Aquacision: A Multiparameter Aquaculture Water Quality Tester and Decision Support System

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Abstract— **The paper presents a multiparameter aquaculture water quality tester and decision support system. The device was developed to aid aquaculture farmers in monitoring water quality parameters and maintaining or achieving optimal levels by suggesting ways on how a farmer can respond to such measurements. The Aquacision device measures six different water quality parameters; temperature, practical salinity, pH level, total dissolved solid (TDS), oxidation-reduction-potential (ORP), and algae density. Measurements were sent to the Aquacision application where they were processed to determine the course of action that was best to maintain or achieve optimal levels through the use of fuzzy rules. The Aquacision sensor measurement accuracy for temperature, practical salinity, pH level, TDS, and ORP are 99.746%, 99.465%, and 99.406%. 99.705%, and 95.575%, respectively during the actual testing. The AQUACISION application using the ISO/IEC 25010 software quality model evaluation with a 1-5 rating scale received an average of 4.633, 4.667, 4.525, 4.750, 4.525, and 4.450 for characteristics of functional suitability, performance efficiency, compatibility, usability, reliability, and portability, respectively. The application also received an average satisfaction of 4.750 which is highly satisfactory.**

Keywords— *aquaculture; temperature; practical salinity; algae density*

I. INTRODUCTION

The world population continuously increases each day and so is the demand for a source of food. In response to the need for food security, people have ventured into aquaculture. Aquaculture refers to the farming of aquatic organisms in a controlled aquatic environment through closed systems or pond systems, submersible net pens, open net pens, or recirculating systems [1]. Aquaculture offers excellent career and income-generation opportunities. Today, it has become one of the many fast-growing food production sectors in the world. Eating fish products has become a part of human culture and diet as it offers a good source of protein, fatty acids, vitamins, minerals, and other micronutrients the body needs according to the Food and Agriculture Organization of the United States. Unfortunately, the attempts to increase aquaculture productivity cause water pollution that in turn decreases productivity. Water pollution through eutrophication is a negative effect of the rapidly growing and under-regulated aquaculture industry. Such problems are the result of poor decisions and aquaculture management actions [2].

To avoid water pollution, there is a need for better decisions and aquaculture management actions. Decisions to be administered must be established from the current aquaculture water quality parameters. As a result, there have been several research made to test the current water quality and the relationship of water pollution with poor aquaculture decisions and actions.

Research conducted for monitoring water quality using wireless networks suggested that the conventional monitoring process of manual collection of samples and laboratory testing and analysis is time-consuming and ineffective. In turn, it was proposed that wireless sensors are more efficient in monitoring water quality [3]. Another research introduced a smartphone-based embedded system designed to measure different water quality parameters in various remote locations [4]. Research on multi-parameter integrated water quality sensors offers a low-cost system for water monitoring [5].

Aquaculture pollution is caused by the excess use of fertilizers, uneaten feed pellets, and the application of other chemicals. Both the fertilizer and feed pellets contain nutrients that if not controlled may cause pollution. Chemicals like lime alter water quality; it increases both the pH level and water hardness, excessive use of such chemicals may result in fish kills as fishes live in certain pH levels [6].

This research was conducted to build a device that can measure different water quality parameters for aquaculture and provide suggestions for decisions and actions to be made. The device has a pH sensor, electrical conductivity sensor, temperature sensor, turbidity sensor, TDS sensor ORP sensor that tests the current aquaculture water quality, and a fluorometer that measures the algae density. The device also comes with an application for the decision support system. The application suggests action constructed from fuzzy logic according to the results of the measured water quality sensors.

