
Low-Cost IoT Solution for Real-Time Monitoring of Aquaculture Water Parameters

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Abstract: This study sets forth a low-cost Internet of Things (IoT)-enabled aquaculture water monitoring system to address the issue of traditional manual water quality assessment methods, a process that is time-consuming, labour-intensive, and inadequate for continuous monitoring. The system was created for small-hold fish farmers who do not have access to any commercial, elaborate systems, which can be very costly, to provide real-time observations of essential water parameters (pH, temperature, and turbidity) that impact fish health, growth, and survival. While the system was developed using an Arduino Uno microcontroller, an ESP8266 Wi-Fi module, and pH, turbidity, and temperature sensors that had been calibrated for accuracy, live data was streamed to Visible Clouds (ThingSpeak) for remote monitoring. Field tests were conducted in Bangladesh at two distinct sites: (1) a controlled fish farming pond in Chattogram and (2) a public lake in a commercial-industrial zone in Mireshorai, Chattogram. All of the sensors for this project were pre-calibrated using standard buffer solutions for reliability and were used with manual sampling for cross-checking measurement comparison. The prototype of the project was able to demonstrate steady operations and quantitative readings over multiple weeks, with a range of average temperature (28.7 °C and 26.2 °C), pH (7.25 and 8.08), and turbidity (3.40 and 3.95 NTU in both sites) for average Nile Tilapia (*Oreochromis niloticus*) and Rui (*Labeo rohita*). The results indicate that the system can be a viable tool to detect unsatisfactory water conditions early enough to initiate early action to reduce fish mortality and possibly increase output on the farm. This approach combines affordability, ease of deployment, and remote accessibility and is likely to facilitate improved sustainability for aquaculture in resource-limited contexts.

Keywords: IoT, Aquaculture, Arduino Uno, ESP8266, Water Quality Monitoring.

1. INTRODUCTION

Aquaculture, also acknowledged as fish farming, is the cultivation of aquatic organisms in a controlled environment (Shete, 2024). Fishing and aquaculture are vital for the livelihood, nutrition, and income of hundreds of millions globally. According to the FAO's State of World Fisheries and Aquaculture 2016 report, global per capita fish supply hit a record 20 kg in 2014, with aquaculture contributing over half of all fish consumed. However, Water is vital for life, and maintaining its quality is critical in aquaculture. The critical parameters, such as pH, turbidity, Ammonia Nitrogen (NH₃-N), Biochemical Oxygen Demand over 5 days (BOD-5), and Chemical Oxygen Demand (COD) in stormwater, influence the water quality of lakes, ponds, and rivers (Uddin, 2024). Water quality directly impacts fish health, growth, and survival (Ahmed, 2024). Poor water conditions can lead to reduced yields and economic losses.

Traditional water quality monitoring techniques are often time-consuming and resource-intensive. The rise of the Internet of Things (IoT) presents significant opportunities for real-time, cost-effective water quality monitoring, thereby improving the sector's productivity, sustainability, and resilience (Rejeb, 2025; Alam, 2024) especially in aquaculture, where consistent water parameters are essential for fish health. Water contamination in aquaculture affects water quality, threatening ecosystem sustainability and aquatic health (Arepalli, 2024). This research work introduces an IoT-based system capable of monitoring pH, turbidity, and temperature, transmitting this data to a cloud platform for remote access and analysis. Therefore, there is a pressing need for a user-friendly, automated system that provides real-time data to ensure the optimal water quality is crucial to maintaining healthy fish populations, especially for small-scale farmers in developing regions. To encounter this challenge, we propose a low-cost IoT-based monitoring system based on Arduino Uno along with the ESP8266 Wi-Fi module and calibrated sensors for pH, turbidity, and temperature. This low-cost IoT system allows monitoring and forwarding data to the ThingSpeak cloud, where it can be accessed for remote visualization and analysis. Our field evaluation of the system at two aquaculture sites in Bangladesh shows how an effective IoT-based monitoring system can contribute to improving sustainability in aquaculture.

The research history in this field has witnessed several works and showcases the demand continuity of further advanced-level research work. For instance, Harun et al. (2018) documented a typical aquaculture farm in Malacca, Malaysia, using Arduino-based monitoring systems including pH, temperature, and dissolved oxygen (DO) sensors, with data showing a high average water temperature (~30°C), ideal for tropical aquaculture species like Tilapia, Patin, and Keli (Harun, 2018). Vijayakumar and Ramya (2015) proposed a Raspberry Pi-based real-time water quality monitoring system employing sensors for pH, turbidity, temperature, DO, and conductivity. Their system, accessed via cloud and mobile devices, featured a Python-based data acquisition routine. Despite its efficiency and low cost, its limitation lies in its reliance on manual command inputs for sensor data retrieval (Vijayakumar, 2015).

