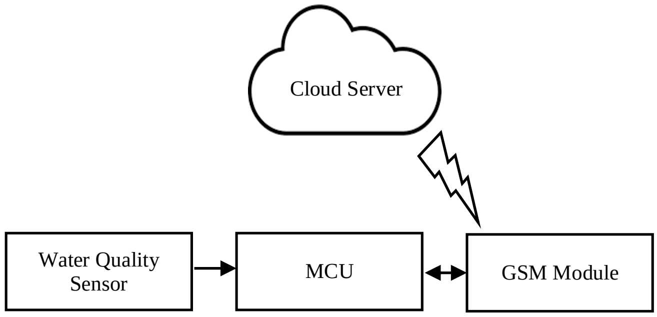

Fig. 1. An overview of general water moitoring systems.

This work proposes a flexible water quality monitoring system for pond aquaculture, which can be configured to fit with a particular aquatic animal. Three types of sensors to measure water quality: pH, temperature, and dissolved oxygen (DO) sensors. Two types of wireless connections can be selected: WiFi and NB-IoT. The system will monitor the water quality all the time and send alert messages to the farmers when it detects that the water quality is in an abnormal range. A dashboard is provided to present real-time water quality data and suggest basic solutions to farmers. To reduce the work process and facilitate farmers, it can also support many areas of use. The details of implementation and experimental results are shown in the following sections.

II. LITERATURE REVIEW

Aquaculture is one of the channels that can generate income for farmers. Generally, in the process of raising farmers, they had to regularly measure water quality. This has many steps, takes a long time, and is difficult to perform when it rains. For water quality control, farmers must have skills and knowledge to these solve problems. By raising different species, the treatment process will be different.

Important economic aquatic animals such as white shrimp, sea bass, and tilapia are popularly cultivated by farmers. Each species requires different water quality values. Table 1 shows the appropriate water quality values for aquaculture. A farmer needs to control the water quality in the culture pond to be at an appropriate level at all times. Especially white shrimp, they are difficult to cultivate aquatic animals because it is easy to panic sensitive to changes in water conditions. During aquaculture, if the water quality is not within the proper range,

TABLE I. THE CRITERIA FOR WATER QUALITY CONTROL.

Aquatic Type	Water Quality		
	pH	*Dissolved Oxygen*	*Temperature*
White shrimp	7.5 - 8.0	> 5 mg/L	28 - 32 °C
Sea bass	7.5 - 8.5	> 4 mg/L	28 - 32 °C
Tilapia	6.5 - 8.0	> 4 mg/L	28 - 32 °C

TABLE II. RECOMMEND SOLUTIONS FOR FIXING BASIC PROBLEMS.

Water Quality	How to fix basic problems	
	Lower than standard	*Above standard*
pH	Dolomite, Hydrate lime	Vinegar 5 %
Dissolved Oxygen	Paddle Wheel, Oxygen powder	
Temperature	Add warm water to the mix or perhaps lower the water level early in the morning.	Add water to raise the water level.

farmers can control water conditions by using the suggested solution as given in Table 2.

In aquaculture, information technology has been introduced to enhance the performance of water condition control systems. Early automation systems were used to monitor water quality in water sources by installing water quality sensors at various points to reduce the process and time of operation [2, 3]. A GSM communication model was utilized to allow monitoring of water quality from a distant center. A notification message is sent when the water is in an abnormal state. This method can help to reduce costs and travel time to collect samples [4]. As a result, it can help the farmer to solve problems promptly [5].

Wireless sensor networks have been applied to the system to send water quality data to be stored in a central system, which can be performed data analytic easily [6, 7]. Moreover, the system was developed to reduce the process of taking care of the pond. It uses an automatic aeration system to control dissolved oxygen and an automatic heating system to control the temperature.

In addition, the remote data communication system by using the telematics system to support the increase in the number of water quality metering units in remote areas was proposed [8]. Internet of Things (IoT) technology was introduced to reduce the cost of the whole system so that information can be accessed from anywhere over the internet network [9, 10]. However, taking care of water quality is one of the main duties that farmers must be done. If the water quality is within the desired range, it will be a positive factor for the productivity of the pond culture. Therefore, using the proper technologies is an important factor for pond culture.

