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# Automated Continuous IoT-Based Monitoring System for Vaname Shrimp Cultivation Management

Dahnial Syauqy*[1], Buce Trias Hanggara[2], Welly Purnomo[3], Widhy Hayuhardhika Nugraha Putra[4], Nyoman Wira Prasetya[5]

[1,2,3,4]*Faculty of Computer Science, Universitas Brawijaya*
[5]*Computer Science Departement, School of Computer Science, Bina Nusantara University*
**dahnial87@ub.ac.id*

## ABSTRACT

Shrimp cultivation in Indonesia has been increasing since the introduction of white leg shrimp or often known as vaname (*Penaeus vannamei*) from the South Pacific waters. The use of a cultivation model with a circular pond with a diameter of 10 meters has begun to attract shrimp farmers in the northern coastal areas of Java, including Tuban Regency. There are several water quality parameters that affects survival rate such as Dissolved Oxygen (DO), Temperature, and Total Dissolved Solids (TDS). Shrimp pond farmers in Tuban Regency have used digital measuring tools to monitor the environmental conditions. However, these measurements cannot be carried out continuously for 24 hours. This often causes delays in identifying problems that occur in ponds and eventually impacts on reducing biomass weight, resulting in not achieving harvest targets. In this study, a continuous monitoring system for water quality management was designed and implemented. The system consists of an IoT-based water quality monitoring device combined with a Shrimp Aquaculture Management Information System. Based on the system that has been built, it is found that the system has been able to acquire all sensor parameters and send them to the server. The results of calibration and prediction using linear regression show that the average data reading error is achieving 14% for DO sensors, and 1% each for temperature and TDS sensors. The aggregated data is presented in tabular and graphic formats so that daily monitoring and predictions can be carried out in ponds.

**Keywords**: Water quality monitoring, IoT, Shrimp Pond, system design.

## 1 INTRODUCTION

Today, fisheries are one sector that can contribute a large amount of foreign exchange. However, the decline in production from ocean fisheries has encouraged the use of pond in land for fisheries businesses. An example form of the land pond utilization is the cultivation of water shrimp ponds in coastal areas. Utojo and Asaad [1] mention that aquaculture business is one of the activities in coastal areas. One of the aquaculture businesses that has large local and international demand is shrimp ponds. This is because shrimp has economic value [2] and is known for its good nutritional value. One type of shrimp that is popular and has constant increment in the demand is the Vaname shrimp (*Litopenaeus vannamei*) which is known as white leg shrimp [3][4]. Generally, some of these requests even come from abroad such as China, Europe, America, and Japan [5]. Vaname shrimp are generally cultivated using a square/rectangular pond. In addition to using a box pond, Vaname shrimp cultivation can be carried out using a circular pond with a diameter of 10 meters, and a height of 1.2 meters. This round pool is more space efficient and can be moved [6]. Tuban Regency is an area in East Java that has quite large fishery potential in which, the area contributes to the value of regional income from fishery resources of more than 3 tons per km [7].

Researchers have conducted many studies on shrimp cultivation in Indonesian territory. Some research shows that production capacity is related to pond management [8][9]. Weak management functions will affect to its lower production [10]. On the other hand, better management functions implementation will push higher production [11]. To increase the production capacity of vaname shrimp, technology is used for shrimp farming [12]–[14]. Shrimp production in ponds is influenced by several factors, including growth rate, stocking density, and survival rate. Technological engineering in shrimp farming can be done by manipulating these three factors. Some examples of the application of appropriate technology related to shrimp ponds are as done by Buwono [15] in the form of using an automatic feeder to help the feeding process which was previously still in the conventional way, and another example is the provision of marine bacteria. [16]. In terms of technology, generally pond farmers implement traditional and combine traditional plus technology [17].