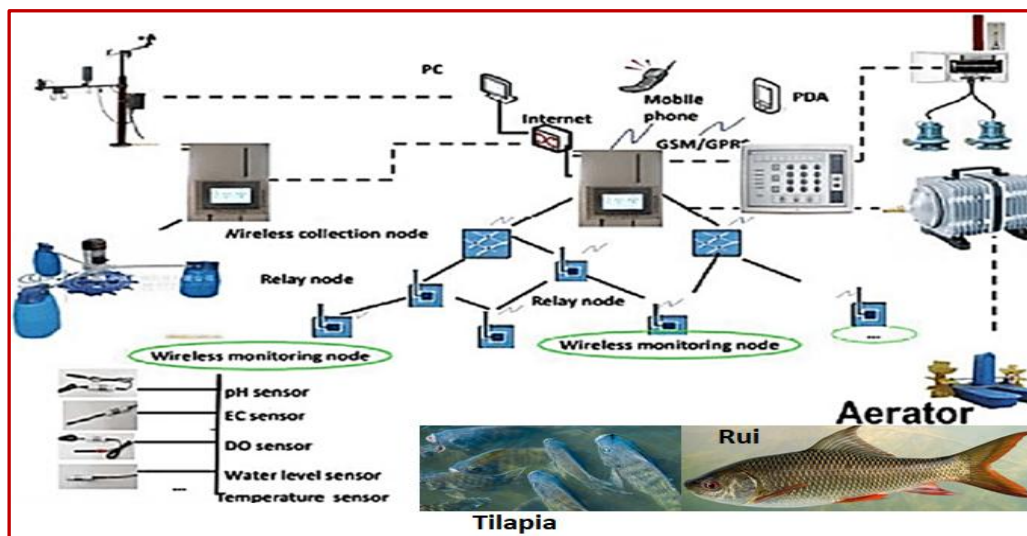


Figure 1: Schematic illustration of IoT functioning in aquaculture (Vinod, 2020).

Yuxiao (2020) introduced a robust STM32-based intelligent aquaculture monitoring system using multi-sensor integration. The setup continuously collected real-time pH, temperature, DO, and turbidity data and transmitted it via mobile networks for evaluation. The system supports remote alarms and analytics, helping farmers pre-emptively address water quality issues, though its scalability and affordability for smallholders may be limited (Yuxiao, 2021). Preetham et al. (2019) emphasized challenges in Indian aquaculture, notably from climatic variability affecting water quality. Their sensor-based monitoring system measured turbidity, temperature, and pH over 24-hour cycles, issuing automated alerts when thresholds were exceeded. Their work accentuates the potential of affordable automation to reduce losses and improve fish yield in commercial farms (Preetham, 2019). In East Africa, Rosette et al. (2020) assessed how water quality affects fish distribution in Lake Victoria. Their study in Uganda used global positioning system (GPS)-based site sampling, capturing species such as Tilapia and Nile Perch, and analyzed data using GIS and SPSS. Key findings revealed that Tilapia thrives in high-pH (9.3) and moderate temperature (26–28.8°C) conditions, while turbidity significantly influenced species abundance. Though impactful, this study relied on manual sample collection and lacked real-time monitoring (Zawadi, 2020). Chowdury et al. (2019) proposed a low-cost wireless sensor network (WSN) to continuously monitor river water using IoT and artificial neural networks (ANN). Their system collected pH, temperature, turbidity, ORP, and conductivity data, classifying water quality as "good," "cautious," or "dangerous." Despite budget limitations restricting sensor deployment breadth, their ANN model offers a scalable, automated, and intelligent monitoring approach for rural or remote locations (Chowdury, 2019). All these reviewed studies highlight the necessity of developing a low-cost, real-time water quality monitoring system in aquaculture using embedded systems and IoT platforms. Limitations of existing systems include hardware costs, a lack of wireless data transmission, and the absence of predictive analytics.

2. METHODOLOGY

2.1 Proposed Model

The system monitors three key water parameters using sensors: pH, turbidity, and temperature. Data is collected by an Arduino Uno R3 and transmitted via ESP8266 to ThingSpeak. A 5V water pump and relay module are included for potential automation of corrective actions. The proposed model is a cost-efficient, real-time water quality monitoring system designed for aquaculture applications. It integrates three essential sensors, pH, turbidity, and temperature, with an Arduino Uno R3 microcontroller and an ESP8266 Wi-Fi module for data transmission to the ThingSpeak cloud platform. This model not only monitors water parameters but also enables automated corrective action through a relay-controlled 5V submersible water pump. The operational workflow begins with the sensors collecting data on water pH, turbidity, and temperature. The Arduino Uno R3 processes these readings and checks them against predefined threshold values. If the measurements lie within acceptable ranges, the system continues monitoring. However, when any parameter exceeds its threshold, a relay triggers the water pump to initiate remediation (e.g., water circulation or replacement). Simultaneously, all real-time sensor data and event logs are transmitted to ThingSpeak for storage, visualization, and remote access.

