DEVELOPMENT OF EMBEDDED SYSTEM FOR PH MEASUREMENT IN FISH PONDS AND MONITORING DATA VIA INTERNET OF THINGS

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ABSTRACT

This paper presents the pH measurement system to construct a water spoilage prevention system for the fish culture in cement ponds, to reduce diseases in fish, and to reduce the problems of the death of fish. The objectives of this research were: 1) to design and construct a system for measuring pH values of water in the fish ponds via Internet of Things, and 2) to determine the efficiency of the pH measurement system. The study instruments were NodeMCU/ESP8266, pH electrode set and Netpie application. The results showed the efficiency of the pH measurement system starting from the first stage of water replacement in the cement ponds as follows: during day 1-15, the suitable pH value for normal living of freshwater fish was 6.002-8.489, and during day 16-19, the acidic value rose with pH 5.381-5.964. The results revealed that the system could display real-time pH values via Internet of Things using the Netpie application with Data Feed function.

KEYWORDS: Embedded System, Internet of Things, pH measurement, Netpie

1. Introduction

Nowadays, humans utilize water for agriculture, fish culture in earthen ponds and in concrete ponds. Fish farming in the concrete ponds, also known as cement ponds, is a popular career in communities in all regions of Thailand. Most of the farmers are interested in culturing freshwater fish such as catfishes, striped snake-head fish, Nile tilapias and common climbing perches due to basic management and care, smaller culture space than culturing other kinds of fish, and popularity in the market. And the fish farmers can also earn more income from this part-time career.

The survey of freshwater fish culture in the cement ponds at Buriram provincial fishery office and of general fish farmers revealed that the fish farmers lacked pH measurement

instruments. At present, they rely on monitoring methods by observing changes occurred in the water with the accumulation of food scraps and wastes from the excretion of fish. This makes it inefficient to measure water quality due to effects on fish growth, problems of fish diseases and fish death. The fish culture in the cement ponds needs proper water quality management process.

Based on these problems, the researcher aimed: 1) to design and construct a pH measurement system in the fish ponds and monitoring data via Internet of Things, and 2) to determine the efficiency of the pH measurement system by culturing fish in the cement ponds. This study applied a pH sensor with a wireless data communication module [1] in the development of embedded system which was controlled by NodeMCU. The data entry system measured by the sensor was analyzed for the data of the changes in values to solve the problems and to be a guideline for improving fish culture process in the cement ponds and to be used in the future.

2. Materials and Methods

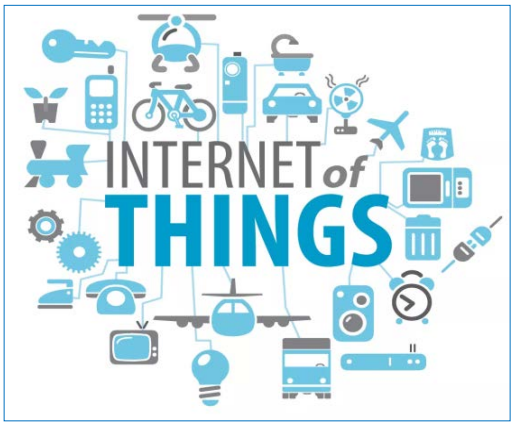
2.1 Internet of Things

Internet of Things (IoT) is a system built to gather data via various commands into the system which can run automatically. The user does not need to run tasks from the computer. In case of giving a command, the tasks can be done with a remote operation such as switching on and switching off a washing machine via a cell phone, and displaying data automatically by commanding task only via a cell phone or displaying data. This technology was applied in the study for displaying pH data via a cell phone which ran on Netpie application with Data Feed function.