Proper water quality management is one of the determining factors for the success of shrimp farming [18]. Some water quality parameters in shrimp ponds are important to be monitored, including Dissolved oxygen (DO), temperature, salt percentage and salinity. Renitasari and Musa [19] conducted studies and techniques for water quality management for white shrimp. In this study, they were observing temperature, brightness, salinity and pH between morning and evening and giving lime (CaCO3), bacteria to maintain water quality. To support the development of the life of Vaname shrimp, the water temperature needs to be maintained so that the range is at 28 to 30°C which affects the shrimp's appetite [20]. In addition, the salinity of pond water also needs to be maintained in the range of 10-34 ppt. If salinity is not maintained and eventually falls outside this range, the worst condition is shrimp death [21]. The next factor that needs to be considered is the level of turbidity and brightness of the pond pond. A good brightness level for shrimp pond cultivation is less than 40 cm [22]. Another parameter is the level of Dissolved Oxygen (Dissolved Oxygen) in pond water. To support good development for shrimp, a good oxygen content is in the range of 5-7 mg per liter [23].

Based on the previous observations of the case studies in the Tuban Regency area, in terms of monitoring water conditions, shrimp pond farmers have used digital measuring tools to monitor the environmental conditions of shrimp ponds. However, measurements have not been carried out continuously for 24 hours. This often causes delays in identifying problems that occur in ponds and impacts on reducing biomass weight, resulting in not achieving harvest targets.

Pauzi [24] have developed a system to monitor pond water quality based on Arduino Uno and Blynk. Sensor devices used are temperature, DO and pH sensors. However, this system still requires the help of the Blynk application as a data server so that it can be monitored remotely. Ramadhan [25] also developed data logging of


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pond water quality parameters based on NodeMCU, LDR sensors and water temperature sensors. This device is connected to the internet and utilizes Google Firebase services as a data container.

The results of these various studies can be used as a reference for researchers in developing an IoT-based water condition monitoring system. The proposed system to be built will collect data from several sensors and then send it to the cloud so that the sensor data can be further utilized in a web or mobile-based Shrimp Pond Management Information System. It is hoped that this research can produce a solution that helps shrimp pond farmers in achieving the harvest target of aquaculture shrimp ponds.

## 2 MATERIAL AND METHODS

### 2.1 BASE DESIGN

To be able to monitor pond water quality, several sensors which consist of 1) Dissloved Oxygen (DO) sensor; 2) Total Dissolved Solids (TDS) sensors; 3) temperature sensor; and 4) turbidity sensor are required and installed in the pool area. From the node location, the sensor data will be sent to the master station located in a special room and then sent to the server in the cloud.

### 2.2 SYSTEM DESIGN

The Pond has a specific size that causes the station node to be positioned at a certain location so that the sensor can be submerged in the water. At the pond location there are several pond points, but in this study, only one pond was selected with about 30 meters from the pond control house where the master station was installed. The design of the placement of the tool in the pond and its location is shown in FIGURE 1.

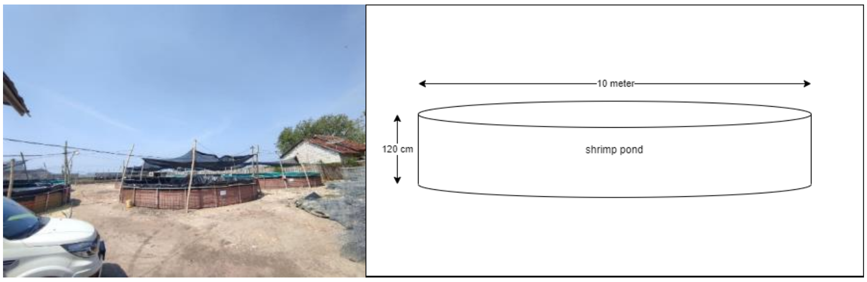


FIGURE 1. Pond size and location

The block diagram of the system is shown in FIGURE 2. The sensor node was placed in one of the pools, and it has Arduino UNO as the main microcontroller. All sensor acquisition were read by Arduino UNO and then sent to the WEMOS D1 module which functions to communicate through Wi-Fi to the master station. Wemos was chosen because it has an external antenna device so that it can be installed outside the box. The box itself was made with industrial grade quality to make it stronger so that it can be installed for a long time for areas with extreme characteristics such as the beach.

