IoT-BASED FISH POND WATER CONDITION MONITORING SYSTEMFORBANGUS FARMING

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ABSTRACT—Water pollution and climate change are considered the two major factors affecting water quality for fish farming. Fish kill happens yearly and it is one of the major problems encountered by the bangusgrowers in Pangasinan, a province in the Philippines. Surface level temperature, wateracidity (pH level) and dissolved oxygen are the usual physical parameters used in determining the water quality for fish farming. The monitoring of these parameters is done manually and periodically by farmers with the assistance of the Bureau of Fisheries and Aquatic Resources (BFAR)by using the YSI Pro 1020, a handheld instrument used for themeasurement of dissolved oxygen, temperature and the pH level of water. As a means of innovating the existing practices of fish farmers, the researchersdeveloped an IoT-Based system that would integrate the functionalities of the YSI Pro 1020 and at the same time provide a periodic recording of water quality for analysis and processing to generate information which can be easily understood by fish farmers. A short message service (SMS) is also integrated in the system to alert the stakeholder should there be degradations on water parameters.

KEYWORDS—*Water Degradation, Fish Kill, Water Quality, Internet of Things, Microcontroller*

1.0 INTRODUCTION

The Philippine production of bangus (milkfish) in 2018 was estimated at 400.12 thousand metric tons. This volume drops by 3.90 %t from the previous year's level of 416.36 thousand metric tons. Of the total milkfish produced, 98.75% were harvested from aquaculture farms while the remaining 1.25% represented catch from the inland municipal subsector. The volume of milk fish produce in each quarter varies. In 2018, the peak harvests of milkfish were noted during the fourth quarter which constituted to 32.18% of the total milkfish produced. The smallest production of 16.5% was recorded during the first quarter [1][2][3][4].

Pangasinan is located in the western part of Luzon and is one of the four provinces in Region 1which shared the greater part of aquaculture produced during the fourth quarter of 2018 totalingto 98.6%. Milkfish comprises 93.5% of the total aquaculture production of Region I. During the fourth quarter of 2018 a total of 50,854 metric tonsof milkfish was produced by the province; thisfigureis higher than its 2017 output of 50,199 during the same quarter.Improved stocking rate was achieved becauseof the availability of quality fingerlings [5][6].
Premature harvesting of milkfish happens in Pangasinan in anticipation of a possible fish kill brought about by abrupt change of hot to cold weather[5][6].Fish kill is characterized by a large number of fish dying over a short period of time, often within a particular area brought about by sudden change in physical water parameters such as a drop in salinity, dissolved oxygen, pH due to large rainfall in saline water, habitat disturbance, change in water temperatures,turbidity and dissolved solids[7][8].

The Philippine government has designated BFAR as the agency responsible for the development, improvement, law enforcement, management and conservation of the Philippines' fisheries and

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aquatic resources. In monitoring the physical properties of fish ponds, BFAR-Pangasinan uses the YSI Pro 1020, a portable instrument used in measuring dissolved oxygen, temperature and the pH level of water. Fish farmers collaborate with the BFAR technicians in the manual collection of water samples to be tested for possible degradation. In essence, the fish farmers are dependent on the BFAR technicians in knowing the water quality of their respective fish ponds.Hence, in most cases preventive measures or remedies like water replenishing and water treatment are not being performed in fish ponds with poor water conditions resulting in fish kill [7].

It is because of this context that the researchersdeveloped a module that wouldautomate the manner of monitoring fish pond water quality using SMS and IoT technology. A micro-controller-based water quality monitoring module capable of measuring water's pH level, dissolved oxygen, and temperature was developed. The data gathered by the sensors attached to the module are processed by the microcontroller and are sent to the cloud-basedsystem server using wireless fidelity(wi-fi)technology. These data are presented in the form of graphs and numerical values which can be viewed through smartphone or computer using web browser. The moduleuses SMS in informing the fish growers/owners on the degradation of fishpond's water quality. Water pumps can then be remotely activated and deactivated using Radio Frequency (RF) technology.