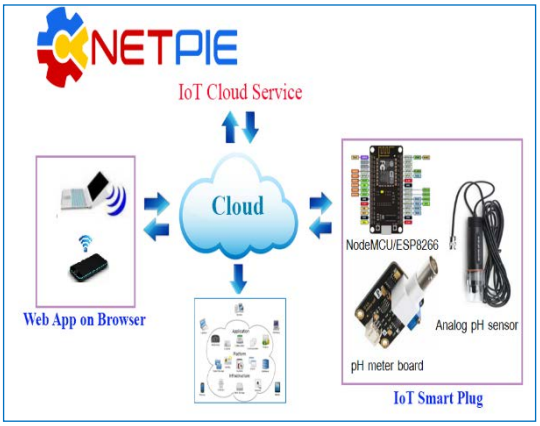
2.2 Cloud computing and NETPIE

Cloud Computing is a rental service system of a computer system or computer resources of service providers. All users can access data system via internet and can provide up-to-date management to the system resources via the network. This study used the Cloud Computing to store data from various devices via Netpie (Network Platform for Internet of Everything) which the cloud platform system was designed and developed to facilitate communication among the devices for the work of the IoT. The forms of the use of Cloud

Computing are similar to MQTT together with the capability of Authentication and Token. It increases communication safety which can connect to NETPIE, which was designed and developed by National Electronics and Computer Technology Center (NECTEC), with various channels including IoT such as Arduino, Raspberry Pi, and ESP8266. This study used the Cloud Computing in the field of communication between devices of NodeMCU/ESP8266 for data connection and a pH display from pH sensor kit. The Internet of Things and cloud computing as shown in Figure 1.



(a) Internet of Things [2]

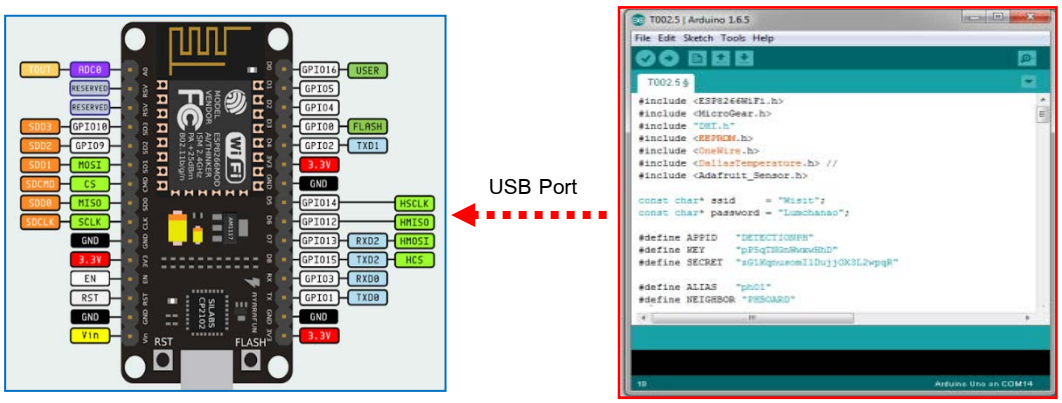


(b) Cloud computing [3, 4]

Figure 1 Internet of Things and Cloud computing diagram

2.3 NodeMCU/ESP8266

NodeMCU is a platform that helps creating data processing system and displaying data via Internet of Things (IoT). It consists of a Development Kit (Board and Firmware). Software on the board, which is an open source, can be applied with C/C++ Programming together with WiFi module (ESP8266), which is the key for connecting to the internet. This makes it available to be used in various ways. This NodeMCU can be used in various ways, especially with regard to IoT such as creating small Web Servers, controlling switching on and switching off power via WiFi. In this study, NodeMCU was used to receive analogue signals of pH measurement and transmit data to NETPIE, as shown in Figure 2.

