Remote Water Quality Monitoring System using Wireless Sensors

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Abstract: - It is found that the current manual water quality monitoring entails tedious process and is time consuming. To alleviate the problems caused by the manual monitoring and the lack of effective system for prawn farming, a remote water quality monitoring for prawn farming pond is proposed. The proposed system is leveraging on wireless sensors in detecting the water quality and Short Message Service (SMS) technology in delivering alert to the farmers upon detection of degradation of the water quality. Three water quality parameters that are critical to the prawn health are monitored, which are pH, temperature and dissolved oxygen. In this paper, the details of system design and implementation are presented. The results obtained in the preliminary survey study served as the basis for the development of the system prototype. Meanwhile, the results acquired through the usability testing imply that the system is able to meet the users' needs.

Key-Words: - Remote monitoring, Water Quality, Wireless sensors

1 Introduction

Aquaculture is the farming of aquatic organism in natural or controlled marine or freshwater environments. Since 20 years ago, aquaculture industry is blooming rapidly and it has been identified as the most popular method in fishery sector [1]. However, one of the pertinent yet persistent issues faced by aquaculture farmers is how to efficiently monitor the water quality of their ponds. Maintaining water quality is vital as it is the most important factor in determining the success and failure of the aquaculture farming. Many fish, shrimp and shellfish have been found dead due to eutrophicated aquaculture ponds and unbalanced ecosystem of the aquaculture water [2].

In most of the aquaculture industries, manual water quality monitoring is employed in order to assess the water quality of the pond. The monitoring activity includes inspection at the pond or conducting colorimetric test to ascertain the current water quality. This test requires a sample of the water to be taken from the pond and analysis will be conducted on the sample taken. The test is usually to measure ammonia level, pH level and dissolved oxygen (DO) level in water. Only trained staff can conduct the test. They have to take a few samples of the water and perform the required test. Each test usually takes between five and ten minutes to accomplish. Test will need to be repeated if samples used are spoiled or no longer usable. Thus, the process is time and cost consuming [3].

In addition, aquaculture farms are normally spacious and humid making daily monitoring and inspecting of the ponds both expensive and time consuming. Aquaculture farmers therefore necessitate a way to monitor the water quality on a regular basis but without having the need to visit the ponds themselves. It has also been discovered that aquaculture farms have requested for an IT system that can monitor the aquaculture environment and alert the users when inadequate environmental situations develop [4].

Therefore, to solve the problems, remote water quality monitoring systems were proposed [1, 5-7]. However most of the proposed implementations were meant for fish species and limited number of literatures exists for prawn breeding ponds monitoring.

Thus, this paper aims to present the details of the design and implementation of a remote water quality monitoring system using wireless sensors for prawn farming. The system is also equipped with an alert feature to inform the farmers on the degradation of water quality via Short Message Service (SMS). The three criteria that has been identified to monitor and to detect water quality changes are water temperature, pH level and DO.

2 Related Work

2.1 Importance of Water Quality to Aquaculture

Water is a 'universal solvent' where various chemical dissolved in the water, as well as all physical attributes affecting them combined to contribute to the water quality. Good water quality level is determined by all attributes present in the water at an appropriate level and not outside tolerable range. Often aquaculture water quality does not equal to environmental water quality. Therefore different parameters are used in monitoring aquaculture farm as compared to environmental water quality. It is also more often that good water quality criteria differ from species to species [8].

Physical, chemical, and biological properties are interrelated and it affects survival, growth, and reproduction of aquaculture. Aquaculture can also have reverse effect to the environment as aquatic organisms consume oxygen and produce byproducts, carbon dioxide and ammonia. Important water quality parameters to be considered are; temperature, salinity, pH, DO, ammonia, nitrite/nitrate, hardness, alkalinity, and turbidity [8].

2.2 Water Quality Parameters

P. Fowler et. al in their study recommended that temperature, DO, and pH be monitored directly on a continuous basis since they tend to change rapidly and have a significant adverse effect on the system if allowed to operate out-of-range [9]. Therefore, these three parameters have been chosen to be monitored in this system.

Temperature refers to degree of hotness or coldness and it can be measured in degree Celsius. Water temperature needs to be monitored regularly as outside tolerable temperature range, disease and stress will become more prevalent. Among the consequences of temperature changes are; photosynthetic activity, diffusion rate or gases, amount of oxygen that can be dissolved, and physiological processes of the prawn and level of other parameters [1].

pH refers to the hydrogen ion concentration or how acidic or basic as water is and pH is defined as $-\log[H^+]$. pH value range from 0-14; pH 7 is neutral, pH<7 is acidic, and pH>7 is basic. Very high pH (greater than 9.5) or very low pH (lower than 4.5) values are unsuitable for most aquatic organisms. Aquatic organisms are extremely sensitive to pH levels below 5 and may die at these low pH values. High pH levels (9-14) can harm fish due to the fact that ammonia will turn to toxic ammonia at high pH (>9) [10].