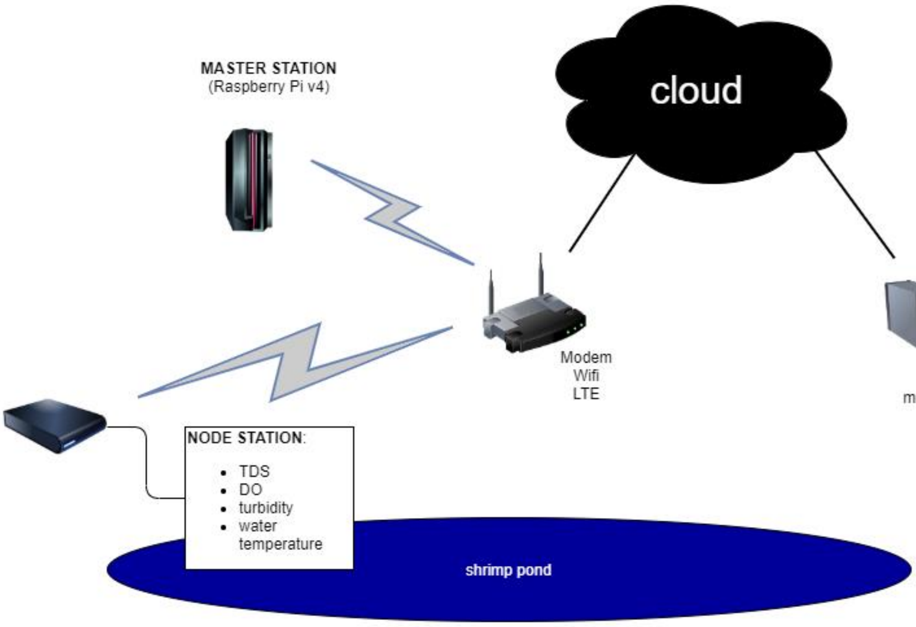


FIGURE 2. System design

The node station acquires data from four sensors: TDS, water temperature, DO (Dissolved Oxygen) and turbidity. All those parameters are then encapsulated in JSON format and sent to Wemos D1 through SPI communication as illustrated in FIGURE 3. The master station was built using a minicomputer device, Raspberry Pi v4 with an LCD display attached on it. This device is connected to the sensor node through an access point that has been configured, so that both points are on the same network.