2.0 METHODOLOGY

2.1 System Development

The system development usedRapid Application Development (RAD) as shown in figure 1.The development is composed of four stages; all of which had to be carefully executed for the successful completion of the project.

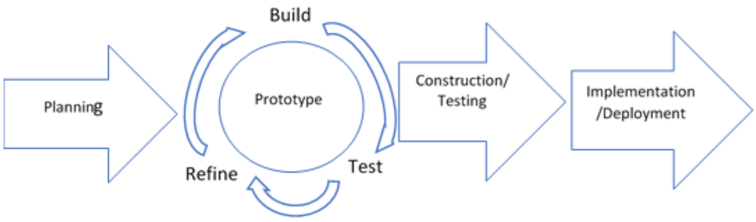

Fig. 1 Rapid Application Development (RAD).

i. Planning

The researchers collaborated with the personnel of BFAR-Pangasinan as well as with selected fish farmers. The practices of water testing performed by BFAR during the time of the study were carefully evaluated. The important physical properties of water which require constant monitoring are water temperature, water pH level, and dissolved oxygen. Similarly, the researchers visited selected fish farmers and observed the respective fish farm management practicesof the fish farmers. The farmers had no means of knowing the water quality of their ponds; however, the farmers were vigilant in monitoring fish mortality as an indication of water degradation. In developing the portable water quality monitoring module, the researchers considered the problems encountered by the BFAR personnel and the fish farmers. They inferred that therewas a need for systematic gathering and recording of water physical properties of fishponds. They especially noted that information regarding water qualities should be easily accessible and understoodby the fish farmers.

ii. Prototype

The temperature, Ph level and dissolved oxygen monitoring system was designed using the software Proteus. Proteus can be used to do the simulation of the designed module and evaluate the design's feasibility and stability. This software allows reduction in debugging time and accelerate the development process [9].ArduinoNanowas used to control the whole system. The system compares the read values to the normal values to decide the status of the fish pond water quality.According to

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BFAR experts, Bangus can tolerate certain range of water properties. Table 1 shows the tolerable range for Bangus/milkfish to live and grow healthy in fishpond.

Table 1. Tolerable water physical property range for Bangus

Parameters	Tolerable Range
Temperature	24-35 ºC
pH	6.5-8.5
(DO) Dissolved oxygen (mg/L)	>5ppm

iii. Microcontroller

The microcontroller used in the project is the Arduino Nano which is developed based on ATmega328p technology. This microcontroller which operates at 16 MHZ is relatively small and is compatible with most digital modules and operates at a voltage of 5V.The micro controller as shown in figure 2 comes with 14 digital pins and eightanalog pins which can be configured as Input or Output (I/O). However, Arduino Nano does not have a built in Direct Current(DC) power jack; hence the complete module has to be powered by battery[10].

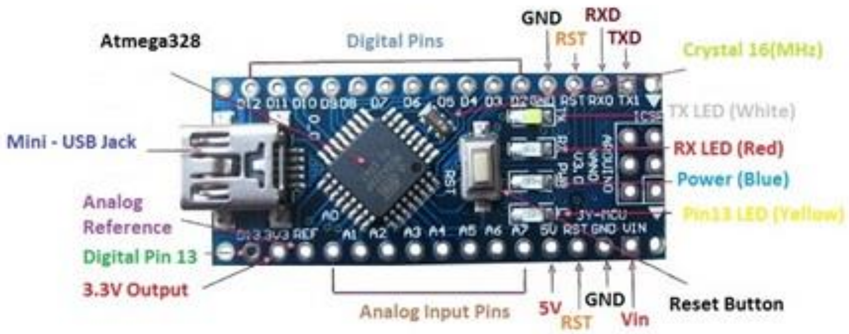

Figure Arduino Nano2.

iv. Battery Charging Module

The TP4056 5V 1A Lithium Battery Charging Moduleas shown in figure 3was used in the project. The TP4056 is a linear charger with constant-current and constant-voltage.Itis ideally used for cell lithium-ion batteries. The TP4056 is appropriate for portable applications because of its Small Outline Package (SOP) and low external component count [11].