DO describes the concentration of oxygen molecular in the water and it's dependent on the temperature of the water and the biological demand of the system [8]. It is used in aerobic decomposition of organic matter, respiration of aquatic organism, and chemical oxidation of mineral. As DO is used by many organisms in the water, it tends to change rapidly. DO is supplied to water through several method; direct diffusion of oxygen from the atmosphere, wind and wave action; and photosynthesis [8].

Table 1 below summarizes tolerable range of chosen water quality parameter for prawn farming [8].

Table 1: Tolerable range for water quality parameters

Parameters	Tolerable Range
Temperature	29-31 ^oC
pH	6.5-8.5
Dissolved oxygen (DO)	>5ppm

2.3 Remote Water Quality Monitoring Systems

Due to the criticality of monitoring water quality of the aquaculture ponds, various systems have been proposed. Ceong et. al [5] proposed an eco aquafarm system that monitors water temperature, dissolved oxygen and salinity. The system can also send an alert to the farmers once the ranges of environmental information are found to be abnormal. Han et. al [6] present a design on environment monitoring system for aquaculture farms. The proposed system offers ubiquitous access to the monitored data from the pond either from the internet or on the mobile phones. Shifeng et. al [7] studied and put forward a system that is based on wireless RF and GSM to measure such parameters as dissolved oxygen and temperature. According to the environment, the system can intelligently control the oxygen-increasing machine and can remotely control the data and receive the report through mobile phone. Another attempt was made by Sharudin [1]. He proposed an intelligent system to monitor the water quality remotely via SMS. The system monitors and records real-time data of two parameters; pH level and DO level, which are reported through centralized station using GSM network through Short Messaging Service [1].

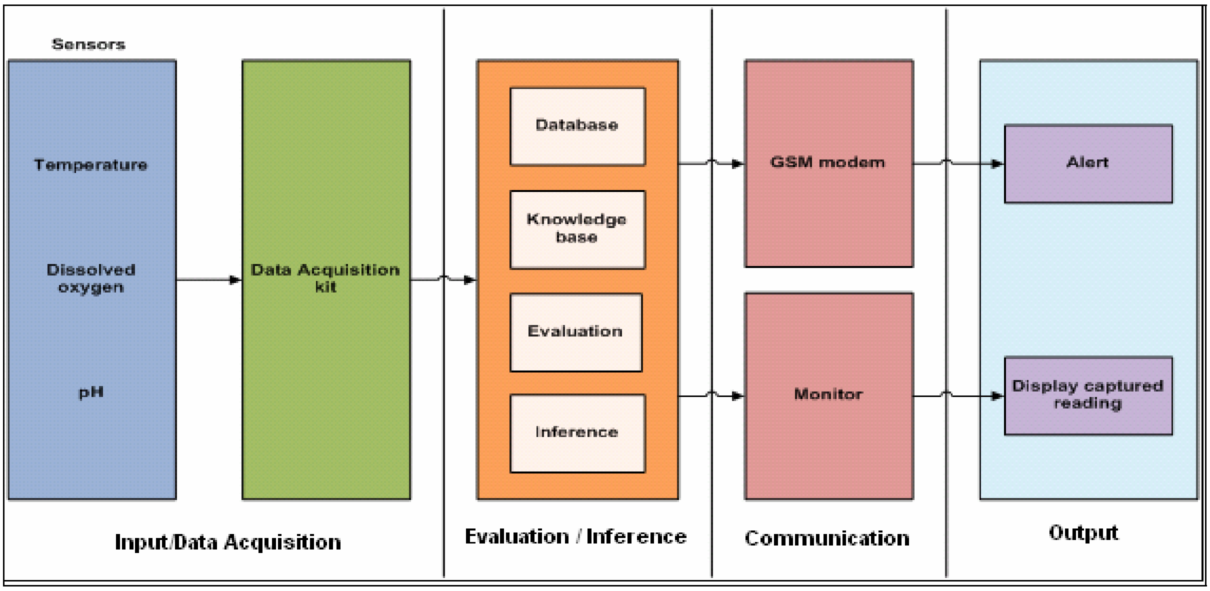

Fig. 1 System Framework

3 System Design

3.1 System Framework

The system consists of four components; tracking, evaluation & inference, communication and result. The framework served as the guideline to develop the system architecture of the system. Fig. 1 depicts the framework components and their interactions.