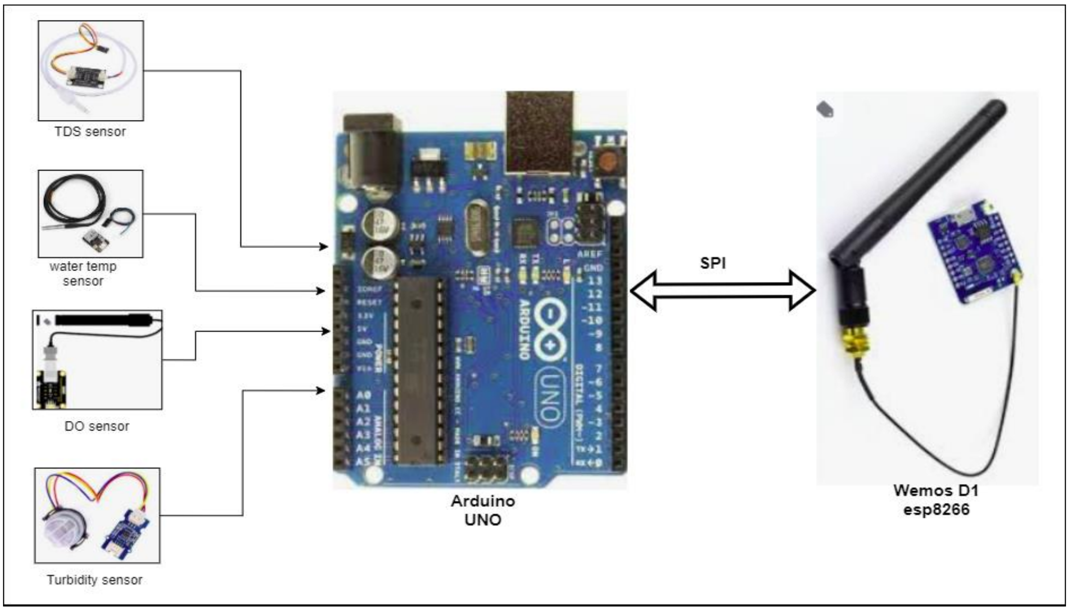


FIGURE 3. Node station circuit


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## 2.3 COMMUNICATION DESIGN

As stated, that node station and master station are connected in the same network. In this case study, a 4G Wi-Fi Router device with a cellular card is used due to its beachfront location and did not yet have a wired internet network. Both the node station and master station are set to have a DHCP IP configured automatically. Then, the data will be sent by the node station using UDP to the broadcast IP, using specific port. The master station continuously listens to that port and will periodically send data to the cloud server once every minute.

With various possible connection losses or hangs, the raspberry Pi as a master station is also equipped with fault tolerant coding to periodically restart itself every 3 hours. During restart phase, the master station will reconnect to the internet, autorun the program, and establish communication to listen for specific UDP port if new data is sent by the station node.

## 2.4 SYSTEM FLOW CHART

The following is the master station flow diagram which is built using the Python v3 programming language according to the prior explanation.