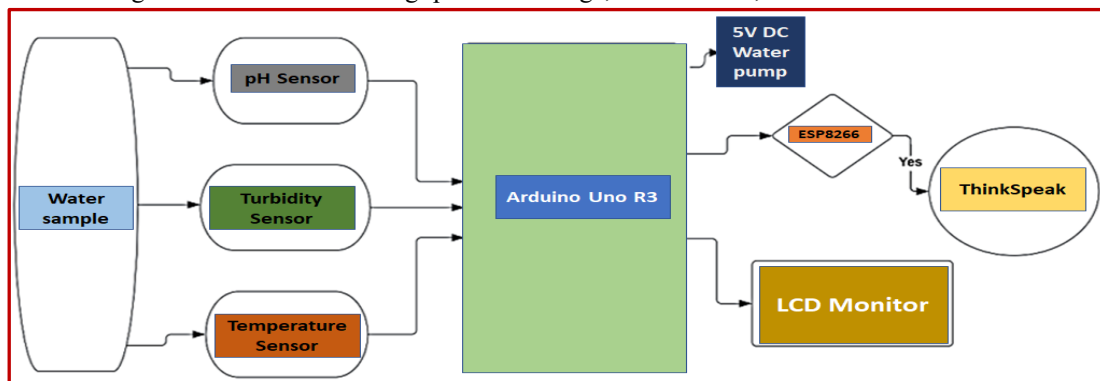


Figure 2: Schematic diagram of the device System.

2.2 System Components and Prototype Development

The prototype system comprises the following major components: Arduino Uno R3 microcontroller (ATmega328P, SKU: ARD-00119), which collects data from sensors and sends commands to actuators, while also displaying real-time readings on a 16×2 liquid crystal display (LCD) (SKU: DIS-00083). An analog pH sensor module (SEN0161-V2) was used to measure the hydrogen ion concentration (pH) of water. It includes a pH probe and onboard signal conditioning circuitry. The sensor is calibrated using software-based calibration and reference buffer solutions to maintain accuracy. A digital (DS18B20) temperature sensor to ensure high-resolution temperature readings. It supports parasitic power mode and has a unique 64-bit serial code, enabling multiple sensors on the same data line. A turbidity sensor (SKU SEN0189) was used to detect suspended particles in water by emitting and receiving IR light. Increased turbidity levels result in greater scattering, reducing the intensity of received light. An ESP8266 Wi-Fi module (ESP-01) was added to the system for wireless data transmission. The module was programmed to transmit real-time sensor data to the ThingSpeak IoT cloud platform for remote access and analytics.

A 5V submersible mini water pump (SRD-05VDC-SL-C) has been used as an actuator to improve water quality when turbidity exceeds acceptable limits. The pump is controlled by a single-channel relay module, acting as an electrically operated switch to enable or disable the pump based on programmed thresholds. All these components were sourced through an online shopping platform known as <https://techshopbd.com/>.

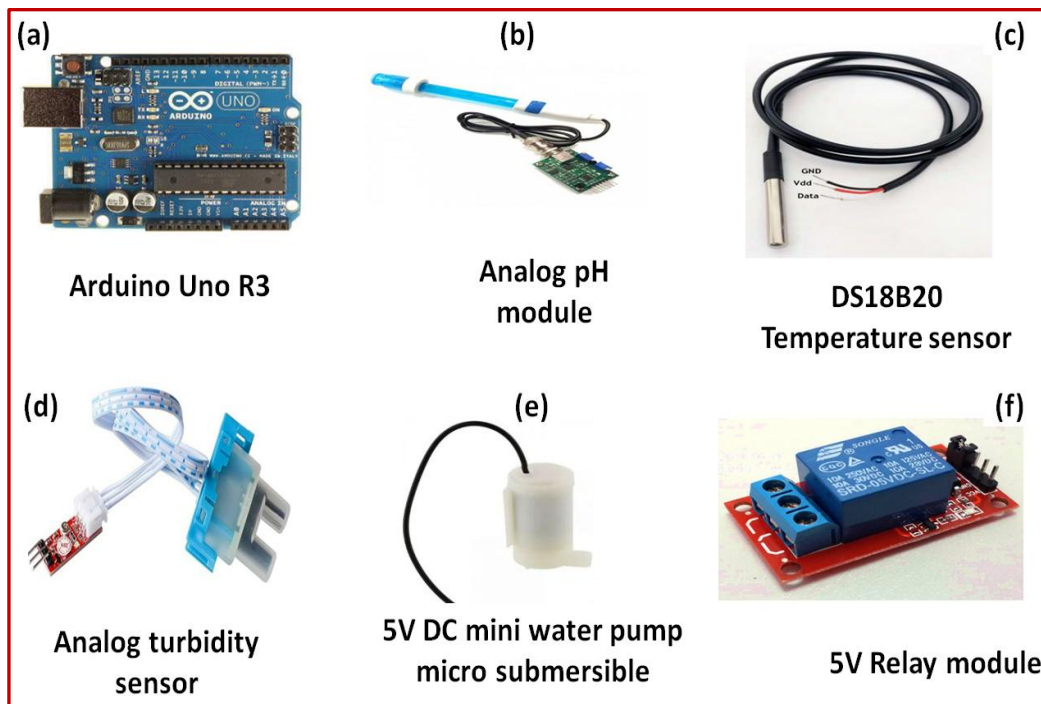


Figure 3: Components used in this work.

