IoT based automatic monitoring system for water nutrition on aquaponics system

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Abstract. Aquaponics is an activity to cultivate plants and fish. Giving the organic liquid fertilizer as a nutrient enhancer will improve the quality of catfish and lettuce yields. However, this causes the water to become dirtier. The deteriorating water is characterized by the TDS value in aquaponic ponds exceeding 500 PPM. If the TDS value exceeds 500 PPM, water drainage will be applied. For treatment of aquaponic, experts use manual control. The system is designed to solve it. The method used in this Final Project is the study of literature to find the basic theory in aquaponics and analyze the problems. The next thing to do is designing the system, starting from the design of automatic control systems to remote monitoring systems. Afterwards, testing tools is conducted to see whether the system is able to run well. Based on the test results, the system can run well; however, a number of deviations are found, including the RTC test showing a delay time for 00.02.10 of RTC compared to the national standard time and an error of 2.4% found on a calibrated TDS sensor testing. The success rate of sending monitoring data is 100% of Antares connectivity testing.

1. Introduction
Aquaponics is an approach of combining two technologies: recirculation aquaculture (fish-farms) and hydroponics (soil-less cultivation of crops) [1]. The fish waste provides an organic food source for the growing plants, while the plants provide a natural filter for the water where the fish lives in. The third participants are the microbes (nitrifying bacteria) and composting red worms that thrive in the growing media. Those microbes are converting the ammonia from the fish waste into nitrites first, then into nitrates and the solids into compost which is food for the plants [2]. Aquaponics have some benefits such as conservation of water resources and plant nutrients, intensive production of fish protein and reduced operating costs compared to the system in isolation. Water consumption in integrated systems including tilapia production is less than 1% of the required in pond culture to produce equivalent yields [3]. Deep Flow Technique (DFT) is a method that is often applied to aquaponics system, i.e. water from fish ponds is flowed into plant containers using closed pipes with high water in pipes 2-5 cm.

Mr. Wayan, an expert and business owner of Aquaponics in Kelapa Dua Karawaci, Tangerang, Banten, said that the provision of liquid organic fertilizer as a nutrient enhancer in the aquaponics system can improve the quality of yields of catfish and lettuce plants [5]. The administration of 2 ml dose of liquid organic fertilizer/250 ml of water given every 2 days at 9 a.m. as much as 50 ml in the aquaponic
system has the best yield compared to the aquaponic system without the provision of liquid organic fertilizer. However, giving fertilizer at a prescribed dose and time can cause the pool’s water quality to quickly become smelly and dirty. The deteriorating water quality can be seen from the value of Total Dissolved Solid (TDS) in aquaponic ponds exceeding 500 PPM (Part Per Million). If the TDS value in the pond is in the range of more than 500 PPM, water drainage and additional water are applied until the TDS value is below 500 PPM.

Knowing the importance of nutritional control for plants and fish in aquaponic systems, a system is created to make it easy to regulate water nutrient levels automatically. This nutrient control system is guided by the method of administering liquid organic fertilizer carried out by aquaponics experts, as well as the method of draining and adding water which is based on the TDS value. The water nutrition control system in aquaponic systems also applies the concept of IoT (Internet of Things) to monitor the TDS value in aquaponic pond containers.

2. Design of the system

![Aquaponics System Design](image1)

**Figure 1. Aquaponics System Design.**

Figure 1 explains that the system requires a microcontroller, TDS, RTC sensors, relays, pumps, wifi module and Antares platform that will work together automatically to achieve the set goals. After determining the relation between the microcontroller and its supporting devices, the assembly process is carried out.

![System Block Diagram](image2)

**Figure 2. System Block Diagram**
The devices used are Arduino Uno as a microcontroller, TDS and RTC sensors as inputs, relays connected to the pump as output, and Wemos D1 Mini as an Arduino connector with the internet via wifi media so that the sensor readings can be accessed through the Antares platform. The design of the system is divided into 3 processes, namely: the process of draining, the process of giving fertilizer and the process of sending data to Antares.