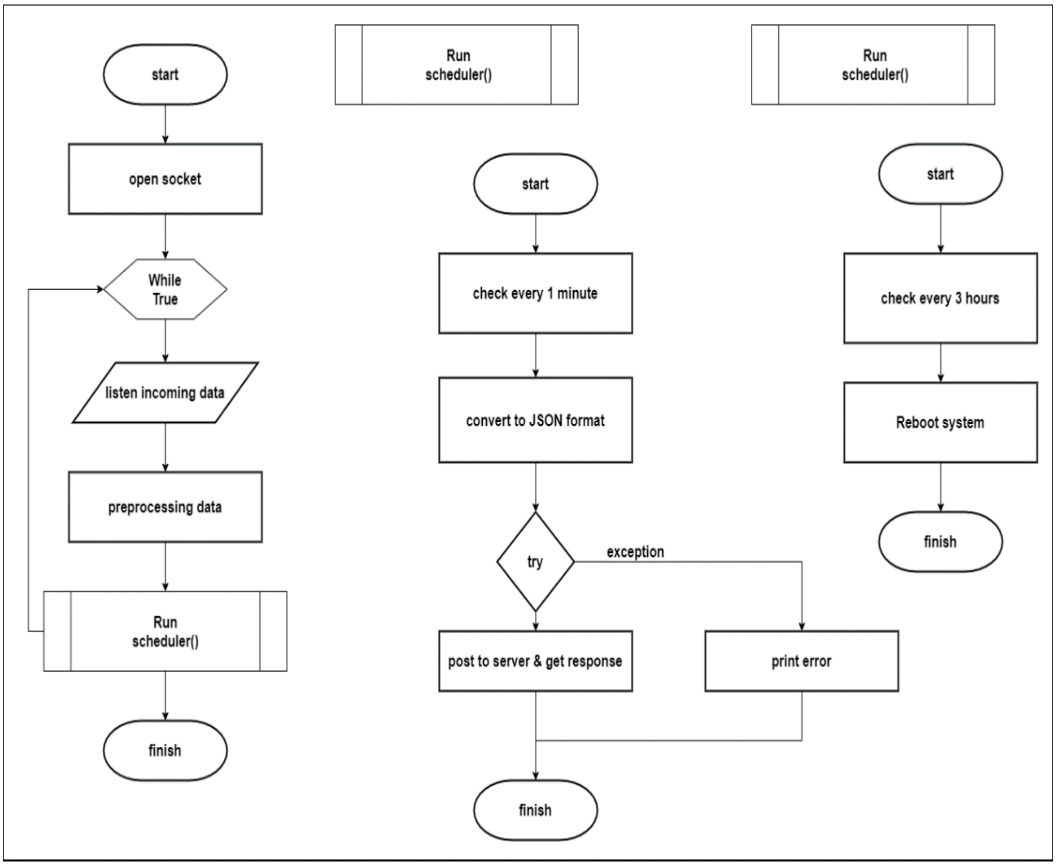


FIGURE 4. Flow diagram of master station

From the Node station side, Arduino UNO continuously sampling alternately from the analog pins connected to each sensor. The obtained data is then given additional node identity data and transferred to Wemos D1. Furthermore, the data is sent continuously if there is data from Arduino UNO to the IP broadcast which is listened to by the master station. To maintain system reliability, Arduino is equipped with a watchdog code with an 8 second timer to ensure that it will restart itself when a hang condition occurs.

## 3 RESULTS AND DISCUSSION

### 3.1 IMPLEMENTATION OD NODE STATION DEVICES

The node station is the earliest part to be built because this part is the most essential and complex part of the system. As shown in FIGURE 5FIGURE 5, all electronic components of the microcontroller and sensors are placed in an industrial grade box to protect against water or moist air entering the device, considering that the device will be installed above a pond on the beach.

FIGURE 5. Node station implementation

### 3.2 SYSTEM INSTALLATION PROCESS ON POND

After the node station and master station have been programmed and functionally tested, it takes a day to do the installation at the pond. The location of the pool is about 30 meters from the control room. The installation of the node station device is planted above the pool and the opposite side of the water pump is chosen to prevent it from being carried away by the current. For the master station, it is placed in the control room building adjacent to the Wi-Fi router. The Wi-Fi router uses the cellular type since there is no wired internet access in the pond area.


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FIGURE 6. Node and master station installation

### 3.3 MONITORING SYSTEM DISPLAY

After all the node station and master station devices have been installed, the next step is to test the data transmission and read it directly on the server. According to the display, it appears that all sensor data is well read and sent periodically once every minute. After the data is successfully sent and having no problems, then the next step is to access it through the pond management information system that has been designed. There are several main menus that can be selected to monitor and query the history data. The first display is in the form of a tabular data containing the timestamp and the readings of each sensor. There is also a button for searching data on a specific date and time.

The second display is a graphic chart (FIGURE 8). With the graphical display, the characteristics and trends of data changes can be monitored. For example, in one day it can be monitored whether the DO value has increased in a certain hour period, when is the highest temperature in that day, and so on.