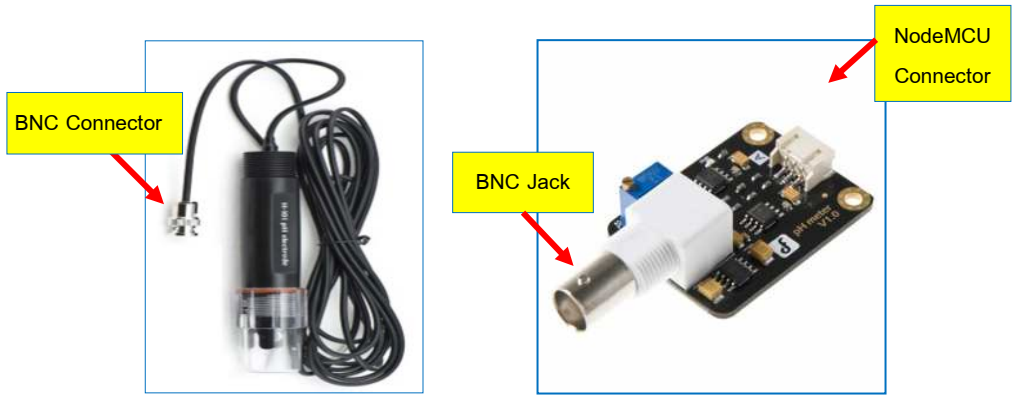


(a) NodeMCU/ESP8266 Board [5] (b) Programming

Figure 2 Upload code to ESP8266 using the connect via USB

2.4 pH Sensor

The pH measurement is based on the principle of Electrochemistry by measuring the potential occurred between a reference electrode and a sensing electrode. The obtained potential derives from the amount of hydrogen ion (H+). The Ionic Potential will be converted into electronic potential. In this study, the pH meter was used as an analogue input port which was connected to the NodeMCU. The pH system was shown in Figure 3 and Figure 4.



(a) Analog pH sensor (b) pH meter board

Figure 3 The pH sensor

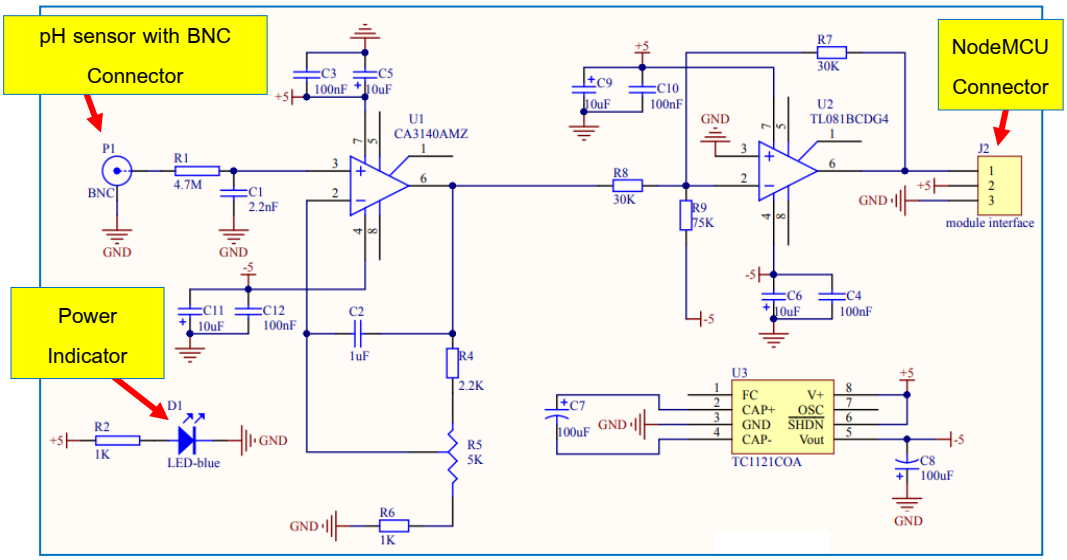


Figure 4 The pH meter circuits [6]

2.5 The Proposed System Architecture Design

The design and construction of a system for measuring pH values of water in the fish ponds and monitoring data via Internet of Things as shown in Figure 5.

