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Design of a Low-Cost Remote Monitoring System for Nigerian Aquaculture using Wi-Fi and on-chip Web Server

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Abstract

Many Nigerian fish farm startups have very low financial capital while having goals of breaking even on time. The pH of the aquaculture environment of the fish being reared is realized to have a very important role to play in making sure that the reared fish develop properly and not die. Consequently, this work is aimed at the design and validation of a low cost electronic remote pH monitoring system. Affordable electronic components such as microcontroller, pH sensor kit and Wi-Fi dongle were gotten, configured, programmed and calibrated to create a wireless pH sensing unit. The microcontroller which was used provided web services which eliminated the need for a full-blown PC to act as a web server. A remote access device was used to pick the real-time pH data which the wireless pH sensing unit generated, using a Wi-Fi link in the WLAN created by the microcontroller. Buffer solutions 4 and 7 were used to calibrate the pH sensing unit. The calibrated system was tested by using it to confirm the pH levels of the already known pH levels of buffer solutions 4, 7, and 9.2. The designed system was able to determine the pH of solutions with an accuracy of ±0.2. The system was able to send email alerts whenever poor pH levels are experienced.

Key words: *Aquaculture, pH level, Remote Monitoring, Wi-Fi*

1. Introduction

Fish farming in Nigeria is a phenomenon which has been on the increase for a few years now. There is a high and continuous increase in demand for catfish as a commodity (Mpiegbulam, 2017) which has to be satisfied. With many people going into the business of aquaculture, especially with a small capital, it is anticipated that substantial profit should be gotten in the shortest possible time.

For a fish farmer to increase the chance of having good adult fish yield, the water quality of the fish fingerlings environment should be of great concern (Towers, 2014) as fish can be deeply affected by the pH level of the environment. Abrupt pH increases can be a life-threatening to catfish fingerlings (Mischke et al., 2012) thereby causing menace to the investment of the aquaculture farmer. Most farmers in Nigeria check pH levels by using pH reagents that only gives a hint about the pH level of a solution which is not always precise.

Scanty works have been done towards electronic catfish monitoring (Ramya et al., 2015), designed and implemented a web-based embedded systems solution to monitor contamination of water from underground water and a fish pond. This work was done in a bid to ensure that the fish that lived in the pond stay healthy while human that drink of the underground water is not compromised in their health. The monitoring was achieved using an Atmel 89C51 microcontroller, pH sensor, temperature sensor, and water level sensor. A wireless sensor node was created using the microcontroller integrated with the sensors and the monitoring system communicate using ZigBee communication standard. An LCD display linked to the microcontroller was used to show real-time status of pH, temperature, and water level. A water quality monitoring system based on wireless sensor network (WSN) was done by (Zhang et al., 2011). Here with WSN wireless nodes which sense pH, temperature and dissolved oxygen and send the observed parameter through ZigBee to a central computer for data storage and processing. Nevertheless, the use of ZigBee standard is not cost effective since it is a transceiver, meaning the receiver must also have ZigBee to receive from

ZigBee. Accordingly, if three or more access point is required, that same number of ZigBee would be required, thereby inflating the costs. Other works done with ZigBee include (Sharpe, 2018), however, this research work is realized with a buffer solution, microcontroller, a low-cost pH sensor and Wi-Fi interface which is not only affordable, but compatible with most devices.

2. Materials and methods

The system was built using low-cost electronic components which primarily serve to measure pH levels in an aquaculture environment, display the real-time values of the pH levels on a Wi-Fi linked remote device and be able to send email alerts through the internet when the pH levels are out of accepted bounds. In this section, the system designed was detailed. Firstly, the architecture of the designed system was presented in Figure 1. Next, the sensor and the affiliated circuit was described in section 2.1, and in Figure 2. Lastly, the configurations used are presented.

2.1 System architecture

The architecture of the designed system is shown in Figure 1. The design is of a microcontroller-based platform which determines the pH level of solutions using a pH measurement kit and transmits the measured pH over Wi-Fi with the help of its embedded web server feature. The network architecture is made up of two parts: The Wireless LAN (WLAN) and the gateway. The WLAN is created and managed by the Access Point (AP). The WLAN allows for Wi-Fi connections to be established between the pH sensing unit and the remote monitoring device. The access point handles allocation of IP addresses which are allotted dynamically, while the IP addresses makes it possible for each device to be located on the network. The gateway device functions to provide access to the components in the WLAN. In particular, it utilizes its modem to transmit and receive data to and from the internet. The gateway also makes it possible for email alert. The designed system has the following components:

i. P4S-342 Microcontroller
ii. Ralink 802.11n USB WLAN dongle
iii. pH measurement kit (E-201-C pH Probe with Logo-Rnaenaor pH sensor module)
iv. Remote Monitoring Device/Access Point/Gateway Device

The pH sensing unit is made up of a pH sensor module, pH probe, Wi-Fi adaptor, and microcontroller numbered as can be seen in Figure 2. The pH probe is connected to sensor module which receives and conditions the pH voltages that are generated by the probe. The sensor is connected to the analog port of microcontroller. The microcontroller computes the pH values from the analog voltage received at the analog port. The Wi-Fi adaptor provides an interface for WLAN connection. It is through the Wi-Fi link that is established that pH requests are received, data are sent, and email alert leaves the sensing unit to the gateway.