III. The Proposed System

The basic diagram of the proposed system is shown in Fig. 2. We can see that there are three parts of the proposed system. The first part is the measuring units which are installed at the ponds. The second part is the cloud unit and the last part is smart devices. The measurement units are responsible for measuring the water quality. After that, the data are sent to store on the database. The cloud unit is responsible for processing water quality and managing the

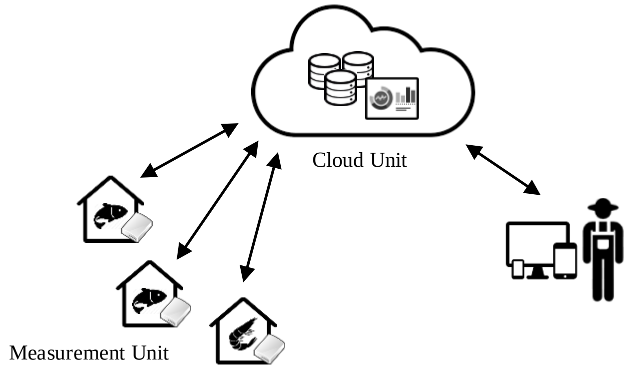

Fig. 2. An overview of the water quality monitoring system for flexible aquaculture.

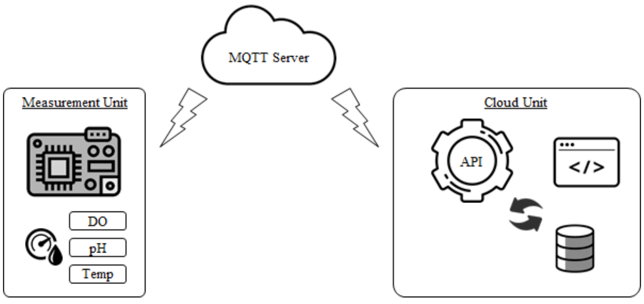

Fig. 3. A diagram of the water quality monitoring system for flexible aquaculture.

core data of the system. The status of the ponds are presented in a dashboard, which a farmer can monitor by using smart devices. No specific software need implement in the smart device because the generic web browser can display the dashboard.

Fig. 3 shows more technical details of the proposed system. Starting from the measurement unit, the water quality is captured by three sensors. These analog data are converted to digital data by MCU and sent to the cloud unit via MQTT protocol. Then, the cloud unit retrieves the transmitted data and store it into the database by a dedicated API. The dashboard is also implemented in the cloud unit. The details of each part are described as follows.

A. Measurement Unit

From Fig. 4, we can see that the measurement unit consists of two parts, i.e., sensor and processing parts. There are three types of sensors including pH, temperature, and DO sensors. The status of the water is detected by three sensors, where the sampling rate can be set from the cloud unit. These signals are converted to a digital signal by the analog to digital convert inside the MCU of the processing part. Then, the MCU conducts MQTT messages to send these data to MQTT broker, which is a web service for MQTT communication. There are two selectable communication interfaces for the proposed system, which are WiFi and NB-IoT. WiFi is suitable for the small coverage area while the NB-IoT can cover the large area, which users can be selected to fit with their application. This system will be installed close to the pond. The power consumption needs to be further considered when the system needs be operated using a battery system. Low power design techniques need to be applied to both software and hardware.

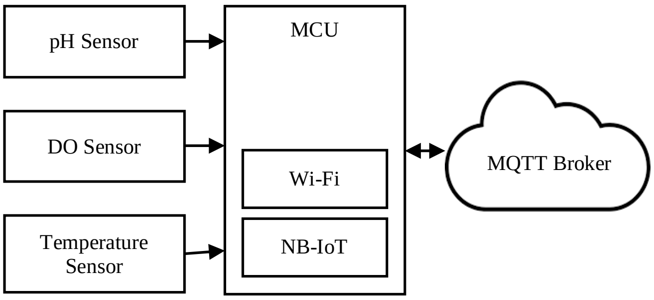

Fig. 4. A diagram of a measurement unit.

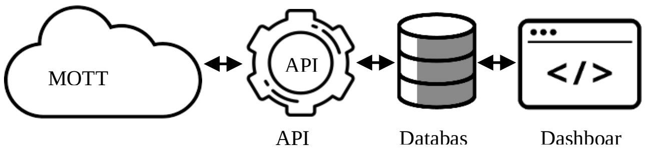

Fig. 5. A diagram of a cloud unit.