3.1.1 Input/Data Acquisition

This component consists of two parts namely sensors and data acquisition kits. The component is built in order to detect the readings of each sensor from the pond and the reading would be gathered by data acquisition kit. Besides that, data acquisition kit is also responsible to convert analog signal received into digital signal.

3.1.2 Evaluation and Inference

This component consists of four sub-components; database, knowledge base, inference, and evaluation. The first sub-component is used to store all data received from data acquisition kit. Knowledge base stores data pertaining to the value of tolerable range for each parameter. Real time data received would be fed into the Inference sub component to determine whether each parameter is within or outside the tolerable range. Evaluation is the process that determines whether or not the water quality meets specified criteria. Evaluation is done using the inference results and the predefined rules based on data stored in the Knowledge base.

3.1.3 Communication

This component entails two parts depending on the type of inference results. If the water quality is within tolerable range, the data will be displayed on the monitor otherwise, the results will be sent via SMS using GSM network as part of the alert message to the farmers. However, the results can still be viewed on the monitor too.

3.1.4 Output

This component allows the results to be retrieved in two methods: can be shown on monitor and can be received via SMS (only if the water quality is degraded and detected by sensors).

3.2 System Architecture

Two types of system architecture are available to be deployed for this kind of project; using PC unit or PAC unit. 'Intelligent Water Quality Monitoring System via SMS' [1] is an example of project done using PAC unit. The Remote Terminal Unit (RTU) is placed remotely where it is connected to GSM modem that sends data log by its sensors to central computer. The central computer stores all data and determines what output should it produce in relative to the inputs received [1].

Weather station unit owned by Universiti Kebangsaan Malaysia meanwhile is an example of a PC unit. The RTU is directly connected to a computer using serial port. The computer logs the reading and display the reading on screen.

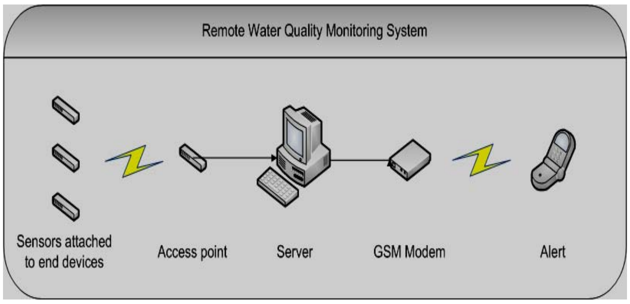

Fig. 2 System Architecture

In this study, the PC unit is used and it still can be placed remotely as it could transmit data using radio frequency. The unit is placed near the pond and the sensors are placed in the water. No operator is needed to attend the system as data would be captured automatically. Fig. 2 illustrates the architecture of the system. The system architecture is divided into four parts. Data acquisition sub-system requires hardware components such as sensors, end devices, and access point. Sensors are attached to end devices and placed at the pond. Sensors pickup reading and transfer it to the end devices. End devices will transmit the reading to the access point wirelessly. Access point is attached to COM port at the server. Server is the central station where the farmers can monitor the water quality reading of the pond remotely.

The server would receive the reading and stores input received in a database. Data received will be evaluated based on the data stored in the Knowledge Base. If the evaluated data did not conform to the rule defined, an alert would be triggered to the farmer immediately. Output of the evaluation will always be displayed on the server's screen despite the condition of the water quality.

4 System Components

Tools used to develop this system comprise both software and hardware.

4.1 Software

The lists of software used in this project are as follows:

4.1.1 SMS Gateway

SMS gateway is required to act as interface between the system and GSM modem. SMS gateway enables SMS being received or sent from computer to or from mobile devices.

4.1.2 Programming Language

Visual Basic is used as the programming language to create the user interface as well as to implement the data processing feature of the system.

4.2 Hardware

The hardware of the system consists of two parts; data acquisition kits, and communication system. The hardware design phase would focus on interfacing the sensors with the monitoring system. The following will be hardware used for the development;

4.2.1 EZ430-RF2500

EZ430-RF2500 is used for this project. The unit consists of two parts; end device and access point. End device is the part that could be placed remotely as it could transmit data to access point using radio frequency. The tools itself have a temperature sensor that detect surrounding temperature. Other sensors such as dissolved oxygen and pH are connected to the tool to pickup readings.

4.2.2 GSM modem

A GSM modem is a wireless modem that works with GSM wireless network. The modem is connected to a server so it could send SMS as an alert to farmer. The modem is attached to a USB port at server.

4.2.3 Mobile phone

A mobile phone is required for testing purposes. The phone would act as client for this system. The system would send message to the second phone once an alert has been triggered.