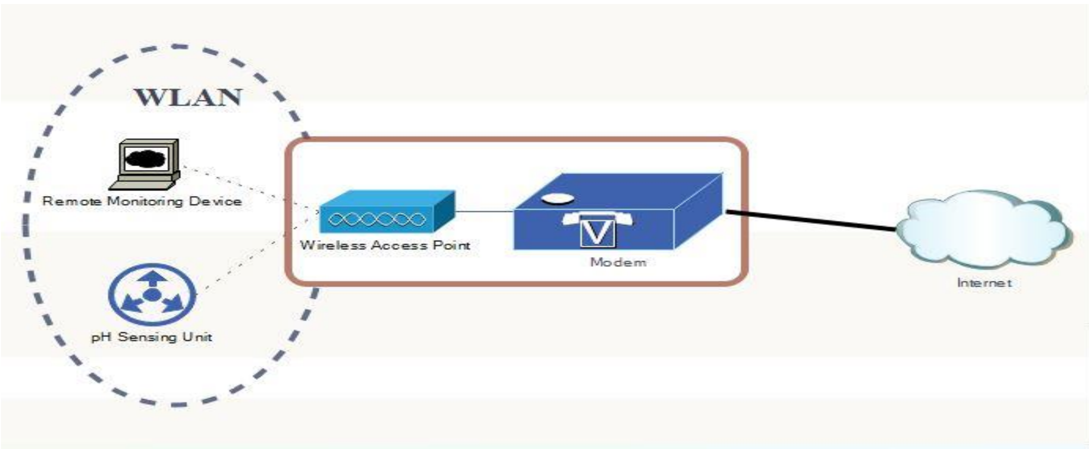

Figure 1: Network architecture of the system

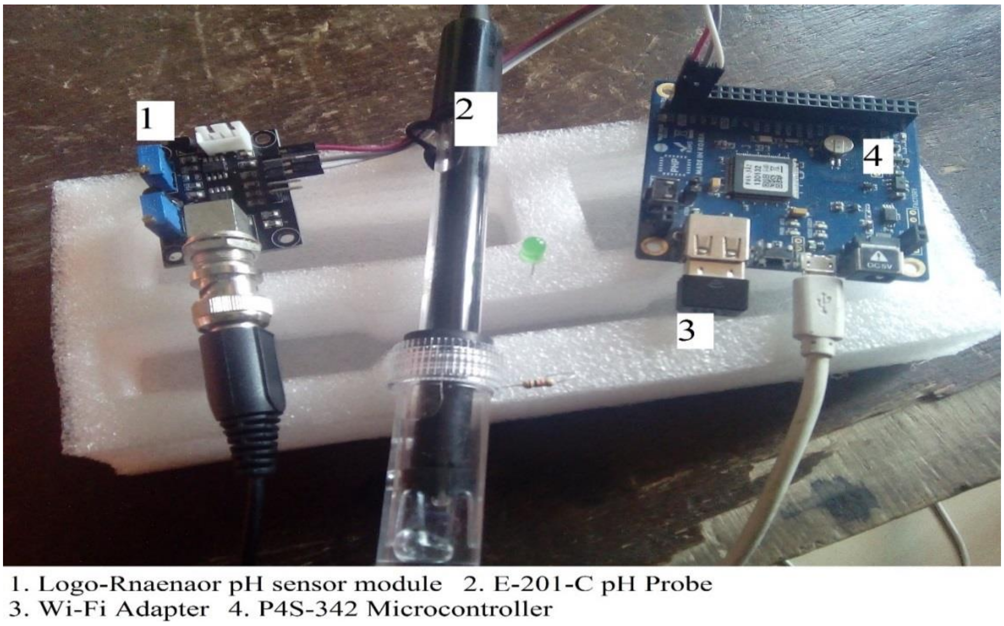

Figure 2: Components of the pH sensing unit

2.2 pH sensor kit calibration

The pH measurement unit had to be calibrated. The calibration process was done by determining the voltage measured by the microcontroller when immersed in buffer solutions. In this work, the calibration was done using buffers 4 and 7. The voltages read from buffer 4 and buffer 7 are as shown in Table 1. Finally, the values were plugged into a straight-line equation and the slope calculated to determine the unknown pH levels using the microcontroller based on the sensed voltage.

