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IMPLEMENTATION OF MICROCONTROLLER BASED EARTH POND WATER QUALITY MONITORING SYSTEM USING SOLAR POWER AND BLUETOOTH TECHNOLOGY IN NIGERIA FISH FARMING SYSTEM

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Abstract

This research is motivated towards implementing a solar-powered water quality monitoring and control system for a warm water earth pond in real-time. Deploying an efficient monitoring and control system to fish farms will enhance the increase of yield, saves time, cost, and increase productivity in Nigeria. The system is designed to measure, analyse, and control the various relevant parameters: temperature, pH, and turbidity. To achieve this, sensors are used to detect changes in the environmental conditions of the pond as regards aforementioned parameters to determine the state of the pond. Furthermore, the system uses actuators as a mechanism to control the inflow and outflow of water using the control signal received from the processing unit. A successful inquiry was established between the Bluetooth module and the hands-free Bluetooth handset. This made it possible to monitor the real-time status of the warm water earth pond through the Bluetooth wireless communication. Noise and instability were observed in the data collected on the Arduino Integrated Development Environment (IDE), and this was resolved using a running average filter algorithm. The research shows that the linearity of the pH sensor is good, haven obtained an R^2 value of 0.9988.

Keywords: Bluetooth, pH sensor, turbidity, temperature, wireless communication, solar power

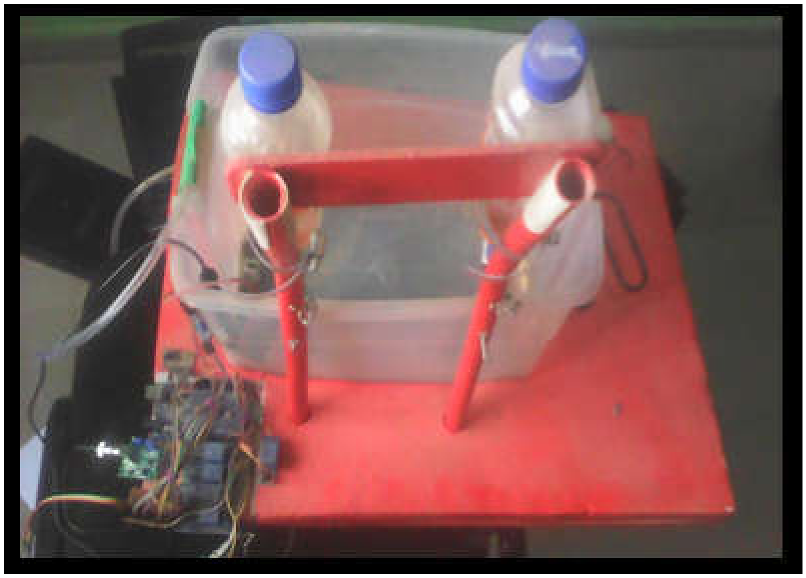
Introduction

Monitoring and controlling the water quality of an in ground pond throughout the season is an important conservation measure that must be used for a clean and healthy environment for aquatic life [1]. Water quality is a measure of the suitability of water for a specific use based on selected physical, chemical and biological characteristics such as dissolved oxygen, pH, turbidity, conductivity, salinity and temperature [1].

In highly turbid water (<30 NTU – Nephelometric Turbidity Unit), light penetrates only a short distance and photosynthesis is reduced [2]. Oxygen production during the day is relatively small, as a result both the growth of fish and their natural food organisms is affected. Thus, relatively low water temperature has an adverse effect on fish by slowing the development of their eggs, reducing the growth of juveniles and older fish, and reducing their food intake. The temperature of the lake also affects breathing, or respiration of fish [3 - 4]. This is because the maximum amount of dissolved oxygen present in water depends on its temperature. Ground ponds in the pH range of 6.5 to 8.5 are generally best suited for adequate yield of fish production. A ground pond pH below 4.5 and a pH equal to or greater than 11 could lead to the death of farmed fish. Also, pond water pH higher than 9 can be harmful to fish eggs and fry [5].

One of the problems faced by aquaculture farmers is the inability to independently and simultaneously monitor and adjust too many parameters [6]. As technology advances, the goal is to develop and monitor water quality parameters using more efficient methods from the comfort zone and at low cost. The traditional method of monitoring pond water quality involves taking water samples at various times and taking these samples to a laboratory for analysis [7]. This kind of approach is used to ensure water quality that is tedious and does not meet immediate needs.