II. METHODS

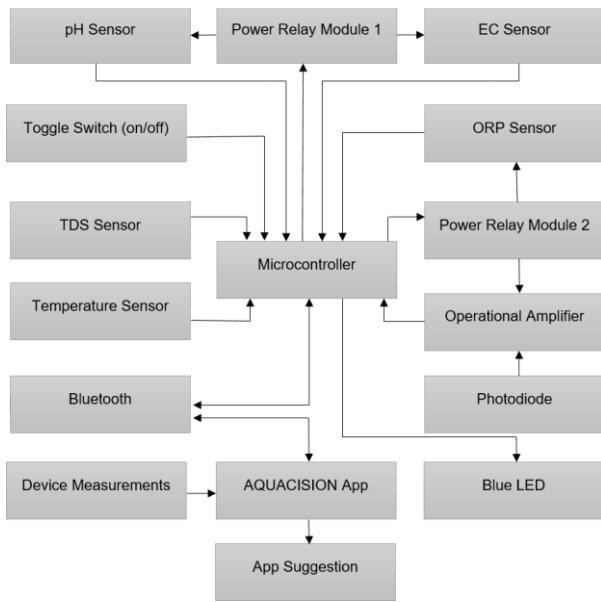### A. Project Design and Specification
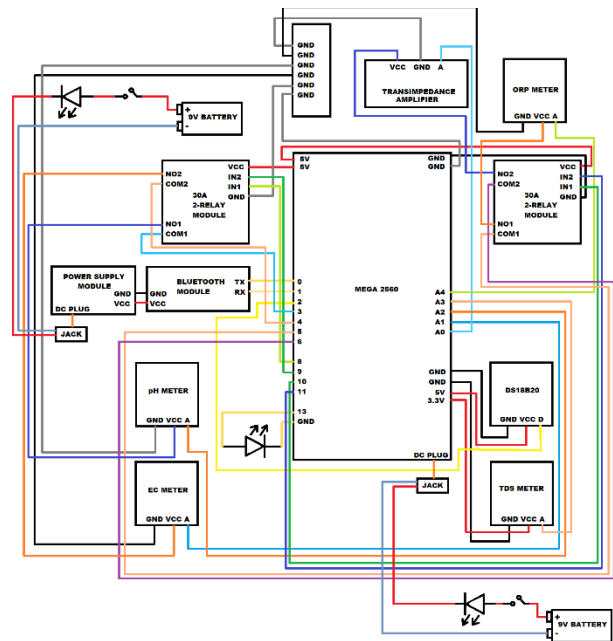
Fig. 1. The block diagram of the device.

Fig. 2. The schematic diagram of the device.

The device is comprised of a microcontroller, pH sensor, TDS sensor, ORP sensor, electrical conductivity sensor, temperature sensor, LEDs, photodiode trans-impedance circuit, Bluetooth module, 2- 2-channel relay modules, and toggle switches as shown in Fig. 1. The microcontroller is the brain of the device. It controls all the processes and activities the device will perform. The toggle switches with LED indicators start the device when set to on and stop the device when turned off. The decision support system will generate suggestions according to the read results from the pH sensor, electrical conductivity sensor, temperature sensor, TDS sensor, ORP sensor, and in situ fluorometer. The six sensors will measure six different water quality parameters necessary in aquacultures. The blue LED and photodiode trans-impedance amplifier comprise the in situ fluorometer used to monitor the algae biomass density. The Bluetooth module is used to create a connection between the device and the application for sending measured parameters for decision generation. The 2-channel relay modules are used to switch between devices in a queue of measuring. It determines which among the pH meter, EC meter, in situ fluorometer, and ORP meter receives the 5V power supply from the Arduino Mega. The application will generate suggestions on actions an aquaculture farmer should take to improve production, utilize resources, or mitigate water pollution. Decisions generated will be displayed together with the sensor measurements in the application.

Fig. 2 represents the schematic diagram of the whole device. 9V battery supplies are connected to both the power supply module and Arduino mega, this serves as the power source of the whole device. A toggle switch to turn on and off and LED indicators to indicate the state of the device are used. 2-channel 5V relay modules are used to turn on and off the sensor modules for pH meter, EC meter, ORP meter, and in situ fluorometer, this is to limit the power usage of the whole device. The TDS meter operates with a 3.3V power supply while the temperature sensor operates with a 5V supply, both are directly connected to the Arduino Mega 2560. The Bluetooth module is connected to the 5V region of the power supply module, having its TX and RX pins connected to the RX and TX pins of Arduino Mega, respectively. The sensor readings of the in situ fluorometer, EC meter, pH meter, TDS meter, and ORP meter are connected to A0, A1, A2, A3, and A4, respectively, while the temperature sensor is connected to D2. The excitation light source of the in situ fluorometer which is a blue LED is connected to D3. Common grounds are used to accommodate all the sensors and components to build the device.

B. Aquacision Application

The Aquacision application is created using Android Studio. Android Studio is an Integrated Development Environment (IDE) designed on JetBrains' IntelliJ IDEA software and designed mainly for Android Development. It supports Graddle-based builds and provides an Android virtual device to test and debug the applications created in Android Studio.