In the dewatering process, the TDS max value is set at 500 PPM and the TDS min value is set at 400 PPM. If the TDS value measured by the TDS sensor is above 500 PPM, the in-pump and out-pump will light up simultaneously. The in-pump will put clean water into an aquaponic pool container, and the out-pump will release dirty water from the pond. Furthermore, if the TDS value measured by the TDS sensor is smaller than 400 PPM, the in-pump and out-pump turns off.

The process of giving fertilizer is set every 2 days at 9 in the morning. When RTC reads the set time, Arduino will instruct a fertilizer pump to added liquid fertilizer with a dose of 2 ml of fertilizer/250 ml of water as for 50 ml. After reading the pump at 50 ml, the pump turns off.

The process of sending data to Antares, Wemos D1 mini, is over an internet network connection. The data is in the form of TDS values found in aquaponic ponds. TDS value data forwarded from Arduino is sent to the D1 mini wemos, then forwarded to send data to the Antares server in the form of status changes. The results of the sensor output displayed on the Antares platform are uploaded so that the data generated by the TDS sensor will be stored and can be monitored by users who are away from the aquaponic system.

**Figure 3. Flowchart System**
3. Analysis

3.1. Sensor Calibration
This test is conducted to calibrate the applied TDS sensor so that the TDS sensor output is in accordance with the TDS meter. Tests are carried out in seeing systematic errors. The formula for error value calculation is [4]:

\[ error = |X - Xi| \%
\]

\[ error = \left| \frac{(X - Xi)}{X} \right| \times 100\%
\]

Where X is the reference data and Xi is the actual data.

Thus, it can be concluded to find error and error percentage in this system, the formulas used are [4]:

\[ Error = |TDS \text{ Meter Value} - TDS \text{ Sensor Value}|
\]

\[ \% \text{ error} = \left| \frac{(TDS \text{ Meter Value} - TDS \text{ Sensor Value})}{TDS \text{ Meter Value}} \right| \times 100\%
\]
Figure 4. shows the value of TDS and TDS Meter sensors in a water container. TDS sensor data collection is in the form of voltage (V) and graph values obtained which will become the range of sensor output values and PPM value obtained from ADC Arduino.

Figure 5. shows the results of the TDS sensor readings after calibration and re-compared with the TDS meter value. The results of these tests show that there are still differences in the value of the TDS and TDS meter sensors. TDS meter reading is lower than the TDS sensor value with an average difference of 13.08 PPM.

Figure 6. shows the highest percentage of TDS errors at 6.1% and the lowest one at 1.4% with an average error of 2.4%. The TDS sensor value has an error that gets lower when the measured TDS value is higher. Therefore, this TDS sensor will be well-recommended when the TDS value to be measured is in the range of 758 PPM-819 PPM. The error can be tolerated, meaning that the sensor is in good
condition. This shows that the performance of the sensor is quite precise and accurate to be used in measuring the TDS value of the aquaponic pond.

Figure 7. shows the response time of TDS sensor performance with an average of 9.22 seconds. Response time is an observation of the system’s output response to change in time, which is observed starting when the input signal/interference/load changes until the response enters in the steady state. Differences in response time and error problems that occur are usually due to the dynamic movement of solid particles dissolved in water.

3.2. Pump Calibration
This test is carried out to calibrate the volume of water released by the pump so that the pump can release the water based on the desired volume.

![Graph of Pump Calibration](image1)

**Figure 8.** Pump Calibration

![Graph of Pump Output After Calibration](image2)

**Figure 9.** Pump Output After Calibration
The results of pump calibration can be seen in Figure 8. Data retrieval is done regularly showing linear values. The pump cannot work at sampling below 2000 ms because it cannot pump water optimally.

The results of testing the pump after calibration can be seen in Figure 9. The figure shows a comparison between the input volume, output volume and volume based on the pump specifications. Obviously, the comparison of input volume and output volume of the pump differs greatly from the pump specification volume. This shows that the pump does not work based on the specifications.

Figure 10 shows that there is an error in pumping water at a large volume. The highest error value is 2.9% when the pump works for 775 ml. So that this pump will be well-recommended when pumping water in the volume range of 50 ml-525 ml. The need for a pump to lift 50 ml of water needed for fertilizer application is accurate so that the pump can be used in the system.