MATERIALS AND METHOD



Hardware implementation of the system architecture

Hardware Implementation

phenomena from the pond environment such as pH, temperature, and turbidity need to be translated into electrical form. This section gives an indebt knowledge on sensors (pH, turbidity, and temperature) interfacing concerning the proposed system.

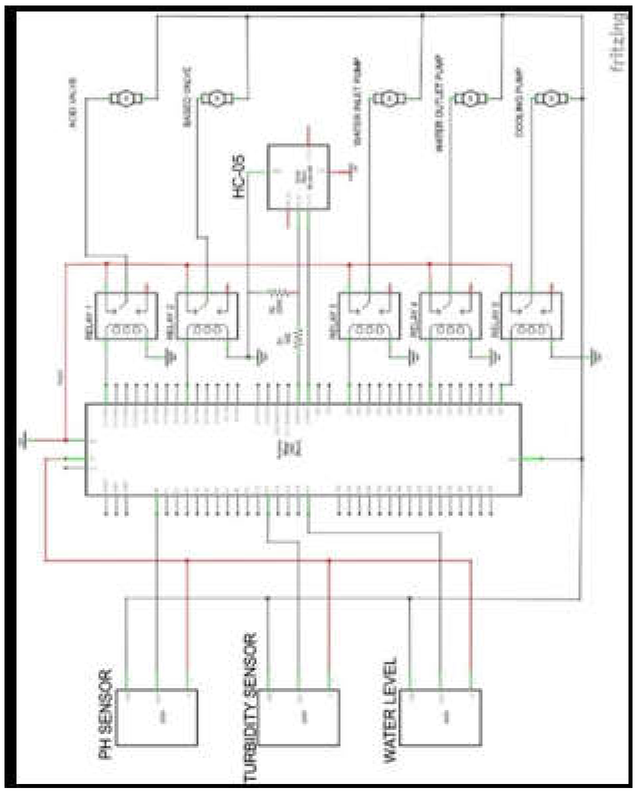
B. Pin Definition of the Arduino Atmega 2560

Details of the Arduino Atmega 2560 are given as:

- Digital pins 18 and 19 on the Arduino Atmega board are the TX (transmit) and RX (receive) pins. Two pins connect the TX and RX pins of the Bluetooth module to the Arduino board and are responsible for serial communication.
- Analog pins A0, A11, and A15 on the Arduino board connect the analog pins of the pH, turbidity, and temperature sensors to the Arduino Atmega board, thereby reading the signals from the sensors.
- The 5V supply output voltage from the Arduino board powers the pH, turbidity and temperature sensors.
- The GND (ground) pin on the Arduino board is connected to the ground of relays, sensors and the Bluetooth module.

VIN, this pin is used to power the Arduino board using 12V power from the solar system.

- D13, D5, D22, D30, and D37 are digital input pins on the Arduino board that are reserved for relays on the PCB. These digital pins on the Arduino board are used to control the relay. Fig. 2 shows the circuit diagram of the implemented system.



Circuit diagram of the implemented system

C. Power System/Alternative Source of Energy

The maximum power requirements for the implemented system is 12VDC, 1.2W to power the solenoid [8]. Components such as the sensors, Arduino, and water pump operate within the range of 3-5V [9]. The technical specification are shown in Table 1.

Table 1: specifications of the sensors implemented in the monitoring system [20],

Sensors	Model	Specifications

pH Sensor	E-201-C	• Operating Voltage: 5V +- 0.2V • Operating Current: 5-10mA • pH Value Range: PH0-14 • Response Time: less than 5 second • Stabilizing Time: less than 60 seconds • Power Consumption: 0.5W • Operating Temperature: -10 to 50 degree Celsius (Optimum: 20 degree Celsius) • Relative Air Humidity: 95% RH (Optimum: 65%RH) • Lifespan: 3 years • Size: 42mm*32mm*20mm • Weight: 25gram • Output signal: Analogue Voltage
Turbidity	Gravity type	• Working voltage: DC5V • Operating Current : 30mA (MAX) • Response time : <500ms • Insulation Resistance : 100M Ω[Min]; • the output way: Analog output 0-4.5V • the output way: high / low signal – High : 5V ; Low : 0V • operating temperature : -30C – 80 C; • Weight : 55g