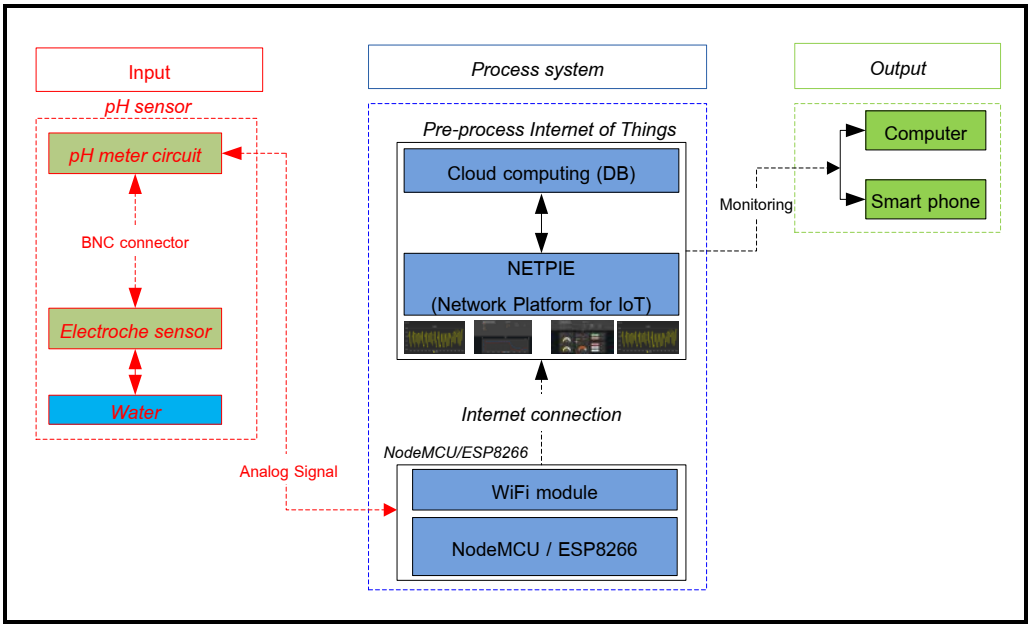


Figure 5 The proposed system design

According to Figure 5, the following are the steps for measuring pH values algorithm:

Step 1: Connect equipments according to the pH electrode that is the connected to the BNC connector on the pH meter board and then use the connection lines, the pH meter circuits is connected to the analogRead port A0 of the NodeMCU/ESP8266 controller, to an analog-to-digital converter (ADC). When the NodeMCU gets power, will see the blue LED on board is on.

Step 2: Upload the code to the NodeMCU/ESP8266 controller.

Step 3: Put the pH electrode into the fish ponds, or directly shorted the input of the BNC connector. Open the serial monitor of the NodeMCU/ESP8266.

Step 4: Connect NodeMCU / ESP8266 to WiFi network in SmartConfig mode.

Step 5: Create a new Application in the netpie.io web site to obtain the Application ID, Application Key, and Application Secret. Under the same application, select one of the two application key types. 1 Key is the Device Key for the NodeMCU/ESP8266 board. Session Key for HTML5 web, then put the ID, Key, Secret code into the programming

2.6 Voltage of the hydrogen electrode

The pH electrodes [7] are electrochemical sensors to generate a voltage depending on the hydrogen activity of the solution, which is compared to the potential of the reference electrode. As the solution becomes more acidic (lower pH) the potential of the glass electrode becomes more positive (+mV) in comparison to the reference electrode; and as the solution becomes more alkaline (higher pH) the potential of the glass electrode becomes more negative (-mV). [8] The equation calculation as follows.

$$E = a - \frac{2.303R(T+273.1)}{nF} \times (pH - pH_{ref}) \quad (1)$$

Where: E = voltage of the hydrogen electrode with unknown, a = ±30mV (zero point tolerance), T = ambient temperature in °C, n=1 at 25 °C (number of charges on ion), F = Faraday constant = 9.6485309*10^4 C mol^{-1}, R = Universal gas constant = 8.314510 JK^{-1} mol^{-1}, pH = hydrogen ion concentration of an unknown solution, pH_{ref} = reference hydrogen ion concentration = 7.