5 Results and Discussion

5.1 Preliminary Survey

A set of questionnaires was administered during the preliminary survey of the research to a group of farmers from two prawn hatchery farms in Perak, Malaysia in order to solicit the requirements for the system.

Fig. 3 presents the response on the vital characteristics that the system must have. 80 percent of the respondents chose accuracy of the system in giving results, 60 percent chose that the report must be informed frequently to the farmers in order for them to know the current status of the pond. Only 20 percent of them agreed to have other characteristics such as user-friendly and fast response.

Question 2 was designed to acquire farmers' response in terms of perceived usage of the proposed remote water monitoring system. The results are shown in Fig. 4. All of them perceived that the system will be used for identifying main water quality problem and for tracking the changes in the water quality. Based on these results, we can infer that the farmers want most a system that can track and identify the cause of the water quality degradation.

Fig. 5 depicts the response on the main water quality parameters that the respondents would like to be monitored for their prawn hatchery farms. The respondents chose three parameters comprises of temperature, pH and DO. This information actually conformed to the result that we obtained through literature survey [9].

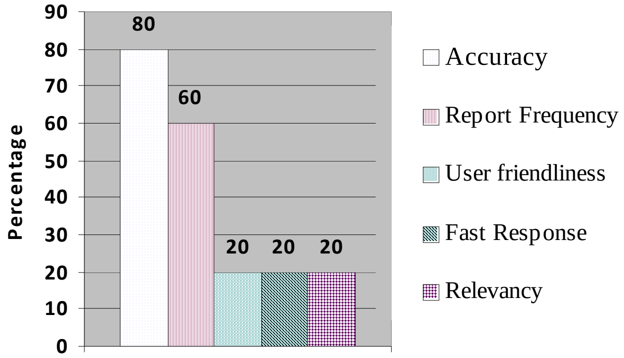

Fig. 3 Characteristics of the system

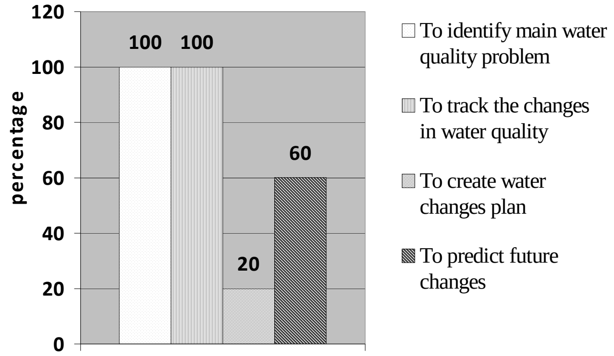

Fig. 4 Perceived usage of the system

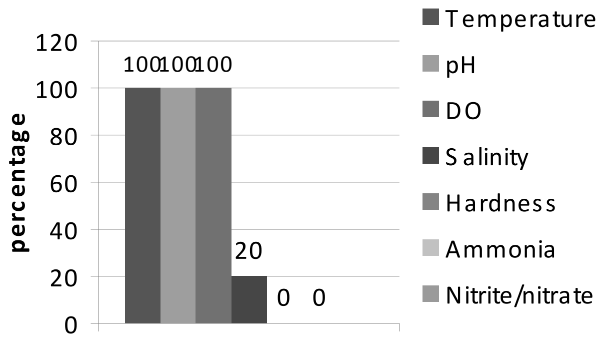

Fig. 5 Main Water Quality Parameters

All the results obtained through the preliminary study served as the basis for our system prototype design and implementation.

5.2 System Interface

Earlier findings in this study have presented that tracking, the changes in the water quality, detecting the cause of water quality degradation and sending alert are the main features that should be incorporated in the system. This sub section describes the implementation of the user interface with regards to these features.

5.2.1 Main interface

Fig. 6 is a screen shot of the main interface. The figure below shows the program has been started. Before the program starts, user has to choose COM Port number in which access point being attached to. After clicking ‘Connect’ button, the program will show whether the port has been accessed. If it stated that the selected port has been connected, the program is now connected to the access point and would able to receive input from it. Then data received from access point would be displayed in ‘Input Received’ and ‘Readings’ text boxes. Readings of all three parameters are displayed on the screen from time to time for the farmers to view and track the current reading of the water quality of their pond. The parameters’ readings are displayed next to the ‘Temperature’, ‘pH’ and ‘Dissolved Oxygen’ text boxes respectively. Status on the water quality is also shown on screen. Date and time of the last update made is also imparted to the user. All these info are pertinent to the farmers in knowing the latest condition of their pond. Other information shown on screen includes last alert sent and the contents of message sent. This will aid the farmers in knowing the recentness of the alert and consequently help the farmers in taking fast and necessary action.