		• Size : 30mm * 20mm * 12mm
Temperature Sensor	LM35	• Calibrated Directly in Celsius(Centigrade) • Linear+ 10-mV/°C Scale Factor • 0.5°C Ensured Accuracy(at 25°C) • Rated for Full−55°C to 150°C Range • Suitable for Remote Applications • Low-Cost Due to Wafer-Level Trimming • OperatesFrom4 V to 30 V • LessThan60-μA Current Drain • Low Self-Heating,0.08°C in Still Air • Non-LinearityOnly±¼°C Typical • Low-ImpedanceOutput,0.1Ωfor 1-mA

Due to its viability, solar energy is used as an alternative energy source for the system, in this way the system could be used in rural areas. In the event of a power outage, the solar panel serves as an alternative source for charging the battery. The basic requirements for solar systems are; solar charge controller, battery and solar photovoltaic panel.

A solar PV panel converts solar energy into electrical energy. Consisting of a small unit called a solar cell, this cell absorbs energy from the sun and converts it into electrical energy through a process called the photoelectric effect [10]. A solar charge controller can be thought of as a switch that connects the battery and the solar panel. It has a voltage regulator and a current booster that protect the battery and solar panel and also regulate the voltage and current coming from the solar panel and going to the battery. In addition, it monitors the battery charge level using a comparator that compares the reference voltage with the battery voltage. Due to its efficiency, the solar charge controller reduces battery overheating, minimizes battery stress and increases battery life [11]. DC Batteries are used to store electrical energy. A battery contains an arrangement of electrochemical cells that convert chemical energy into electrical energy. In this part of the research work, a lithium battery is used because of its advantages over the lead-acid type of battery. It has a fast charging time, a low rate of self-discharge, significantly higher reliability and a very long service life compared to leadacid batteries.

D. Software Implementation

The core software component used to implement the software is the Arduino Integrated Development Environment (IDE). The Arduino IDE is where the code is written and uploaded to the Arduino board. The Arduino code was written in C++ along with the addition of special features. The USB cable is used to connect the Arduino board to the computer system. Serial Monitor is a great tool for real-time monitoring and debugging. Through the serial monitor, interaction with the Arduino board is possible. The first step before programming is to extend the capabilities and functions of the Arduino board by importing additional libraries (#include <SPI.h>, #include <SD.h>).

All global variables (temperature; T, water level L, clarity C, etc.) were declared in the format "type name and proposed system. The system is initialized by checking the water level in the pond. If it is less than or above the expected threshold, the inlet or outlet pump take action else turbidity (C) is checked, if the clarity of the pond water is below the required, inlet, and outlet valve are opened until clarity is confirmed. Subsequently, the system checks if the pH level falls below 6.5 or rises above 8.5. If yes, a treatment solution is supplied in drops (0.5S) from either of the treatment container (A or B) to the pond as the case may be. Hold-up time is applied for the treatment reagent to mix, until the error is been cleared. Finally, the system checks if the temperature is above the desired temperature, if yes a cooling system is activated which exchange the topmost hot water with the button water. Table 2 shows the desired ranges of water quality parameters and control action to be taken.

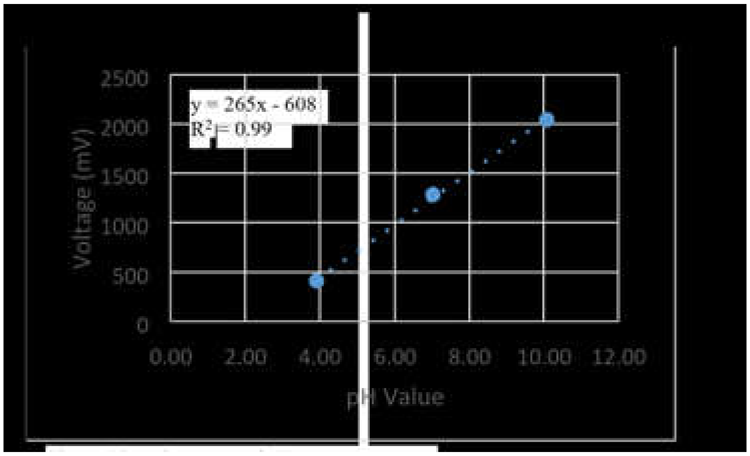


Fig 4. Linearity curve of pH sensor

III. Results And Discussion

A. Results

Each of the sensors was properly placed in the constructed plastic container pond. The constructed pond accommodate 15 litres of water and is 40 cm by 20cm in size. Each of the sensors was tested separately to determine its effectiveness and efficiency in measurement. The measured results of each sensor are displayed using arduino IDE serial monitor.