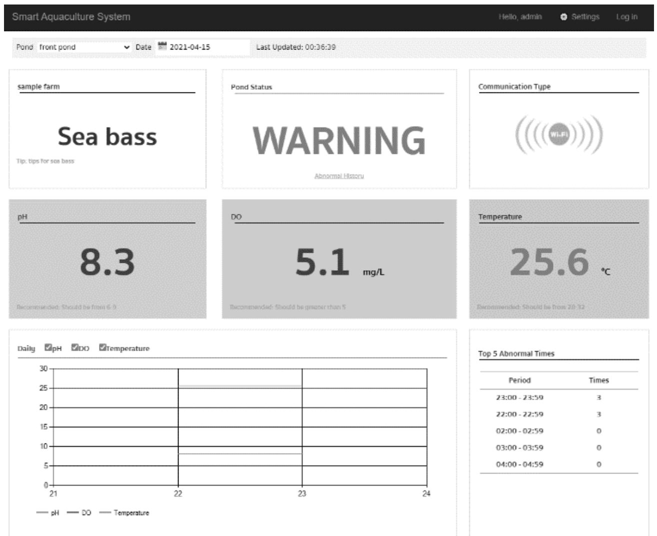

Fig. 6. An example dashboard page.

B. Cloud Unit

Cloud unit consists of 3 parts that are API, database, dashboard. The system is responsible for managing the main data of the system and display Dashboard data in the form of a website. Starting from an API, the water quality data are received from MQTT Broker, then it is compared with the specified water quality criteria set by the cultured aquatic animals. If it is not within the specified criteria, the notification message is sent to the farmers and also recode to the database. Then, Dashboard will retrieve the data from the database and display the data in various formats. The interface of the dashboard is shown in Fig. 5.

The dashboard is developed in the form of a website to display the information about the pond. Farmers can use various information to analyze problems, including types of aquatic animals, current status and water quality values of the pond, transmission format of measurement unit, daily water quality values in graphs, and the top 5 times when ponds enter abnormal states most often. Shown as shown in Fig. 6.

IV. Experimental Results and discussion

To evaluate the performance of the proposed system, several experiments are set up including sensor reliability tests, data transmission test, and notification message test. The details of each test are described in the following.

A. Water quality measurement test

As described in the beginning, there are three types of water condition sensors including pH, temperature and DO. The reliability tests for these sensors are conducted as follows.

1) pH Sensor Reliability Test

For the pH reliability test, we performed the experiment using a small simulated aquarium. Then, add pH4 buffer solution which is the standard solution, immerse pH sensor and standard measuring instrument. The results were recorded every minute for 30 minutes.. After that, we repeated the other 2 tests by replacing plain water and adding pH7 and pH10, respectively.

From the experiment, we found that the prototype can obtain the pH close to the standard measuring instrument as shown in Fig. 7, where the x-axis is pH from the standard instrument and the y-axis is pH from the sensor of the proposed system. Some variation of results that obtains from the sensor can be computed and the accuracy of this sensor, when compared with the standard instrument, is about 98.5%.

2) Temperature Reliability Test

For the temperature test, we prepared a water supply into a small simulated aquarium. The test is similar to the pH test except that the hot water is used to change the condition of the water in the state of the pH solution. For the first round, nothing was mixed in and the temperature was capture by the sensor of the quality measurement unit and the standard measuring instrument. The measurement results were recorded every 1 minute for 30 minutes. The second round was done by mixing hot water and repeat the same process. For the final round, more of hot water was mixed to the plain water to have a higher temperature than the second round and then repeat the same process.

From the experiment, we found that the prototype can show a similar value of temperature to the standard measuring instrument as shown Fig. 8, where the average accuracy was about 97.6%.

3) Dissolved Oxygen Reliability Test

For the last test of the sensor, the similar method was conducted in this test. We prepared water supply into a small simulated aquarium. The dissolved oxygen sensor of the quality measurement unit and the standard measuring instrument are then immersed in it. The measurement results were recorded every 1 minute for 30 minutes and then repeated by changing the water using water from aquarium 1 and aquarium 2, respectively.

From the experiment, we found that the prototype set was able to measure close to the standard measuring instrument. For water supply, water from Aquarium 1 and Aquarium 2. The average accuracy was 95.1% as shown in Fig. 9.