Table 1: Buffers 4 and 7 voltage readings

x (V)	Y (pH)
4.446207583	4.0
3.69567875	7.0

Figure 3: pH readings from the buffer 4 solution

3. Results and discussion

Achieving the design of a pH monitoring system with the capability to provide real-time pH level information through a technology such as Wi-Fi, which does not break the bank, is quite a feat to surmount. The remote monitoring device successfully connected with the web server with the P4S-342 microcontroller within a WLAN. The web server had an IP address of 192.168.43.219. The web browser of the remote monitoring device is used to access the real-time pH measurements being read by the microcontroller.

The sensed pH values were transmitted over Wi-Fi to a connected remote monitoring device, which observes the real time pH value on a web browser. pH values of buffers 4, 7, and 9.2 are seen in Figures 3,4 and 5. When undesired pH levels are reached, the system sends an email alert.

The pH sensing unit carries out the pH measurements with a great level of accuracy. The remote pH monitoring system was used to read and confirm the pH level of the already prepared buffer 4 solution. pH reading was generated by the microcontroller and transmitted over Wi-Fi to the remote monitoring device. In Figure 3 (on the left-hand side), the pH probe is immersed in the buffer 4 solution. The microcontroller determined the pH level based on the intermittent reading of voltage levels from the pH probe. The web browser page (on the right-hand side of Figure 3) showed the real-time pH value that was being read at intervals. The readings were displayed on the browser interface and updated in the text area. Values that fall within the pH range of 4±0.2 were displayed. From Figure 3, a sequence of values such as the first ten pH values - 4.01, 4.05, 4.05, 4.09, 4.09, 4.09, 4.09, 4.10, 4.09, 4.09 – were displayed.

After the pH level confirmation was done on the buffer 4 solution, the remote monitoring system was further used to confirm the pH level of the buffer 7 solution, as shown in Figure 4 (on the left-hand side). The pH level swiftly shifted from values around a pH reading of 4 – as seen in Figure 3 - to a reading around pH 7 after the pH probe was dipped into the buffer 7 solution. The pH readings were sent to the browser interface through the already established Wi-Fi link. Values that fall within the pH range of 7±0.2 were displayed. From Figure 4, a sequence of values such as the first ten pH values - 7.00, 7.00, 7.00, 7.00, 7.00, 7.00, 7.00, 7.00, 7.00, 7.00 – were displayed.

For the last pH level confirmation, the pH probe was dipped into a buffer 9.2 solution (Figure 5, to the left). The values shifted from the previous readings which hovered around pH 7. Ten consecutive values of 9.19, 9.05, 9.14, 9.05, 9.10, 9.09, 9.09, 9.21, 9.04, 9.13 were displayed while the pH probe was in the buffer 9.2 solution.