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Figure 3. TP4056 5V 1A Lithium Battery Charging Module

v. Analog pH Sensor

The Analog Sensor used in the project is shown in figure 4. It is an Analog pH Meter Kit which comes with an industrial real-time online electrode which is ideal for Arduino microcontrollers. Its industry standard electrodecoupled with simplified wiring connectionmakes it very suitable for long term online monitoring. This module requires 5.0 volts and has a measuring range of 0-14 pH. It can tolerate temperature range of 0 to60.[12].

Figure 4. Analog pH Sensor

vi. Analog Dissolved Oxygen Sensor

The Analog Dissolved Oxygen Sensor used in the project is shown in figure 5. It is perfectly compatible with Arduino microcontroller. It has a GalvanicProbe, Detection Range of 0~20mg/L, Pressure Range of 0~50PSI, and up to 98% full response, within 90 seconds [13].

Fig. 5 Analog Dissolved Oxygen Sensor

vii. Temperature Sensor

The project used the DS18B20 Temperature Waterproof One Wire Sensor as shown in figure 6.This sensor comes with a stainless-steel tube 6mm diameter by 30mm long. It is effective in water with temperature range from -55 to 80℃ (-67℉ to +257℉). The sensor has a built-in 12-bit ADC and can directly be connected to any of the Arduino digitalinput/output.

Fig. 6 Temperature Waterproof One Wire Sensor

2.2 Construction and Testing

Figure 7 shows the overall building blocks of the system.

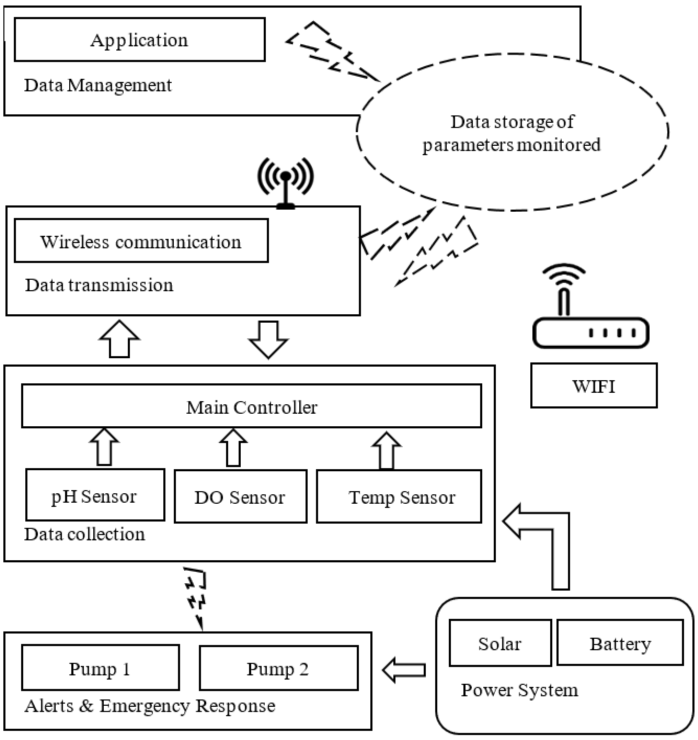

Fig. 7 Building Block of the System

i. Five Main Subsystems

1. **Data collection** – The system starts with the maincontroller(Arduino Nano) periodically collecting datafrom the three sensors. The analog data collected are transformed to numerical values which are then sent to the cloud server. The cloud server processes and compares the data with the set normal parameters of water. When it detects abnormalities, the cloud server sends back data to the main controller which then sends SMS or activates/deactivates theelectric water pumps.
2. **Data Management**–This contains the system application which can display, access and retrieve

data in the cloud database. The systemsettingsareincludedinthisblock.PHP scripting language was used in developing the website application. Information with regards to water quality can be viewed using any web browser.