The Aquacision application contains TextViews to display the measurements sent from the Aquacision device, to act as labels of each measurement and field, and to display the generated suggestions based on fuzzy logic. It contains Spinners that create dropdown menus for the user, ListView that allows a list of options to be displayed, and also

SrollViews, ConstraintLayouts, and LinearLayouts for a fixed and arranged display of objects.

The fuzzy logic sets are incorporated in the application as well as the creation of Bluetooth adapters and threading processes for the application and the device to communicate.

Fig. 3.   The intro screen of the mobile application.

Fig. 3 shows the opening interface of the Aquacision application. The "Turn On" button (1) allows the user to turn on the Bluetooth connection of the mobile device. The "Paired Devices" button (2) opens the Bluetooth interface of the application.

Fig. 4.   The Bluetooth interface of the mobile application.

Fig. 4 shows the Bluetooth interface of the AQUACISION application. The Bluetooth interface shows a list of Bluetooth devices that the mobile phone has paired with. The list view (3)

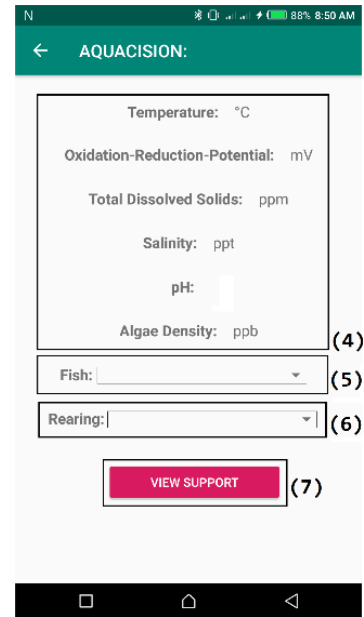enables the user to establish a connection with the chosen Bluetooth device.

Fig. 5.   The monitoring screen of the mobile application.

Fig. 5 shows the measurement display interface of the application. The first block (4) displays the read measurements from the sensors in the device. The second block (5) is a dropdown menu that allows the user to choose the type of fish being reared in the aquaculture. The third block (6) is a dropdown menu that allows the user to choose the type of rearing employed. The "View Support" button (7) is a button that directs the user to the actions recommended to the user (decision support mechanism interface).
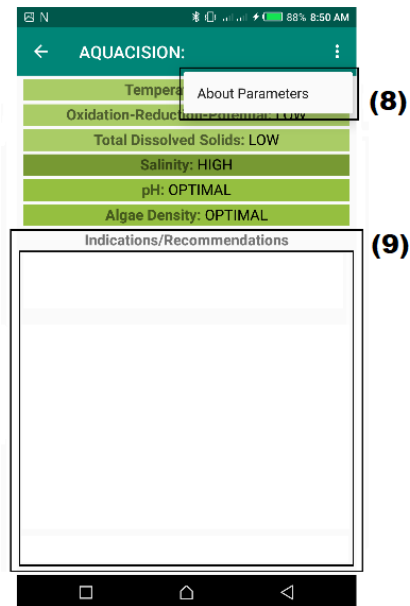

Fig. 6.   The decision support interface of the mobile application.

Fig. 6 shows the decision support mechanism interface of the application. The item menu (8) directs the user to the

parameter information interface which displays information about the parameters. The text box (9) displays the actions suggested for the user to take. The application used shades of green to indicate whether measured parameters are low, optimal, or high. The lighter the shade, the lower the measured value is.
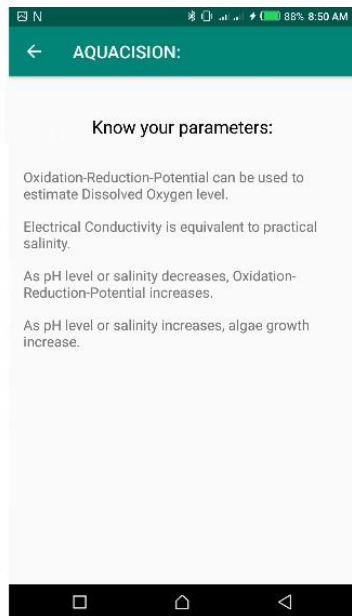

Fig. 7.   The parameter information interface of the mobile application.

Fig. 7 shows the parameter information of the application. The interface displays information about the parameter relationships and how the measurements are used in fuzzy logic to generate suggestions for the aquaculture farmer.