2.7 Transfer function of the pH electrode

The pH electrode is a passive sensor, which means no excitation source (voltage or current) is required. Because the pH sensor measures the difference in electrical potential, output between a pH electrode and a reference electrode. It produces a voltage output that is linearly dependent upon the pH of the solution being measured. [9] The transfer functions of the pH electrode, equation as follows.

$$pH = pH(s) + \frac{(E_S - E_x)F}{RT\ In(10)} \tag{2}$$

Where: pH = hydrogen ion concentration of an unknown solution, $pH(s)$ = pH of standard solution=7, E_S = Electric potential at reference, E_x = Electric potential at pH measuring electrode, F = Faraday constant = 9.6485309*10^4 C mol^{-1}, R = Universal gas constant = 8.314510 JK^{-1} mol^{-1}, T = temperature in Kelvin. [9]

The transfer function in Figure 6 and Figure 7 shows that as the pH of the solution increases, the voltage produced by the pH-measuring electrode decreases. [9] As shown in Figure 6.

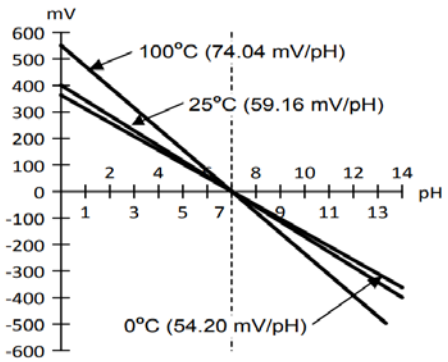


Figure 6 pH electrode transfer function [9]

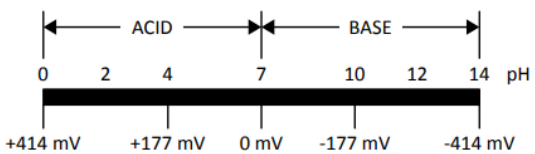
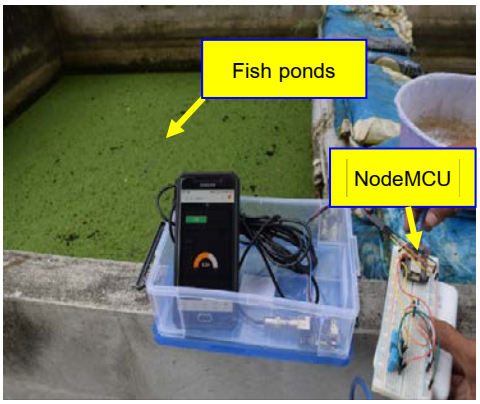


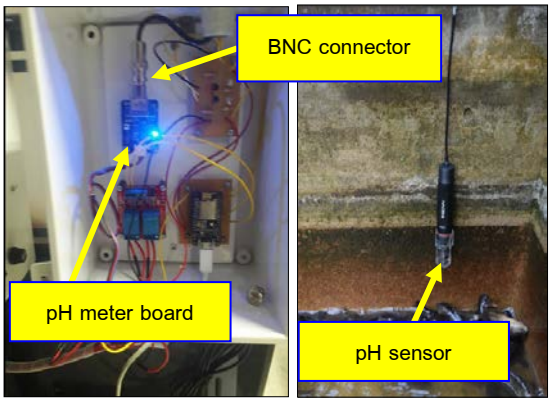
Figure 7 The pH scale [9]

3. Experiment and Results

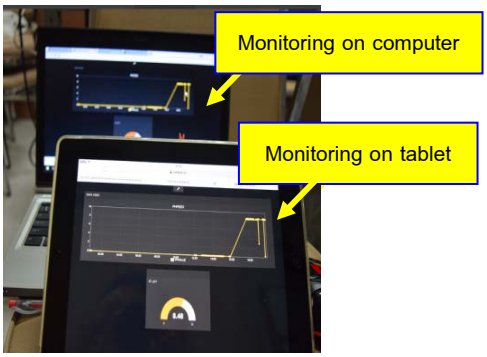
The experiment for determining the efficiency of pH measurement system in the fish ponds and monitoring data via internet used communication network as a medium to transmit data via the internet. The results of designing and constructing the pH measurement system was shown in Figure 8.