3.3. Drainage Test
Drainage test is carried out on an aquaponic pond containing 400 L of water with an initial TDS value of 544 PPM. Further dilution is carried out by inserting 170 PPM of clean water and removing dirty water in the pond. The test sample is taken 30 times every 20 seconds with both pumps (1200L/H) simultaneously.
In Figure 11, it is known that the average change in TDS value when draining is 5 PPM, meaning that each drainage pump that is on for 20 seconds can reduce the TDS value by about 5 PPM. The difference between the initial TDS value, i.e. 544 PPM and the final TDS value, i.e. 394 PPM is 150 PPM. Then, the system of dewatering characteristics uses the comparison formula as follows:

\[
\frac{a_1}{a_2} = \frac{b_1}{b_2}
\]  

(5)

\[
\frac{\text{Time for draining}}{\text{TDS for draining}} = \frac{\text{Time for drain (Testing)}}{\text{TDS for draining (Testing)}}
\]

(6)

\[
\frac{X}{150 \text{ PPM}} = \frac{20 \text{ s}}{5 \text{ PPM}}
\]

(7)

Based on the equation (7) it takes 600 s to reduce the TDS value from 544 PPM to 394 PPM.

3.4. RTC Accuracy

This test is carried out periodically by looking at the comparison of time between the RTC and the national standard time and processed by looking at the performance of the RTC accuracy whether the pump can work based on the set point time.

![RTC Accuracy](image)

Figure 12. RTC Accuracy.

The results of the RTC DS1307 test explain that there are deviations, namely the time in the RTC is longer 00.02.10 than the national standard time. The system will be regulated by the time the RTC is added 00.02.10 to follow the national standard time. Changes or delays in RTC are due to the limited capacity of the Arduino power supply. The amount of electric current permitted to pass through the digital pin I/O on Arduino is 40 mA. The power supply from Arduino will divide the power into several I/O pins such as pins for TDS sensors, pH sensors, RTC and wemos. Therefore, each I/O pin gets a weak/less current. With a lack of electricity supply, the delay appears on the RTC, so that the time on the system does not match the time in the appropriate RTC library. Based on the results of pump testing, no deviation is found. The pump can be lit on all input time samples.
3.5. Antares Connectivity

| TDS and PH | Data Delivery Time | Data Transmission | Data Accepted |
|------------|--------------------|-------------------|---------------|
| "tds" : 280 "PH" : 5.8 | 21.23.32 | SUCCESS | 21.23.32 |
| "tds" : 280 "PH" : 5.8 | 21.24.32 | SUCCESS | 21.24.32 |
| "tds" : 280 "PH" : 5.8 | 21.25.32 | SUCCESS | 21.25.32 |
| "tds" : 282 "PH" : 5.8 | 21.26.32 | SUCCESS | 21.26.32 |
| "tds" : 282 "PH" : 5.8 | 21.27.32 | SUCCESS | 21.27.32 |

From Antares connectivity tests, the results of the success of data transmission are obtained in all samples. There is no visible delay and network interference during the experiment. This shows the performance of Arduino and Wemos D1 Mini works is considered good.

![Figure 13. Monitoring Data Results from Antares Platform](image)

3.6. Water Quality

Water quality analysis is carried out to know the characteristics of changes in water quality after the application of a fertilizer system. This observation is carried out every day starting from May 15, 2019 to June 13, 2019 with a random hour sequence. The variables observed are TDS and information in the working system.
Figure 14. TDS Value Changes.

From the observations for 30 days, the average increase in TDS value per day is 2.93 PPM. Changes in the value of TDS continue to increase due to the metabolism of fish that are increasingly dissolved in water. During this one-month observation, fertilizer administration system can work every 2 days based on the rules set, but not for the drainage system (the TDS value has not exceeded 500 PPM).

4. Conclusion
The system of adding fertilizer with a dose of 2 ml of fertilizer/250 ml which is done every 2 x 24 hours at 09.00 am as much as 50 ml can run well. The automatic fishpond water drainage system can stabilize TDS values below 500 PPM, and the monitoring system can display TDS values that are updated every hour through the Antares platform.

5. References
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