3. **Data Transmission**–This includes the wireless communication module where SIM800L and wi-fi were used. The wi-fimodule is connected to the nearest wi-fi hot spot for internet connectivity. This connection serves as a conduit between the microcontroller and the cloud server. It also has a RF transmitter to automatically turn on or off the electric water pump.
4. **Alert and Emergency Response**- A practical way to correct water degradation is to pump fresh water to the pond. During the conduct of the project, the researchers used two electric powered pumps. An appropriate relay circuit that is radio frequency activated was designed thereby enabling the water pumps to be remotely controlled.
5. **Power System** – The system has a smart power system. A 5 VDC at 100W Solar panel was used in the system to charge the battery. The system is equipped with a LG 5VDC MJ1 18650 1000mah Lithium-ion battery.

2.3 Development of the Proposed System

i. Software Development

The following development tools were used in the project.

The Arduino Nano codesfor sending SMS messages, activating the pumps, analog to digital conversion of data was developed using C++. The system web page was developed using PHP scripting language. The system webpage is responsible incontrolling and displaying water data into its dashboard. It can also generate printablefiles. The data base of the system was developed using MySQL. The data base store captured water parameters like temperature, pH, dissolved oxygen, normal water parameter limits, time and date of the read values, status of the water pumps and batteries. The free web hosting site that was used in the development and testing of the project was Webhostapp. Figure 8 shows a screen shot of the webpage showing the status of water parameters, water pumps and battery.

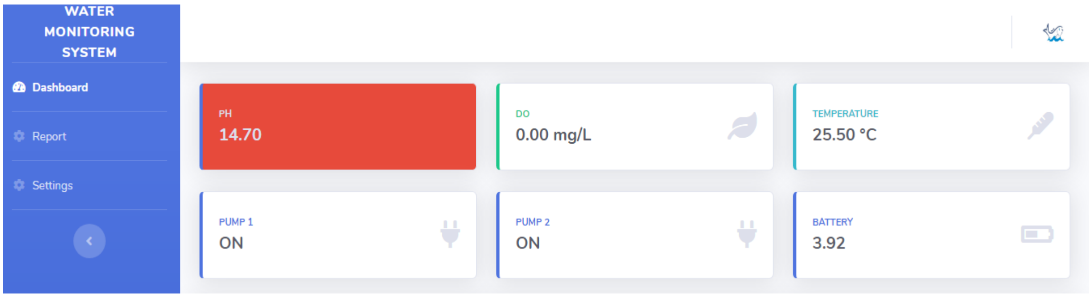

Figure 8. Screen shot of the Webpage

ii. Hardware Design

The hardware enclosure is shown in figure 9. The LG 5VDC MJ1 18650 2800mah lithium-ion rechargeable battery was used. The battery can support the hardware module continuously for three days without charging.It has a dimension of 12mm x 18mm and a weight of 100g.

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Figure 9. Hardware enclosure.

3.0 RESULTS ANDDISCUSSION

3.1The Respondents

Thirty Fish farmers and caretakers of selected fish ponds participated in the evaluation of the system primarily in the evaluation of the water parameters display. The fish farmers and caretakers are at least elementary graduates, have an access to cell phone and amajority use social media.Five personnel from BFAR likewise were involved particularly in testing the accuracy of the water parameter reading. Fifteen professionals from the academe and the industry as well as fifty senior computer engineering students were also involved in the evaluation of the overall functionalities of the whole system.