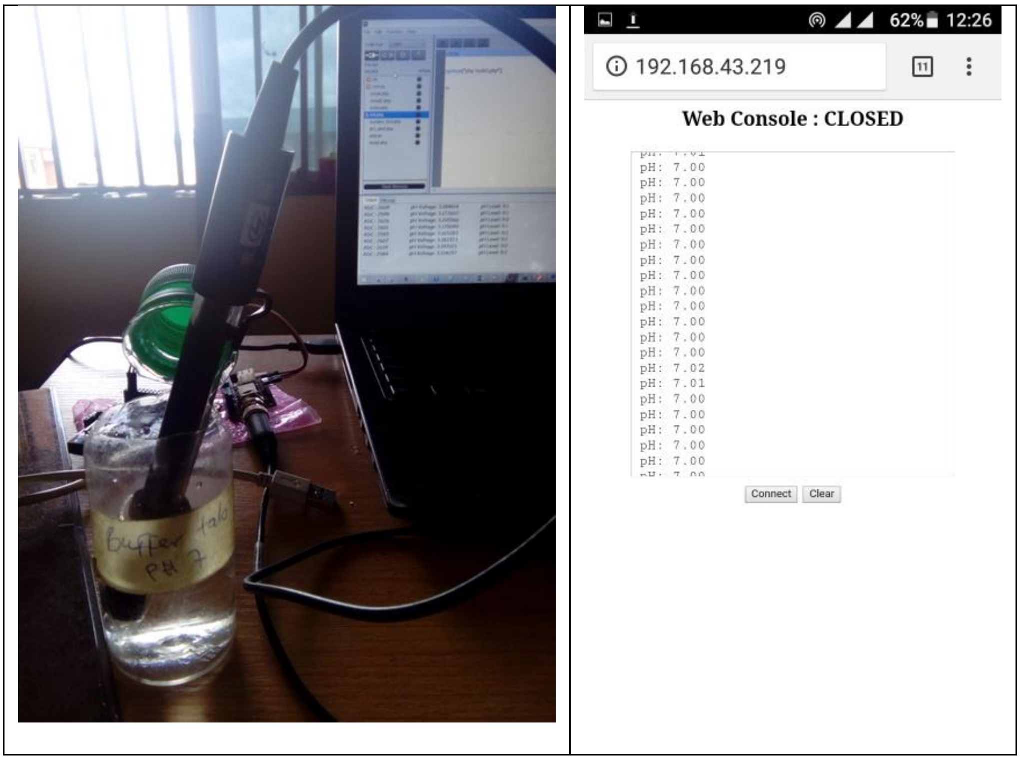

Figure 4: pH readings gotten from buffer 7 solution

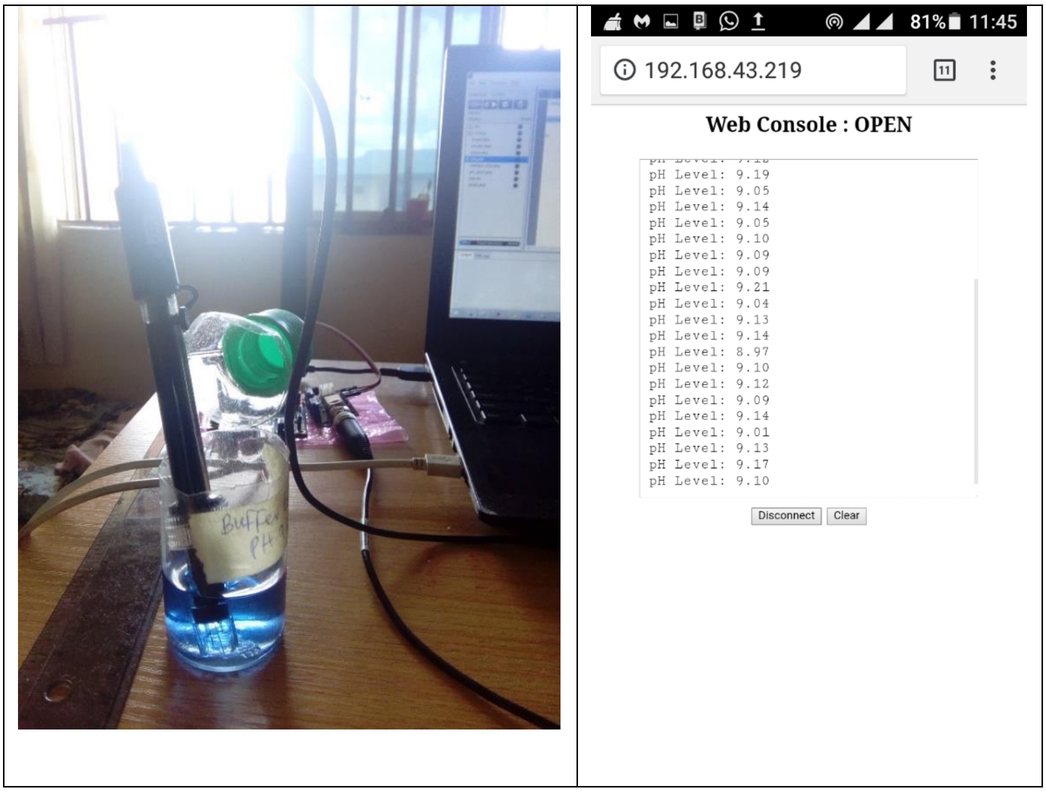

Figure 5: pH readings from the buffer 9.2 solution

4. Conclusions

In this paper, the design of a low-cost remote pH monitoring system has been shown. The system design was done based on the thriving of catfish fingerlings. The system can monitor pH of solutions and transmit real time pH level values to a remote monitoring device over Wi-Fi. The network architecture has been shown. Low-cost components have been used in the design to make it affordable for the farmers in developing countries like Nigeria. The microcontroller was programmed as a web server, making it possible to send real time pH information to the browser of the remote monitoring device. This eliminated the need for a separate PC which would have acted as a web server on the network. The system can take pH reading with an accuracy of ±0.2, which makes it reliable for aquaculture applications. The cost of the designed system is about 130 dollars and can be affordable. When the solution is at a pH level outside favourable conditions, an email alert is sent for attention to be given to the fish tank that is being monitored.

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