All of the components were first assembled on a breadboard for prototyping and then soldered onto a printed circuit board (PCB) for robustness. The system was powered using a 5V USB supply from either a laptop or portable power bank. As the electronics needed protection and deployment was in mind, a custom waterproof enclosure was created to house the circuitry and sensors.

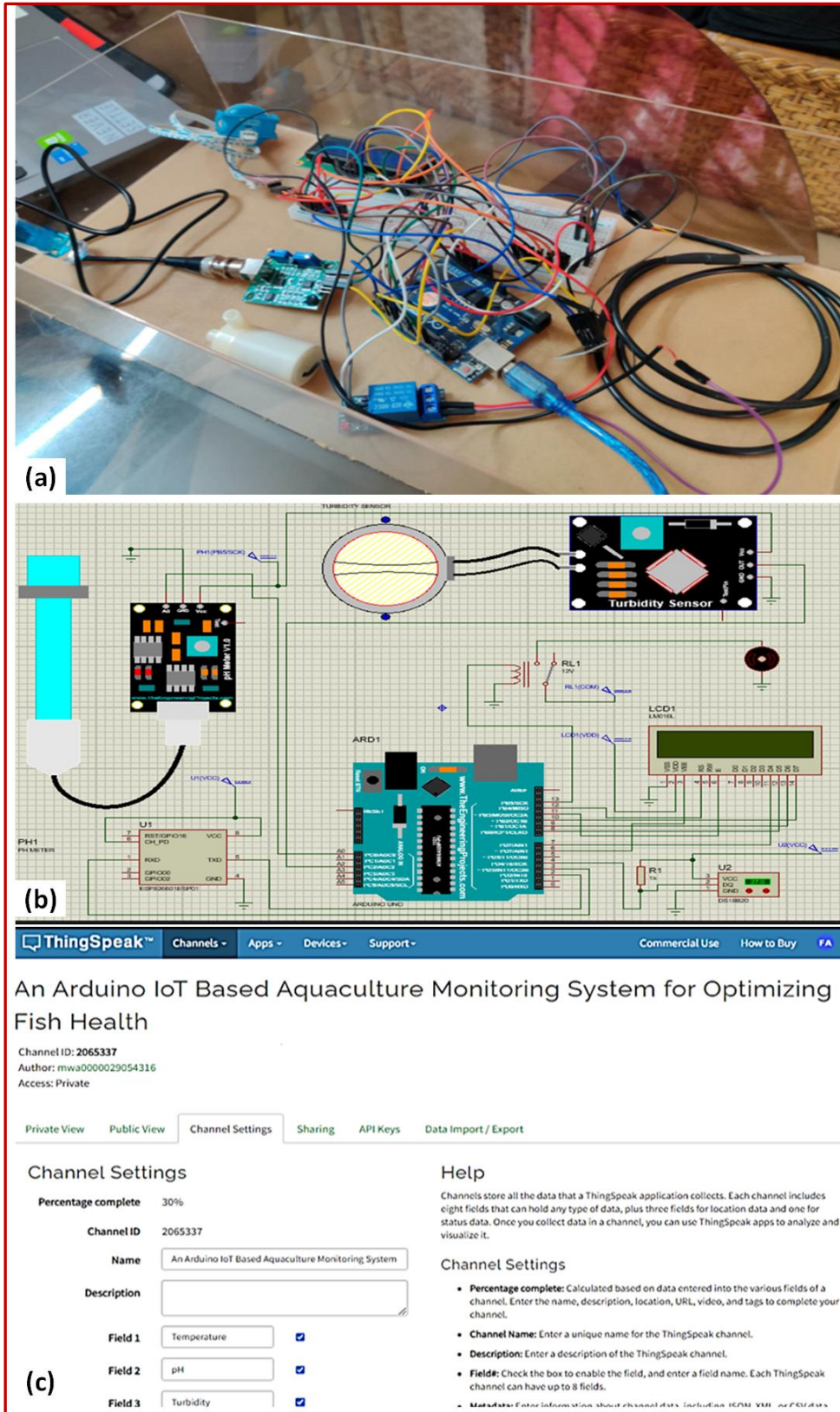


Figure 4: (a) Device prototype; (b) Schematic Diagram Pin out of the Components; and (c) Channel opening

3. DATA COLLECTION AND ANALYSIS

Data collection was carried out in a pond and a public lake environment (images of sites are shown in Figure 5). Field validation was conducted at two freshwater aquaculture sites in Bangladesh to evaluate system performance:

Site-1: Controlled Fish Farming Pond - Located in Chattogram, the site is a smallholder aquaculture pond and is actively managed for Nile Tilapia (*Oreochromis niloticus*) and Rui (*Labeo rohita*). We monitored these ponds in March-April 2024, during the dry pre-monsoon season. The climate in this sampled area during this time, by average air temperatures ranging from 28 - 32 °C and average relative humidity of approximately 65%, and limited rain. The pond is aerated manually and fertilized every week. We deployed the sensors in the center of the pond, around 50 cm from the water surface, by suspending them on a floating platform that was 2 m from the shore.