Table 2: Desired Ranges Of Water Parameters And Control Action

Serial no.	**Measured parameters**	**unit**	**Desirable range**		**Measured values**	**Action taken**
			Minimum value	**Maximum value**		
1	Temperature	Degree Celcius (ºC)	28 ºC	32 ºC	>35 ºC	Outlet water pump is turned ON & then Inlet water pump is turned ON
2	Turbidity	Nephelometric Turbidity Unit (NTU)	-	30 NTU	>30 NTU	Open water outlet valve
3	pH	-	6.5	8.5	<6.5	Release base

					>8.5	Release acid

The following processes were followed to determine accuracy and performance of the pH sensor.

- Three standard solution numbered X, Y, Z were provided
- The pH sensor was dipped into each of the solution to measure the pH/mV. After each measurement the pH sensor was carefully rinsed using distilled water to keep it dry.

- In standard solution X (pH=3.90, at 250C), 409mV was recorded, in standard solution Y (pH=7.01, at 250C) 1282 mV was recorded, and in standard solution Z (pH=10.06, at 250C) 2041mV was recorded.

Fig. 5 shows a pond scenario with a pH of 5.76, which is below the accepted pH range (6.5 – 8.5) for a warm water earthen pond [12]. From the written arduino code, the low pH results in valve A being excited, which was opened and the base was released for 0.5S, which is 0.2ml. An agitation time of 1 second was observed after each release of 0.2ml of treatment solution into the pond. This process was repeated until the pH rose to 6.73, which is within the desired range. Serial monitoring shows a high water temperature in the lake of 33oC. The top water in the pond, which tends to be at a higher temperature, is exchanged for bottom water by passing the top water through a cooling liquid. The temperature sensor shows a gradual decrease in temperature.

Environment in Fig. 5 shows a scenario of a rise in pH (8.65) in the pond system. Solenoid valve B received an open valve signal from Arduino board as a result of high pH OF 8.65. This valve releases lime of 0.2ml onto the pond continuously until the pH reduces to 8.31, which is within the required range for aquatic life.

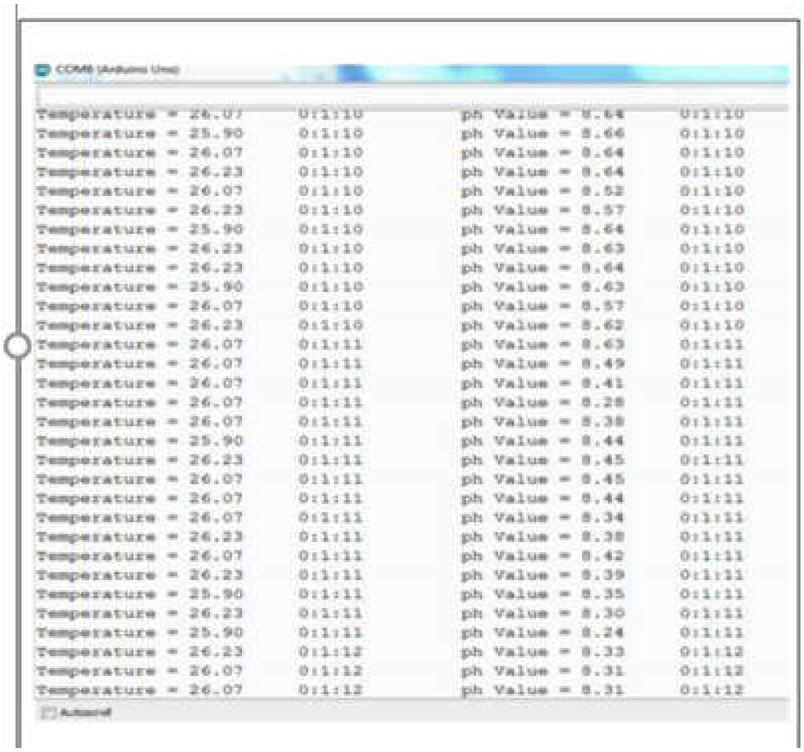


Fig. 5. Results of pH measurement in decreasing order of pH value

Warm water fish, grows best at a temperature above 20^0C. A temperature above 30^0C, could lead to reduction in yield and mortality of the fishes at extreme temperature.