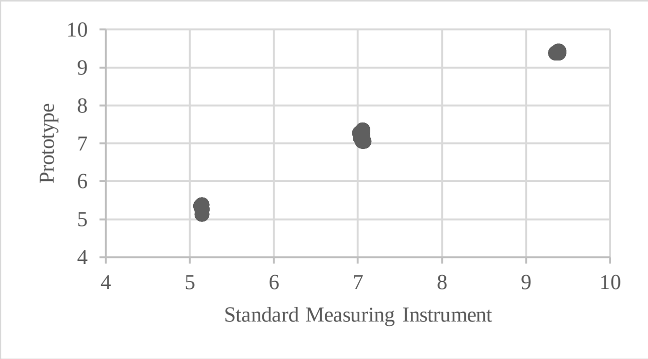

Fig. 7. Experimental result of pH sensor test.

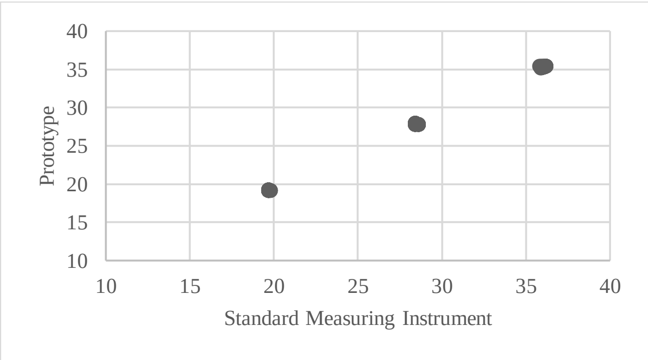

Fig. 8. Experimental result of tempareture sensor test.

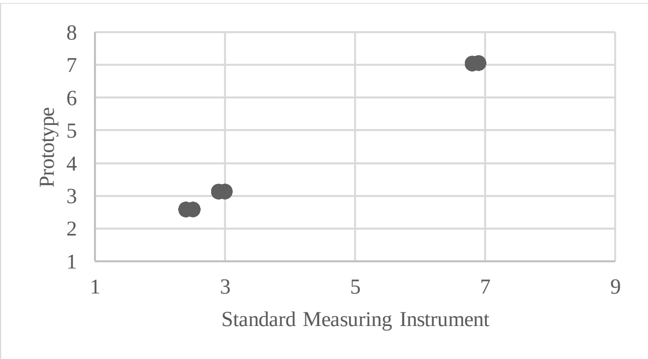

Fig. 9. Experimental result of DO sensor test.

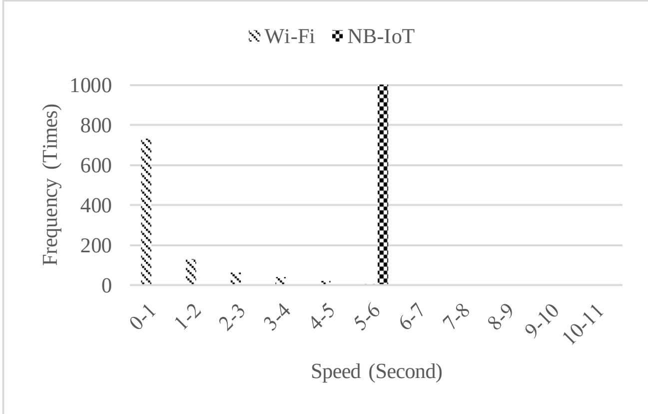

Fig. 10. Transmission speed results of WiFi and NB-IoT.