Site-2: Public Lake Near Mirershorai Economic Zone - This site is a freshwater lake located near the Mirershorai Economic Zone, located in Chattogram. This site could experience fluctuations in water quality due to random runoff from seasonal industrial activities. The ASD data collected from this site added gravity to the analysis as the analysis continued from the same time. This lake is home to various native fish species as it is not managed for aquaculture. The sensors were situated 1 m below the water surface at about 10 m from the shore. They were tethered to a submerged pole so they wouldn't drift during measurement time.

Each sensor continuously measured its respective parameter, pH, temperature, or turbidity, and transmitted the data to the Arduino Uno. These readings were displayed locally on an LCD and uploaded to the ThingSpeak IoT cloud platform via the ESP8266 module.

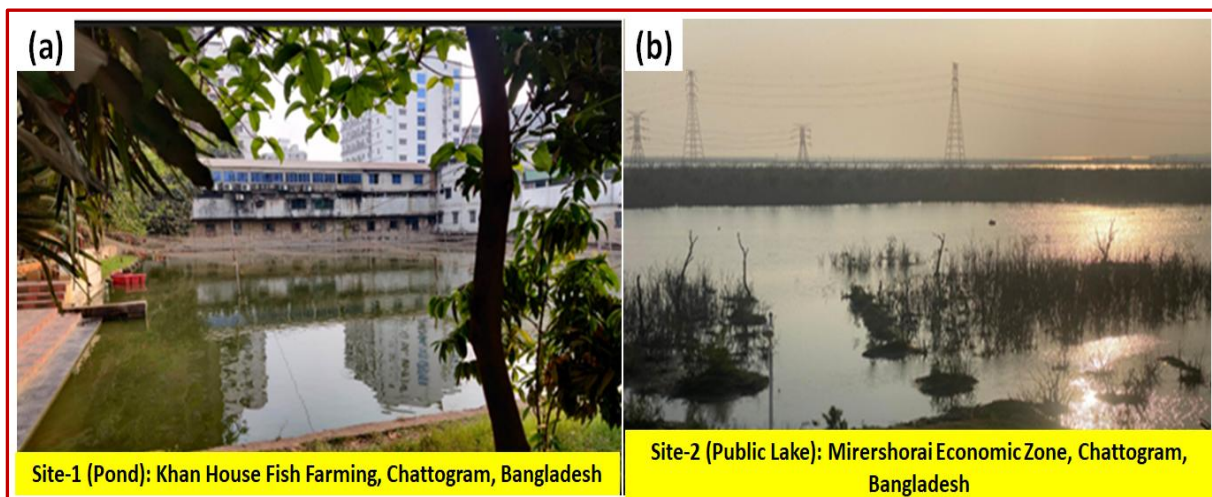


Figure 5: Images of testing sites (a) Pond located in a controlled fish farming area, and (b) a public lake near an industrial area in Bangladesh.

The IoT system developed recorded site-1 water parameters with averages of 28.7 °C for temperature, 7.25 for pH, and 3.40 NTU for turbidity. These values for temperature fall in the recommended ranges for Nile Tilapia (*Oreochromis niloticus*) and Rui (*Labeo rohita*) in which the optimal temperature range of 25–32 °C and pH should be in the range of 6.4–8.3 for healthy growth and survival. A prior study indicated that Nile Tilapia at 28 °C raised under similar conditions produced almost twice the growth rate compared to fish raised at 24 °C or 32 °C, as well as the optimal feed conversion ratio (FCR) suggested this temperature [14]. By using real-time water quality monitoring, the proposed system provides a pathway for aquaculturists, should any water quality parameters shift, to correct the deviations and potentially enhance fish growth performance and FCR. After testing the pond, it was found that the average values of pH are 7.25, temperature is 28.7, and turbidity is 3.40, as shown in Figure 6. The temperature value of 28.7 °C is within the suitable range for many fish species, as the optimum temperature for fish growth in the culture pond is between 25-32 °C. The pH value measured is 7.25, and a pH range from 6.4 to 8.3 is favorable for fish growth according to a research study. That indicates the values collected

from the pond water are acceptable. The turbidity value of 3.40 is slightly higher than the recommended range for some fish species. For all pond water, turbidity must not exceed 5 nephelometric turbidity units (NTU) above natural conditions. For different fish, different values are considered optimum. Analysis shows that all parameters are within the optimal range for Tilapia and Rui growth. Turbidity levels were slightly elevated but acceptable.