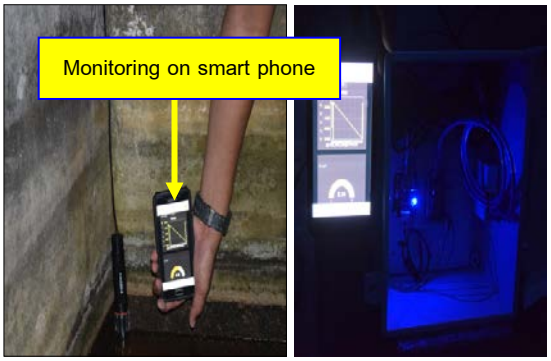
(a) Interfacing pH with NodeMCU/ESP8266



(b) Connecting Diagram



(c) Monitoring on computer



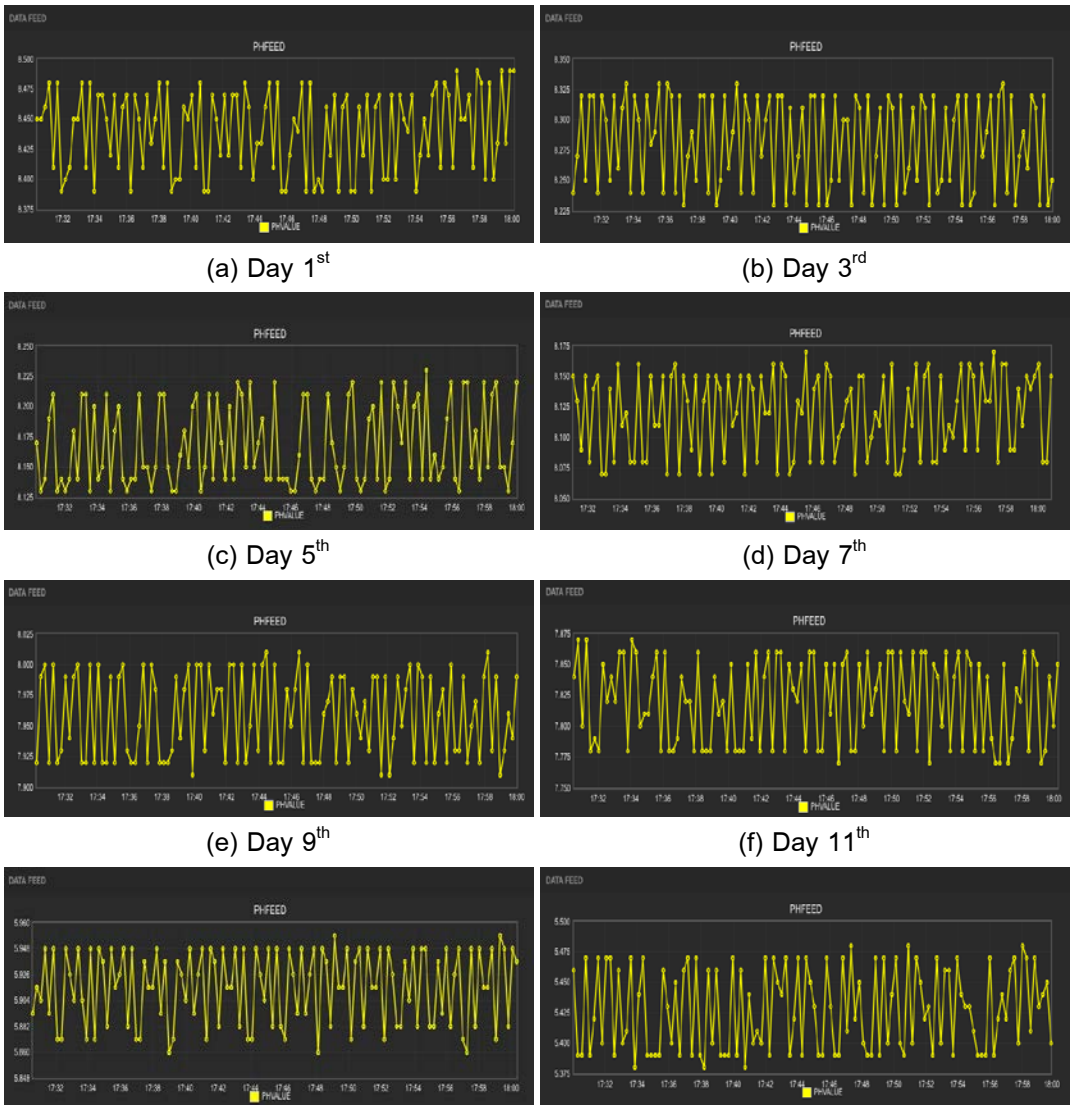
(d) Monitoring on smart phone

Figure 8 Design and construct results

According to Figure 8, the results regarding the pH measurement system of fish culture in the cement ponds were tried and utilized at Buriram provincial fishery office. The system can display the pH values starting from the first stage of water replacement in the cement ponds. The constructed tools used in this study can effectively help reduce the problems of the spoilage of water, diseases in fish and the death of fish in the fish culture in the cement ponds.

3.1 The Results of the Efficiency of PH Measurement System

The development of embedded system to be used to prevent the spoilage of water could display data via NETPIE application using the platform of Internet of Things. The system would measure the pH values starting from the first stage of water replacement in the cement ponds until it reached the suitable value for water replacement as shown in Figure 9.