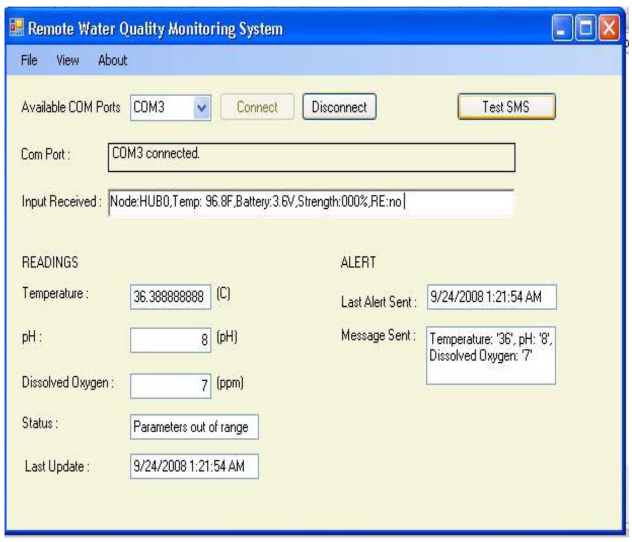

Fig. 6 Screen shot of the Main Interface

5.2.2 Record interface

There are two types of report that can be viewed; data recorded and alert sent. Data recorded report keeps track of all the sensors readings for every 30 seconds. There are six items recorded in the report which are date and time when the reading takes place, temperature reading, pH reading, DO reading and status of the water quality.

Alert sent report as depicted in fig. 8 includes information such as receiver number, message contents, time of message being sent and status of the sending.

The contents of both reports can be used for further analysis on the water quality of the pond as well as can be kept as history of information on monitoring.

Fig. 7 Screen shot of Alert Sent Report

5.2.3. Alert interface

The interface of the alert is as shown in Fig. 8. The contents of the alert are consists of the status of the water quality and the readings of all three parameters. By knowing the exact reading of each parameter, the farmers can infer which parameter(s) contribute to the degradation of the water quality. Thus, he can take immediate and appropriate action before the condition of the pond gets worsen.

Fig. 8 Screen shot of Alert interface

5.3 Usability testing

The second set of questionnaire was designed in order to get users' feedback on the system. It has been designed to measure ease of use, usefulness, compatibility and motivation of the farmers while using the system. The scales were taken from current TAM [11] with questions reconstructed to match the items to the current topic. This exercise was conducted among the farmers in a controlled environment at their farm where respondents will be granted access to the system prototype and given a questionnaire. They were required to rate the system by exploring its functionalities on a 7-point scale (1 being strongly disagree and 7 being strongly agree).

The results of usability testing are analyzed using frequency distribution [12]. Table 2 shows the frequency distribution obtained for the variables.

Table 2: Frequency Distribution of Usability Testing

Construct	Agree	Neutral	Disagree
Ease Of Use	85	12.5	12.5
Usefulness	86.6	13.4	0
Compatibility	80	20	0
Motivation	86.6	13.4	0

The results exhibit that most of the users agree that the system fulfills their needs in terms of Ease of Use, Usefulness, Compatibility and Motivation. Low percentages in respondents disagreeing to ease of use can be disregarded as negative responses tend to be relatively small compared to positive responses. This disagreement may also be attributable to their lack of experience in using a computer system before.

5 Conclusion

Remote water quality monitoring system using wireless sensors is developed to assist aquaculture farmers in monitoring the water quality of their ponds. The aim of this system is to alleviate the problems caused by manual monitoring such as tedious colorimetric test and exhaustive inspection due to humid and spacious farm. Benefit of using the system includes more efficient monitoring of the pond since the system would monitor the water quality in a timely manner and alert the farmers upon detecting degradation of the water quality. Three parameters are monitored in this system which are pH, temperature and dissolved oxygen.

In this study, the details of system design and implementation are presented to show the mechanism of the proposed solution. The results obtained in the preliminary survey study served as the basis for the development of the system prototype. Meanwhile, the results acquired through the usability testing imply that the system has proven to meet specific needs of what the users' required.

While this study provides several findings for practical development of the system, however this study has few limitations. Most notably, the current system only monitors three parameters. Therefore, more parameters are needed in order to obtain more accurate results. The proposed solution can also be further enhanced by allowing the system to detect the water quality suitable for various kind of aquaculture as the current system can only monitor the water quality suitable for the prawn. Further notable improvement that can be made on the system includes adding prediction feature into the system so that the system can predict the water quality beforehand for the farmers to proactively monitor the ponds.

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