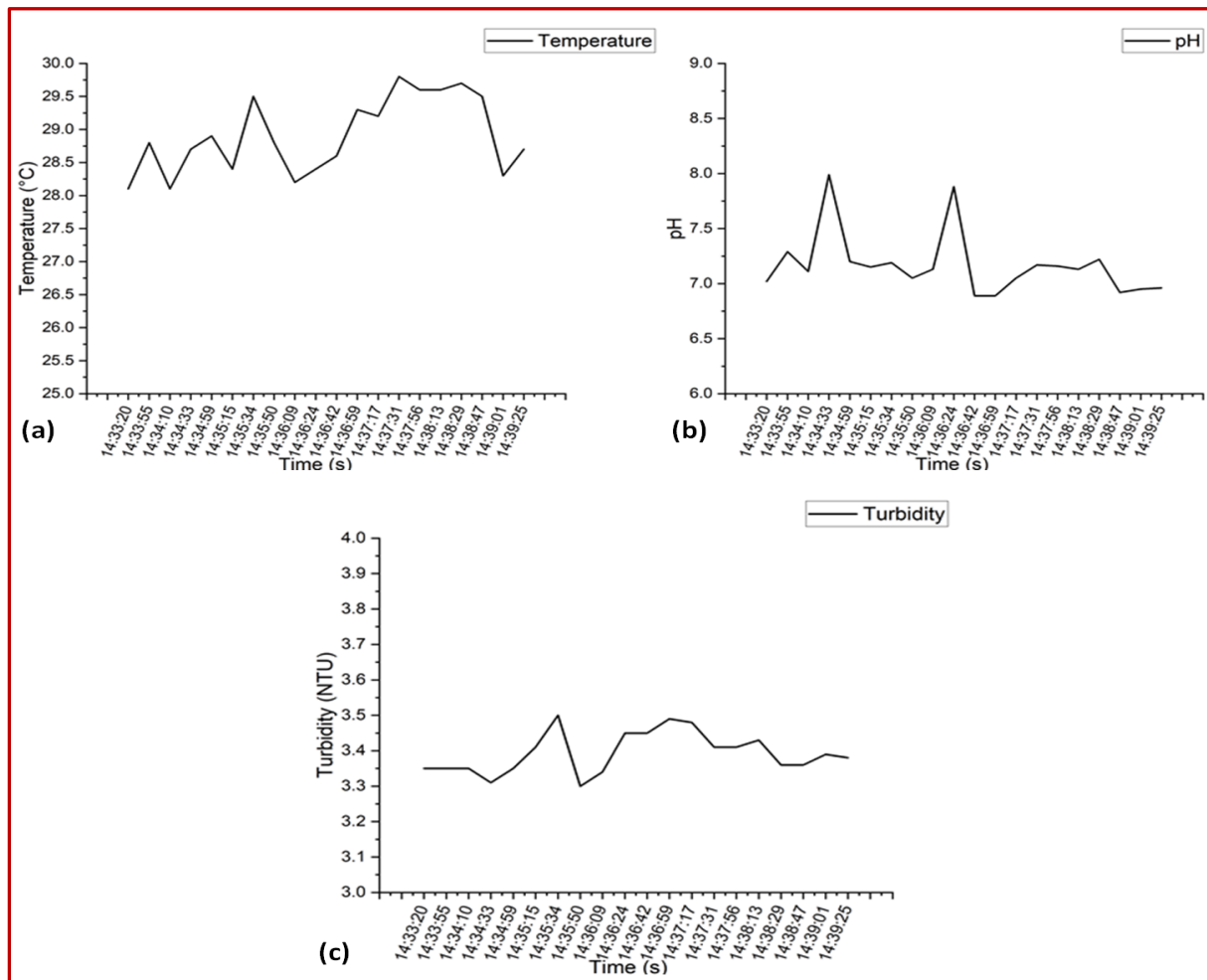


Figure 6: Testing result and Analysis on Site-1; measured temperature (a), pH (b), and Turbidity (c).

In site 2, freshwater lakes support a variety of aquatic organisms. The water quality data of both ponds and lakes can be used to identify trends and patterns in the aquatic ecosystem. Changes in pH, turbidity, and temperature can impact the health and productivity of both ponds and lakes. Site two, after testing the pond, it was found that the average value of pH is 8.08, temperature is 26.2, and turbidity is 3.95 NTU, as shown in Figure 7. The temperature value of 26.2 °C is within the suitable range for many fish species, as the optimum temperature for fish growth in the culture pond is 25-32°C. The pH value came out to be 8.08, whereas a pH ranging from 6.4 to 8.3 is favorable for fish growth according to a research study. This indicates the value collected from the lake is higher. The turbidity value of 3.95 is higher than the recommended range for some fish species. But for all lake water, turbidity must not exceed 5 NTU above natural conditions. Though parameters are acceptable, pH and turbidity were slightly higher, likely due to industrial runoff. Lower temperature is attributed to greater water depth.