(a) Day 1st (b) Day 3rd

(c) Day 5th (d) Day 7th

(e) Day 9th (f) Day 11th

(g) Day 17th (h) Day 19th

Figure 9 The pH Measurements results

According to Figure 9, the results showed that the pH measurement system was effective in converting analog signals into digital signals by displaying pH values via NETPIE application with the Data Feed function, and the obtained pH values in each period of measurement (day, time) could be compared in real time as shown in Figure 10.

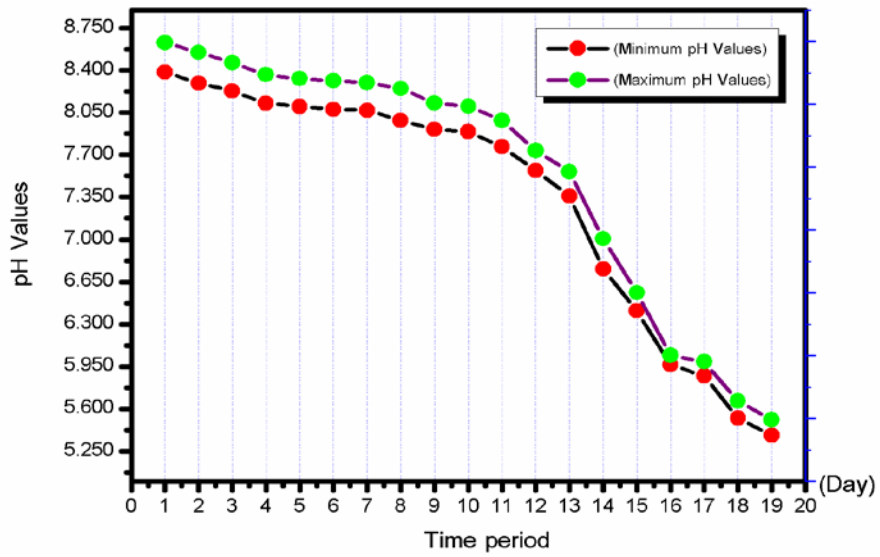


Figure 10 Graph representation of the comparison results of the pH values in each period

According to Figure 10, the graph showed that the comparison of the obtained pH values in each period (day, time) was displayed in real time. The results of this study showed the average of the lowest and the highest pH values. The results of the pH measurement revealed that during the period of day 1-15, the suitable pH value for normal living of freshwater fish was in the range of 6-9, and during day 16-19, the pH value was below 6 which was considered more acidic. This resulted in the spoilage of water.