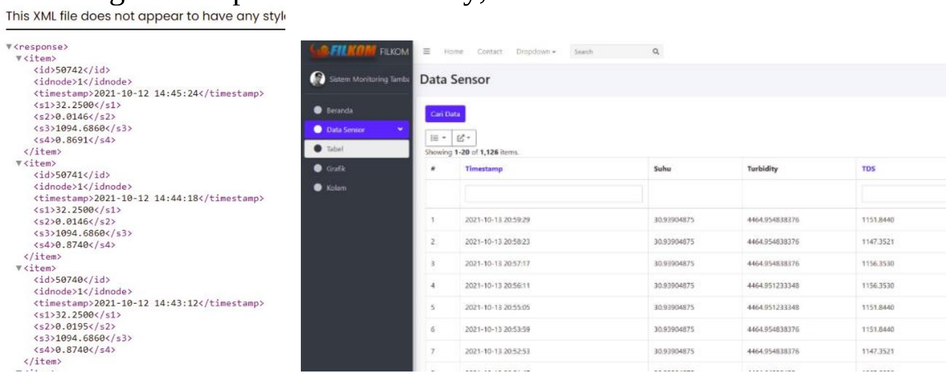


FIGURE 7. (a) Data sent to the server and (b) Tabular data

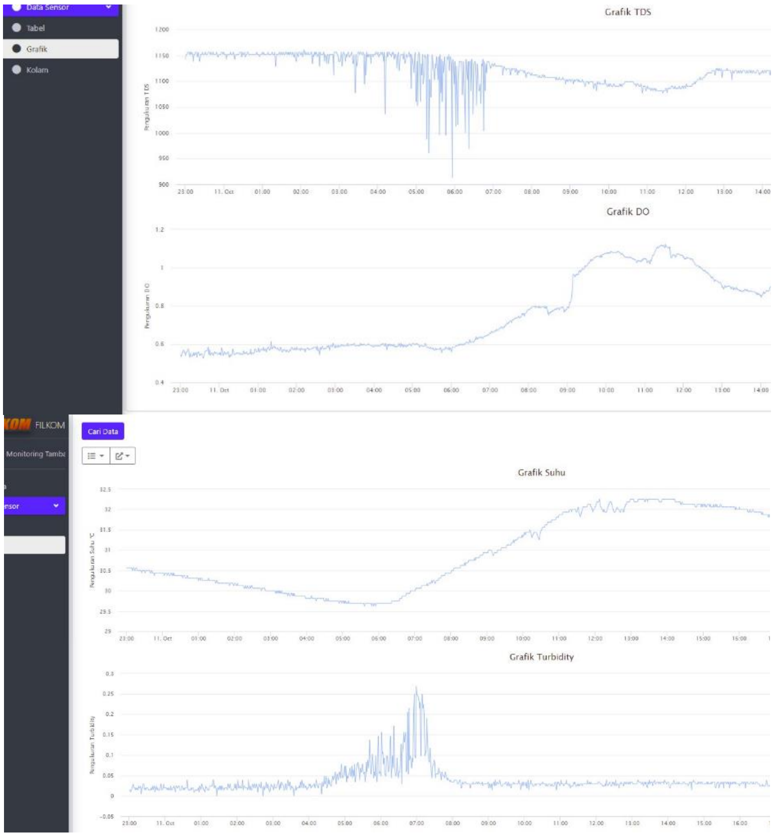


FIGURE 8. Graphical data

## 3.4 SENSOR TESTING AND CALIBRATION

Sensor testing and calibration is intended to determine whether sensor readings can be compared with measuring instruments which is usually used by pond managers. In this test, 3 sensors were calibrated, such as the DO sensor, TDS sensor and temperature sensor. Below are the procedures to calibrate the sensors:

1. After the sensor data is displayed on the server, it is monitored daily
2. Pond managers are asked for assistance in taking daily sampling periodically, morning and evening. Morning is done around 6-8 AM, and afternoon is done around 2-4 PM
3. Tabulate data according to date and time
4. calibrate using linear regression
5. Regression results in the form of equations are entered to update the data listed on the server

Calibration is done by using linear regression between the data read by the sensor and the data from the measurements using standard measuring instruments such as depicted in FIGURE 9. The results of the regression are then used to make predictions as shown in the prediction column. The results of calibration and prediction using linear regression show that the average data reading error is about 14% for DO sensors, and 1% each for temperature and TDS sensors.