Real-time pond pH, pond temperature and turbidity are monitored via Bluetooth wireless communication. The aquaculture environment information stored in the phone is received from each sensor node in real time, so that the user can access the aquaculture environment information. A successful query was made between the Bluetooth module and the hands-free Bluetooth handset. Before establishing a connection, the two Bluetooth devices shared individual addresses (paging), as shown in Figure 6. Results of the Bluetooth communication range depend on transmitter output power, receiver sensitivity and physical obstacles in the transmission path. In the presence of concrete walls, the Bluetooth signal will be weakened, reducing the range that the signal can cover. Choosing a Bluetooth module with a transmitted power of -20dBm (0.01mW) to +20dBm (100mW) is a good compromise between range and power consumption. The experimental results presented in this research show that effective monitoring and control solutions for the pH, temperature and turbidity of the warm water of the Earth Pond have been adopted for practice.

IV. Conclusion

In this research, a solar system that monitors and controls temperature, pH, and turbidity is presented. The system detects changes in the natural system to provide a basis for their proper management. Deploying this system in a warm water ground pond will increase yield maximization by ensuring effective monitoring and control of water quality in the pond environment. Farmers control ponds through a better decision-making process. In the same way, management does not depend on human activities, it is carried out automatically in order to save costs and increase productivity. The system records the efficiency of data transmission and reception. Data can be received and monitored at a distance of 100m.

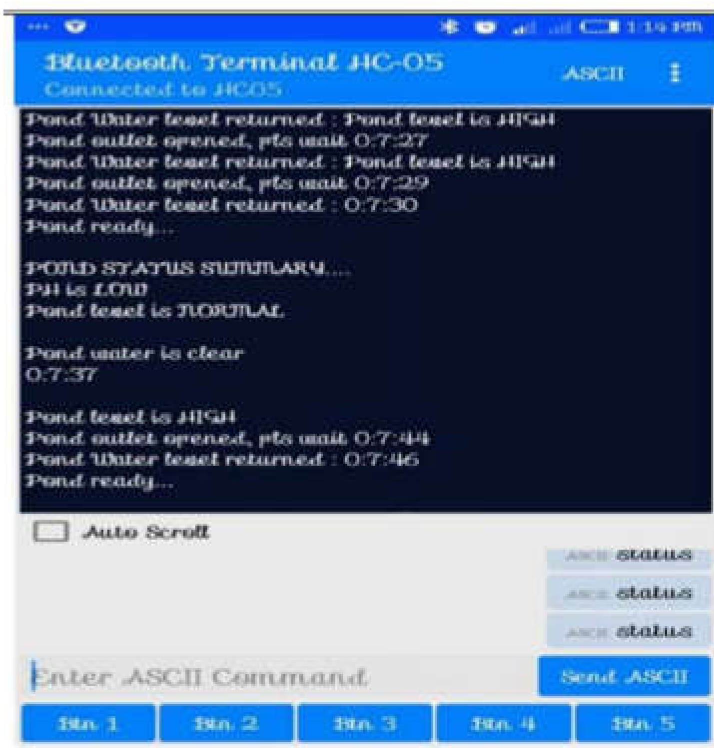


Fig. 6. Results of the Bluetooth communication

Sensors readings are stabilized using a filter algorithm. It was observed that the readings from the sensors are not very stable and contain noise. To avoid errors in outputs and calculations, sensors reading are filtered using a running average filter algorithm. The pH sensor tends to degrade in its accuracy in measurements, after measuring a pH below 2 or above 12. High accuracy (< = 0.02 pH) of the pH sensor is maintained by regular calibration of the sensor using a standard solution.

reception. Data can be received and monitored at a distance of 100 m from the surroundings of the pond using the Bluetooth Low Energy communication protocol.

Viability of the solar system in most parts of the nation, explains why it is been used as an alternative source of energy, thus making the system remain active for a long time when deployed in remote areas.

A simplified form of low-pass (moving averages) was used to filter out random interference from the analog signals received from the sensors, smoothing the signal in digital form. System results were validated through real-time measurement and communication data. The results showed that efficient and highly accurate monitoring and control of water quality was achieved.

IV. Acknowledgment

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