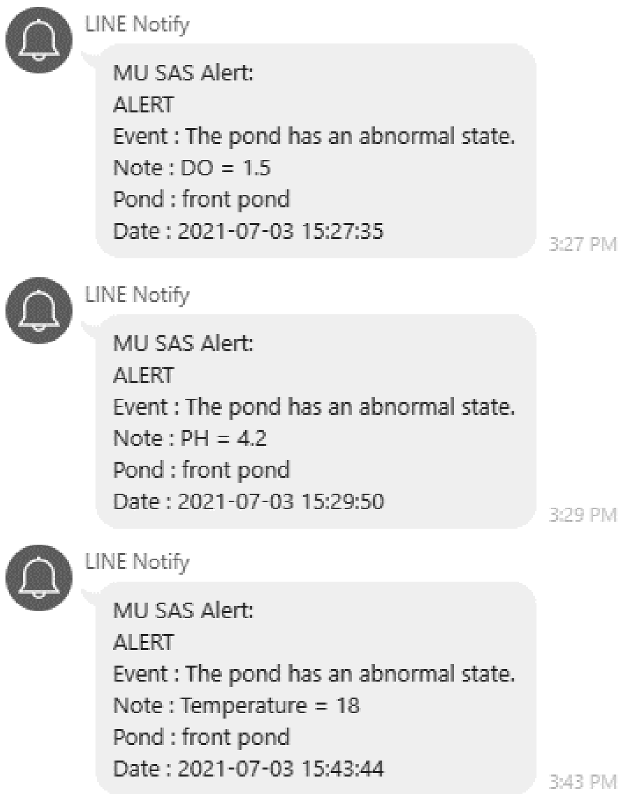

Fig. 11. An example of a message to notify related persons.

B. Data Transmission Test

There are two types of connections, WiFi and NB-IoT. In this test, we experimented to compare this transmission connection. We defined the data set used for each submission as the same data set. Starting from start sending data until receiving an OK response from storage and display data.

From the experiment, we found that in 1000 data transmissions, the WiFi speed was 731 times less than 1 second, and the rest spread from 1-11 seconds. While NB-IoT has a transmission speed of 5-6 seconds, the amount of 1000 times as shown in Fig. 10.

C. Notification Message Test

For the notification message test, we conducted this test by varying those three parameter of water quality. The small simulated aquarium was applied for this experiment. We start with change the value of dissolved oxygen to be lower than the specified threshold. The data of water quality was send to the cloud unit to test the alarm. Then the notification message is sent to the farmer via LINE application. After that, we repeated these steps with pH and temperature, respectively.

From the experiment, we found that the cloud unit can effectively monitor and notify the water quality value. Fig. 11 shows an example of the notification message when the system detects that the water quality value is not within the specified criteria.

From the experiment, we found the accuracy of the prototype to measure pH 98.5%, temperature 97.6%, and dissolved oxygen 95.1%, but there was still data fluctuation and slow response compared to the standard instrument. This is because the sensors are selected according to the cost perspective. The prototype is efficient at transmitting both wireless and NB-IoT technologies, although NB-IoT is slower but can be installed over long distances because it is a used mobile network. This makes the prototype more flexible to use.

This work was evaluated in the small aquarium. For future work, the field experiment is needed to explore the ability and also the weakness of the proposed system. Several modifications of the proposed system can be done such as adding other types of sensors or integrate with the water treatment system. More sensors can be applied to increase the capability of the system to handle a wider variety of applications. Integrating with the water treatment system can make the system to be an autonomous system.

V. Conclusion

This work aims to create a prototype of a flexible water quality monitoring system for pond aquaculture. The system is designed to be configurable for three types of aquatic life: white shrimp, sea bass, and tilapia. Three types of sensors are used to measure water quality: pH, temperature, and DO sensors with 2 types of wireless connections: WiFi and NB-IoT. All data is stored on cloud servers. The proposed system includes an alert system for detecting the anomaly detection of the water quality. There is also a dashboard that presents real-time data for analysis and decision-making to reduce the process of water quality monitoring and facilitate farmers. In addition, farmers can use the information to analyze and make decisions to solve problems. This will help reduce the rate of loss of productivity for farmers.

References

[1] Choongan, C. (2018). Thailand's fisheries situation (Technical Paper No. 6/2018). Bangkok, Thailand: Fisheries Development Policy and Strategy Division, Department of Fisheries. Retrieved from https://www.fisheries.go.th/strategy/fisheconomic/doc/Thailand's fisheries situation.pdf

[2] Boyd, C.E. and Lichtkoppler, F. (1979). Water quality management in pond fish culture (Research and Development Series No. 22). Alabama, USA: Auburn University.

[3] Boyd, C.E. (1989). Water quality management and aeration in shrimp farming (Fisheries and Allied Aquacultures Departmental Series No. 2). Alabama, USA: Auburn University.

[4] Boyd, C.E. (1998). Water quality for pond aquaculture (Research and Development Series No. 43). Alabama, USA: Auburn University.