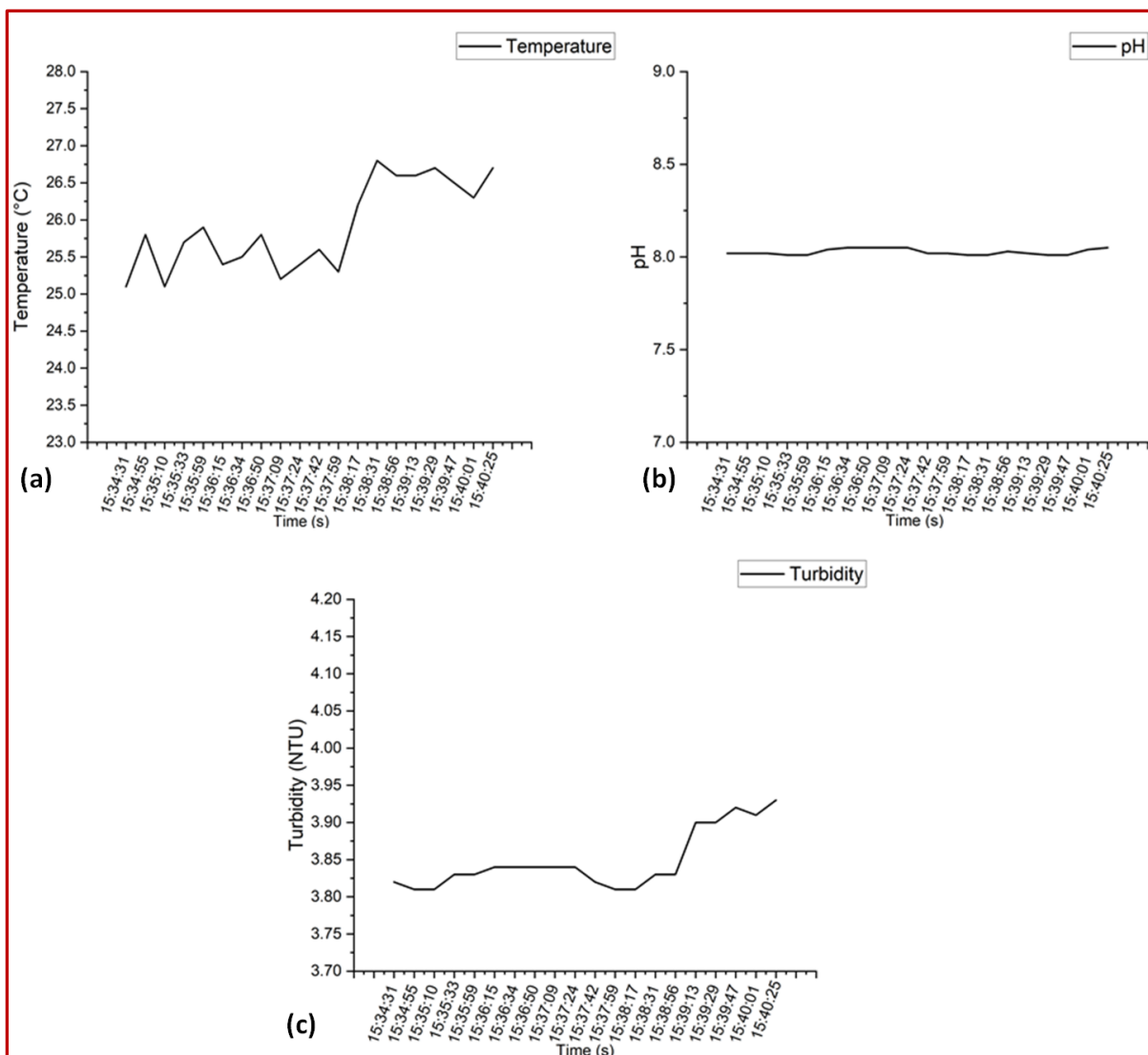


Figure 7: Testing result and Analysis on Site-2; measured temperature (a), pH (b), and Turbidity (c).

In summary, Site-1 provided more optimal conditions for Tilapia fry growth. Site-2's elevated pH and turbidity indicate a need for more frequent monitoring in industrial zones.

5. COST ANALYSIS

Affordability is a fundamental element of our proposed IoT-based aquaculture water monitoring system. To support our assertion of “low cost,” we summarize the capital costs of the main system components, provide an estimate of operating costs, and explore how these costs compare to traditional monitoring processes. Table 1 summarizes the capital cost breakdown.

Table 1: Capital Cost Breakdown

Component	Quantity	Total Cost (Taka)
Microcontroller	1	500
pH Sensor	1	2500
Temperature sensor	1	150
Turbidity sensor	1	820
Power Supply	1	560

Communication Module	1	60
Water pump (small)	1	200
Structural Materials	-	1000
Total Capital Cost		5790 Tk, Eq= 50 USD

***Note: The prices are approximate market values as of 2024 and may vary by region and supplier.*

5.1 Operational & maintenance, and cost comparison

- **Sensor Calibration:** pH sensors typically require calibration every 1–2 months to maintain accuracy. Calibration solutions cost approximately 600-1000 TK per kit, which can be used for multiple calibrations.
- **Sensor Replacement:** The lifespan of pH sensors ranges from 6 months to 1 year, depending on water conditions. Replacement sensors cost approximately 400-600 Tk.
- **Power Consumption:** Continuous operation draws approximately 1–2 W. Assuming a 24/7 operation with local electricity cost of 1.50 Tk/kWh, the monthly power cost is roughly 15 Tk.
- **Other Maintenance:** Occasional cleaning of sensors to prevent fouling is recommended and requires minimal labor cost.