C. Testing and Evaluation

The AQUACISION application is evaluated by 20 respondents using the ISO/IEC 25010 software quality model standard through a 1-5 rating scale. The 20 respondents are composed of 5 respondents who are new to aquaculture, 5 aquaculture farmers, and 10 respondents who have studied professional fields related to aquaculture. The variety of respondents is to test the overall quality of the application using the sub-characteristics presented in the standard used.

The accuracy of the device was measured in this study using the percent accuracy formula (1) which measures the degree of how close are calculated or measured values are to their actual values. The percent error is given as the ratio of error to actual value then multiplied by 100. The percent error is subtracted from 100 to get the percent accuracy.

$$\% \ Accuracy \ = \ 100 \ - \ \left(\frac{theoretical \ value \ - \ measured \ value}{theoretical \ value} \ * \ 100 \right) \quad (1)$$

III.   RESULTS AND DISCUSSION

The device shown in Fig. 8 was brought to local fisheries for calibration and testing and the application was installed to mobile phones for survey. The data gathered are shown in tables and were interpreted using appropriate metrics.

The whole device has a measuring part that can be submerged into the aquaculture and a handheld switch part to turn on and off the whole device. The submergible part of the device is made waterproof to safeguard the electrical components enclosed inside.

Fig. 8.   The working prototype of the Aquacision device.

The researchers calibrated the device and conducted the testing in the local fish ponds in Ballesteros, Cagayan with the supervision of the local aquaculture farmers. Through the first set of tests, the researchers measured the water parameters of five different ponds using their devices and pen-type commercial water testers.

TABLE I.   WATER TEMPERATURE TESTING

Pond No.	Trial No.	Commercial Device (°C)	Aquacision (°C)	Accuracy (%)
1	1	28	28.09	99.679
	2	28	28.10	99.643
2	1	27	27.07	99.741
	2	27	27.09	99.667
3	1	28	28.05	99.821
	2	29	29.04	99.862
4	1	27	27.03	99.889
	2	27	27.09	99.667
5	1	30	30.08	99.733
	2	29	29.07	99.759

TABLE II.   ELECTRICAL CONDUCTIVITY TESTING

Pond No.	Trial No.	Commercial Device (ppt)	Aquacision (ppt)	Accuracy (%)
1	1	8.87	8.92	99.436
	2	9.22	9.27	99.458
2	1	9.65	9.69	99.585
	2	10.01	10.05	99.600
3	1	8.91	8.94	99.663
	2	9.01	9.07	99.334
4	1	8.71	8.76	99.426
	2	8.86	8.92	99.323
5	1	9.32	9.36	99.571
	2	9.35	9.42	99.251

TABLE III.   PH LEVEL TESTING

Pond No.	Trial No.	Commercial Device	Aquacision	Accuracy (%)
1	1	7.51	7.55	99.467
	2	8.07	8.09	99.752
2	1	8.01	8.09	99.001
	2	8.75	8.79	99.543
3	1	8.57	8.61	99.533
	2	8.59	8.67	99.067
4	1	7.97	8.03	99.247
	2	8.03	8.05	99.751
5	1	9.27	9.31	99.567
	2	9.21	9.29	99.131

TABLE IV.   TOTAL DISSOLVED SOLIDS TESTING

Pond No.	Trial No.	Commercial Device (ppm)	Aquacision (ppm)	Accuracy (%)
1	1	9157	9175.33	99.780
	2	9097	9116.21	99.789
2	1	8651	8677.51	99.694
	2	8431	8454.07	99.726
3	1	8552	8574.20	99.740
	2	8321	8347.42	99.682
4	1	8323	9351.58	99.693
	2	9287	9321.03	99.634
5	1	7856	7881.22	99.679
	2	7741	7769.79	99.628

TABLE V.   OXIDATION-REDUCTION-POTENTIAL TESTING

Pond No.	Trial No.	Commercial Device (mV)	Aquacision (mV)	Accuracy (%)
1	1	79.57	83.53	95.023
	2	68.23	71.59	95.075
2	1	87.03	91.39	94.990
	2	81.87	85.41	95.676
3	1	81.23	84.96	95.408
	2	77.75	80.23	96.810
4	1	71.59	74.01	96.620
	2	63.89	67.20	95.074
5	1	91.54	96.07	95.051
	2	83.98	87.32	96.023

It has been observed that the Aquacision water quality measurement has excellent accuracy as shown in Table I for water temperature, Table II for electrical conductivity, Table III for PH level, Table IV for total dissolved solids, and Table V for Oxidation-Reduction-Potential. The developed system shows excellent results in measuring water temperature with an average accuracy of 99.746; electrical conductivity or salinity with an average accuracy of 99.465; pH level with an average accuracy of 99.406; total dissolved solids with an average accuracy of 99.705; and oxidation-reduction-potential with an average accuracy of 95.676.