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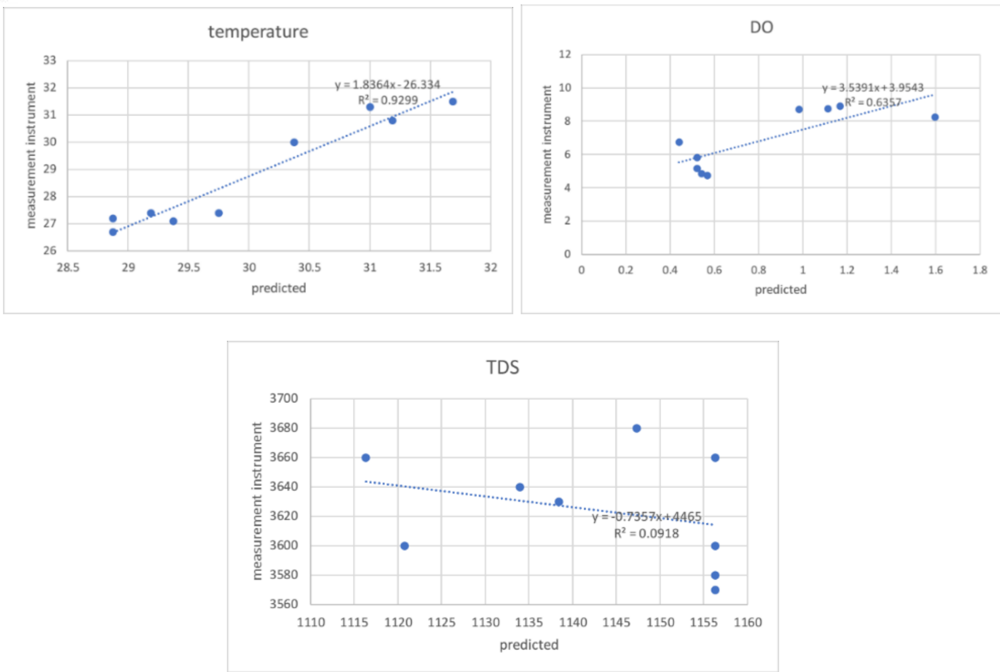


FIGURE 9. Linear regression of predicted value from measurement instrument

TABLE 1.
Linear regression on sensor readings compared to instrumental readings

| Instrumental readings | | | Prediction (by system) | | | error | | |
|---|---|---|---|---|---|---|---|---|
| DO | TDS | temp(°C) | DO | TDS | temp (°C) | DO | TDS | temp (°C) |
| 5.17 | 3570 | 27.4 | 5.80 | 3614.231 | 28.29 | 12% | 1% | 3% |
| 8.26 | 3600 | 31.5 | 9.60 | 3640.437 | 31.85 | 16% | 1% | 1% |
| 4.87 | 3580 | 27.1 | 5.87 | 3614.231 | 27.61 | 21% | 1% | 2% |
| 8.74 | 3630 | 31.3 | 7.89 | 3627.428 | 30.59 | 10% | 0% | 2% |
| 4.72 | 3660 | 26.7 | 5.95 | 3614.231 | 26.69 | 26% | 1% | 0% |
| 8.7 | 3660 | 30 | 7.42 | 3643.66 | 29.44 | 15% | 0% | 2% |
| 5.83 | 3680 | 27.2 | 5.80 | 3620.853 | 26.69 | 0% | 2% | 2% |
| 8.92 | 3640 | 30.8 | 8.08 | 3630.698 | 30.93 | 9% | 0% | 0% |
| 6.75 | 3600 | 27.4 | 5.51 | 3614.231 | 27.26 | 18% | 0% | 0% |
| Average error | | | | | | 14% | 1% | 1% |

## 4. CONCLUSION

Based on the results of the design and implementation, it is concluded that the water quality monitoring system for vaname shrimp ponds requires reliability and is placed in a special position to be able to reach the position of the water in the pool. This was achieved by several things, namely the packaging system using industrial grade boxes and communication devices with external antennas, as well as making a stand for laying the system on the edge of the pool along with sensor floats. With about 30 meters from the control house, Wi-Fi is used as a communication medium between the node station and the master station. The information system has been designed to be able to monitor the system remotely using the internet network. This system is intended for pond managers to always be able to get daily measurement results on DO, TDS, temperature, and turbidity parameters. The system can also be remotely as a form of anticipation for system maintenance using the Pi Tunnel that has been configured on the master station device. The following are some suggestions given regarding the development of this research monitoring system: 1) Sometimes the sensor surface is covered with moss that is on the water surface. Therefore, the placement and design of the float should accommodate to avoid moss; 2) It is recommended that the internet network is better by using cable-based network. This is due to in coastal areas, cellular networks sometimes have problems in terms of signal; 3) In the future, it can be further developed for the application of a more comprehensive management information system for pond management by considering the values of the monitoring system as the basis for recommendations for actions that need to be taken by managers.

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