3.2 The pH Electrode Values Analysis

The principle of pH measurement is electronic instruments. There are two main components: the electrode and electric potential measurement, the voltage measuring is converted to the pH value, which output result of pH electrode is Millivolts (mV). The voltage measuring results of converted to the pH values shown in Table 1 and Figure 11

Table 1 Output voltage results of the pH electrodes

Voltage (mV)	pH Values	Voltage (mV)	pH Values	Voltage (mV)	pH Values	Voltage (mV)	pH Values	Voltage (mV)	pH Values
95.58	5.381	34.97	6.411	-44.96	7.768	-63.30	8.079	-72.77	8.235
90.00	5.489	29.66	6.501	-50.87	7.869	-65.08	8.102	-76.32	8.295
87.64	5.521	14.91	6.754	-52.65	7.893	-66.56	8.125	-78.68	8.331
80.56	5.641	4.88	6.929	-57.97	7.982	-66.79	8.129	-81.64	8.385
66.99	5.871	-21.29	7.361	-53.83	7.912	-69.22	8.171	-83.42	8.413
62.27	5.951	-27.21	7.463	-57.97	7.984	-69.81	8.186	-87.56	8.489
61.68	5.964	-33.72	7.572	-59.16	8.009	-70.99	8.203	-	-
59.16	6.002	-37.27	7.632	-62.71	8.069	-72.18	8.229	-	-

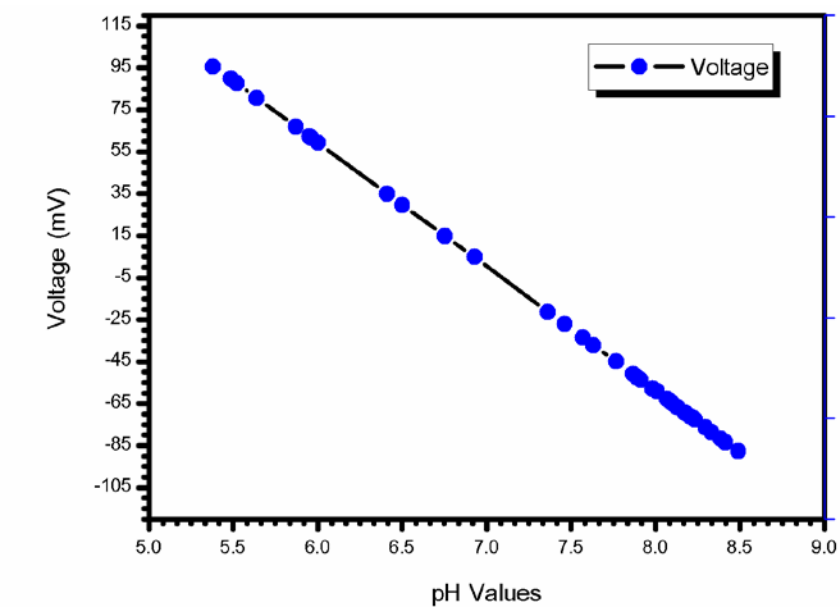


Figure 11 Graph representation of the output voltage of pH electrodes

According to Figure 11, the graph showed an analysis of the values of pH Electrode output of the conversion of analog signals into digital signals. The system could store these numeric signal values in Cloud Computing in order to be displayed via NETPIE application with the Data Feed function.

4. Conclusions

This paper presented the development of embedded system for pH measurement in the fish ponds and monitoring data via Internet of Things to prevent the spoilage of water in the fish culture in the cement ponds, to reduce the diseases in fish, and to reduce the problems of the death of fish. For this study, the pH measurement system was designed and created. The study instruments were: 1) NodeMCU which served as a platform to help develop embedded system to control the device of I/O, together with data transmission via the WiFi module (ESP8266), which was key for connecting to the Internet, 2) pH Sensor which is an electronic instrument used for pH measurement, 3) Netpie system which served as a communication system among devices or things in the IoT network via Netpie platform of cloud services, and 4) Internet of Things which is a part of communication and interconnect via protocols in both wired and wireless communication, the data will be displayed via smart phone and computer. The results showed the pH measurement system during the period of day 1-15 that the suitable pH value for normal living of freshwater fish was in the range of 6-9, and during day 16-19, the pH value was below 6 which was considered more acidic. This resulted in the problem of spoilage of water. It can be concluded that the pH measurement system can efficiently display pH value data.

Acknowledgement

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