The presented work has been compared with past literature [4] [7] [8] [9], and it has been found that Aquacision water quality measurement is equal to or better than the result that is currently accepted. The device could be a low-cost tool for location-based water quality measurement as well and it could be used in the laboratory of aquaculture agencies.

TABLE VI.   ALGAE DENSITY TESTING

Pond No.	Trial No.	Aquacision (ppb)
1	1	1.33
	2	1.13
2	1	2.89
	2	2.75
3	1	2.35
	2	2.21
4	1	2.07
	2	1.91
5	1	1.54
	2	1.32

The algae density testing shown in Table VI is another water quality parameter that has not been incorporated into existing water quality monitoring devices [4] [7] [8]. It is important to measure algal density because, in most aquatic environments, algae play a significant ecological function as the dominant primary producer [10].

TABLE VII.   ISO/IEC 25010 SOFTWARE QUALITY EVALUATION RESULTS

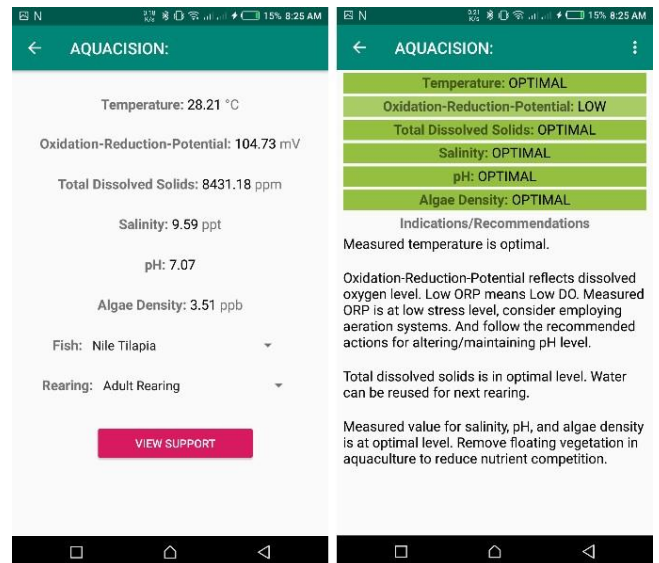| Characteristics	Average
Functional Suitability	4.633
Performance Efficiency	4.667
Compatibility	4.525
Usability	4.750
Reliability	4.525
Portability	4.450
Satisfaction	4.750

Fig. 9.   The decision support mechanism of the Aqucision app.

Table VII presents the average evaluation result for each characteristic in the ISO/IEC 25010 software quality model standard through a 1-5 rating scale, with 1 being the lowest and 5 being the highest. An average greater than 4 or equal to 5 is considered excellent, average equal to or less than 4 but greater than 3 is considered very good, average equal to or less than 3 but greater than 2 is considered good, average equal to or less than 2 but greater than 1 is considered fair and average equal to

1 is considered poor. The results for the standard characteristics of functional suitability, performance efficiency, compatibility, usability, reliability, and portability have averages of 4.633, 4.667, 4.525, 4.750, 4.525, and 4.450, respectively. The results suggest that the application is excellent in the evaluated characteristics. Furthermore, the average overall satisfaction is 4.750 which is also in the excellent average range.

Fig. 9 shows the tests conducted while using the Aquacision application. Using the baseline data and fuzzy tables provided in the appendix, it can be determined that the application provides an accurate support mechanism for the aquaculture farmer. The Aquacision application is not only a water monitoring system but also a decision support system that will be valuable for fish farmers.

IV. CONCLUSION

Aquaculture water quality parameter monitoring and decision support system was proposed to generate a decision support mechanism using the device measurements and fuzzy rules to have an aquaculture farming that best utilizes farming resources without negatively impacting the environment and improve fish production and environment. The Aquacision sensor measurement has excellent accuracy during the testing. The Aquacision application using the ISO/IEC 25010 software quality model evaluation received excellent scores from the respondents.

Through thorough analysis of the functions and data gathered of the Aquacision device and application, the following recommendations are determined to enhance both the device and application: a mechanism that can indicate that the device is ready to send data to mobile application through Bluetooth; and include more details about the parameters measured in the parameter information interface.

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