[5] Florida Department of Agriculture and Consumer Services. (1999). Farming Marine Shrimp in Recirculating Freshwater Systems, (pp. 146-152). Florida: Harbor Branch Oceanographic Institution.

[6] Deqing, M., Ying, Z. and Shangsong, C. (2012). Automatic measurement and reporting system of water quality based on GSM. 2012 Second International Conference on Intelligent System Design and Engineering Application, (pp. 1007-1010). Sanya, Hainan, China.

[7] Vaddadi, S.K., Sadistap, S.S. and Kumar, P. (2012). Development of embedded wireless network and water quality measurement systems for aquaculture. 2012 Sixth International Conference on Sensing Technology, (pp. 637-641). Kolkata, India.

[8] Nasser, N., Ali, A., Karim, L. and Belhaouari, S. (2013). An efficient wireless sensor network-based water quality monitoring system. 2013 ACS International Conference on Computer Systems and Applications, (pp. 1-4). Ifrane, Morocco.

[9] Sung, W., Chen, J. and Wang, H. (2014). Remote fish aquaculture monitoring system based on wireless transmission technology. 2014 International Conference on Information Science, Electronics and Electrical Engineering, (pp. 540-544). Sapporo, Japan.

[10] Simbeye, D.S. and Yang, S.F. (2014). Citation: Water quality monitoring and control for aquaculture based on wireless sensor networks. Journal of Networks, 9(4), 840-849.

[11] Nguyen, D., Nguyen, T., Tra S., and Luong, K. (2015). Automated monitoring and control system for shrimp farms based on embedded system and wireless sensor network. 2015 IEEE International Conference on Electrical, Computer and Communication Technologies, (pp. 1-5). Coimbatore, India.

[12] Chen, J., Sung, W. and Lin, G. (2015). Automated monitoring system for the fish farm aquaculture environment. 2015 IEEE International Conference on Systems, Man, and Cybernetics, (pp. 1161-1166). Kowloon, China.

[13] Wiranto, G., Maulana, Y.Y., Hermida, I.D., Syamsu, I. and Mahmudin, D. (2015). Integrated online water quality monitoring an application for shrimp aquaculture data collection and automation. 2015 International Conference on Smart Sensors and Application, (pp. 111-115). Kuala Lumpur, Malaysia.

[14] Hongpin, L., Guanglin, L., Weifeng, P., Jie, S. and Qiuwei, B. (2015). Citation: Real-time remote monitoring system for aquaculture water quality. International Journal of Agricultural and Biological Engineering, 8(6), 136-143.

[15] Prasad, A.N., Mamun, K.A., Islam, F.R. and Haqva, H. (2015). Smart water quality monitoring system. 2015 2nd Asia-Pacific World Congress on Computer Science and Engineering, (pp. 1-6). Nadi, Fiji.

[16] Aziz, B., Muchtar, E. and Hariadi, F.I. (2016). Human-machine interface for water quality monitoring system of white-legged shrimp pond. 2016 International Symposium on Electronics and Smart Devices, (pp. 73-78). Bandung, Indonesia.

[17] Africa, A.M., Aguilar, J.A., Lim Jr., C.S., Pacheco, P.A. and Rodrin, S.C. (2017). Automated aquaculture system that regulates pH, temperature and ammonia. 2017 IEEE 9th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment and Management, (pp. 1-6). Manila, Philippines.

[18] Encinas, C., Ruiz, E., Cortez, J. and Espinoza, A. (2017). Design and implementation of a distributed IoT system for the monitoring of water quality in aquaculture. 2017 Wireless Telecommunications Symposium, (pp. 1-7). Chicago, IL, USA.

[19] Das, B. and Jain, P.C. (2017). Real-time water quality monitoring system using internet of things. 2017 International Conference on Computer, Communications and Electronics, (pp. 78-82). Jaipur, India.

[20] Hairol, K.N., Adnan, R., Samad, A.M. and Ruslan, F.A. (2018). Aquaculture monitoring system using Arduino Mega for automated fish pond system application. 2018 IEEE Conference on Systems, Process and Control, (pp. 218-223). Melaka, Malaysia.

[21] Saha, S., Rajib, R.H. and Kabir, S. (2018). IoT based automated fish farm aquaculture monitoring system. 2018 International Conference on Innovations in Science, Engineering and Technology, (pp. 201-206), Chittagong, Bangladesh.