3.2 Reliability Test

The reliability and accuracy test of the system was done in the school laboratory andin the BFAR laboratory. A five-point Likert scale was used in the evaluation of the system. The lowest evaluation made was on the speed of the system which is brought about by the slow internet connection. Nonetheless, the overall rating of the system is at 4.88 corresponding to excellent in the scale. Table 2 shows the detailed results of the survey.

Table 2: Reliability and Efficiency test of the system

Reliability and Efficiency of The Developed System as evaluated by 20 professionals and 50 senior computer engineering students	**5**	**%**	**4**	**%**	**3**	**%**	**2**	**%**	**1**	**%**	**MEAN**
The analysis of the water quality generated by the system is accurate.	65	93%	5	7%	0	0%	0	%	0	%	4.9
Abnormal water element is easily detected by the system.	60	86%	10	14%	0	0%	0	%	0	%	4.9
The system documentation is informative.	65	93%	5	7%	0	0%	0	%	0	%	4.9
The system presents helpful information that would aid fish farmers	60	86%	10	14%	0	0%	0	%	0	%	4.9
The system is consistent.	65	93%	5	7%	0	0%	0	%	0	%	4.9
The speed of the system is fast enough.	50	71%	20	20%	0	0%	0	%	0	%	4.7
The system is easy to use	68	97%	2	3%	0	0%	0	%	0	%	5.0
OVERALL MEAN											4.88

Table 3 shows the perceived benefits of the proposed system as evaluated by selected fish farmers and care takers. The overall rating of the system is at 4.85 which corresponds to excellent in the 5-point scale used in the survey

Table3: Perceived Benefits of the Water Quality Monitoring System (N=30)

Perceived Benefits by the 30 Fish Farmers and care	**5**	**%**	**4**	**%**	**3**	**%**	**2**	**%**	**1**	**%**	**MEAN**

takers											
The information generated by the system can help me to monitor the water quality of my fishpond, helping me to identify whether or not a problem exists in my pond.	27	90%	2	7%	1	3%	0	%	0	%	4.8
The information generated by the system can make me aware of the water quality of my pond, resulting in the prevention of possible fish kill.	27	90%	3	30%	0	0%	0	%	0	%	4.9
The information generated by the system can help me inform the authority on the degradation of water quality of my fishpond, prompting them to take necessary measures to prevent possible fish kill in the area.	28	93%	2	7%	0	0%	0	%	0	%	4.9
The information generated by the system can make me more cautious and ready whenever the water quality of my fishpond is becoming undesirable.	26	87%	4	13%	0	0%	0	%	0	%	4.9
The information generated by the system can make me confident that no imminent fish kill would happen anytime soon as the system keeps me updated of the water quality of my fishpond.	26	87%	3	10%	1	3%	0	%	0	%	4.8
The system allows me to be aware of the possible oxygen depletion that may result in fish suffocation leading to sudden, large fish kills.	27	90%	3	10%	0	0%	0	%	0	%	4.9
The system allows me, to a certain degree, to be independent, not relying too much from the information provided by the government authority	28	93%	2	7%	0	0%	0	%	0	%	4.9
The system canmake me be proactive in my approach to fishpond management.	25	83%	4	13%	1	3%	0	%	0	%	4.7
OVERALL MEAN											4.85

4.0 CONCLUSIONS

The critical water parameters that may cause fish kills are temperature, pH level and dissolved oxygen. The practical way of improving water quality is by pumping fresh water to the pond. Automating the water quality monitoring as well as activating water pumps as corrective measure can be done using IoT technology. Appropriate sensors can be connected to Arduino Nano microcontroller for periodic sampling of water quality. Captured water parameters can be stored to the cloud using wi-fi modules. Viewing of current fish pond water quality can be done through the systems website using any web browser. Activating or deactivating electric water pumps remotely can be done using RF modules. Informing fish farmers and any other stakeholders of fish pond water quality can be done automatically by integrating SMS module to the microcontroller. The implementation of the system would simplify the water quality monitoring thereby reducing the risk of fish kill.

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