The overall upfront cost of our system (less than 6000 Tk) is substantially lower than the water quality monitoring systems available commercially, depending on the functions and accuracy. For instance, professional multi-parameter water quality sondes could cost over 100,000 Tk, making those systems inaccessible for small-scale and/or resource-limited aquaculture operators. The proposed IoT system offers continuous real-time monitoring with minimal recurring costs as compared to traditional manual or chemical methods (using test kits or laboratory testing). Manual test kits can cost around 1200-2000 Tk per test and require labour for sample collection and subsequent analysis. Thus, the cost and time to test continuously by hand will increase as the frequency of manual testing increases.

Overall, the suggested IoT solution provides a very low-cost option that moves toward cost-effective and reliably automated monitoring, which supports real-time management of water quality for the aquaculture management plan of more stakeholders in the aquaculture space.

6. LIMITATIONS AND FUTURE DIRECTIONS

In addition, this research has a few limitations. The validation of the prototype system occurred over a relatively short monitoring time of two months within the pre-monsoon season (February to April) in Bangladesh. The environmental variability experienced during other seasons was not explored. Although the prototype system reliably collected real-time data, there may be issues with sensor fouling based on the length of deployments, as well as sporadic issues with the data transmission when the WiFi presence was poor. Furthermore, the measured values for pH, turbidity, and temperature were not validated with standard methods in laboratory conditions, which may have provided an additional confirmation of accurate measurements.

Future work may extend the monitoring period to incorporate seasonal variations as well as include additional water quality measures that would involve DO, NH₃-N, and BOD. Additionally, integrating industrial quality sensors that have an anti-fouling capability and creating a mobile/web-based dashboard can improve system and data accessibility. Comparative validation with standard lab methods is also recommended to strengthen confidence in the data reliability of the system.

7. CONCLUSION

The development of an IoT water monitoring system utilizing pH, turbidity, and temperature sensors, along with a Wi-Fi module, has the potential to revolutionize water quality monitoring in various industries. The system provides real-time data on the water quality parameters that are critical for maintaining the health of aquatic animals, crops, and the environment. The integration of the ESP8266 Wi-Fi module allows the system to transmit the data collected by the sensors to an online platform such as ThingSpeak, enabling remote monitoring and analysis.

The system can be used in a wide range of applications, including aquaculture, hydroponics, and water treatment plants. The data collected by the sensors can be used to optimize water management practices, prevent adverse effects on aquatic life, and reduce the risk of waterborne diseases. Moreover, the use of an IoT water monitoring system can lead to improved efficiency and cost-effectiveness compared to traditional water quality monitoring methods, as it reduces the need for manual data collection and processing.

In summary, the IoT water monitoring system has the potential to improve the sustainability and safety of water management practices, thereby contributing to the well-being of society and the environment. Future research can focus on optimizing the sensor technology and expanding the scope of the system to include other water quality parameters.

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Informed Consent Statement: Not applicable.

Data Availability Statement: Data will be available on request.

Supplementary: Prototype device code

```
#include <Wire.h>
#include <LiquidCrystal.h>
#include <OneWire.h>
#include <DallasTemperature.h>

#define ONE_WIRE_BUS 4

// Initialize the LCD library
LiquidCrystal lcd(12, 11, 7, 8, 9, 10);

// Turbidity variables
float turbidityThreshold = .6;
float turbiditySensorPin = A2;
float turbidityVoltage;
float turbidityValue = 0.0;
```

```

// pH variables
float calibrationValue = 21.34 - 0.7;
int phThreshold = 7;
int phSensorPin = A0;
unsigned long int avgVal;
int bufferArr[10], temp;
float phAct;

// Temperature variables
OneWire oneWire(ONE_WIRE_BUS);
DallasTemperature sensors(&oneWire);
float celcius = 0;
float fahrenheit = 0;
int tempThreshold = 31;

void setup() {
  // Initialize the LCD display
  Serial.begin(9600);
  analogWrite(6, 100);
  lcd.begin(16, 2);
  lcd.print("Sensor Values");
  delay(2000);
  lcd.clear();

  // pH
  Wire.begin();
  Serial.begin(9600);

  // Temperature
  sensors.begin();
}

void loop() {
  // Turbidity
  int sensorValue = analogRead(turbiditySensorPin);
  turbidityVoltage = sensorValue * (5.0 / 1024.0);
  turbidityValue = turbidityVoltage * 1.0000; // convert to NTU
  displayValues("Turbidity", turbidityValue, "NTU", turbidityThreshold);

  // check if threshold exceeded
  if (turbidityThreshold < 0.6 && turbidityValue >= turbidityThreshold) {
    lcd.setCursor(0, 1);
    lcd.print("Threshold exceeded");
  }
}

```

```

// pH
for (int i = 0; i < 10; i++) {
    bufferArr[i] = analogRead(phSensorPin);
    delay(30);
}
for (int i = 0; i < 9; i++) {
    for (int j = i + 1; j < 10; j++) {
        if (bufferArr[i] > bufferArr[j]) {
            temp = bufferArr[i];
            bufferArr[i] = bufferArr[j];
            bufferArr[j] = temp;
        }
    }
}

avgVal = 0;
for (int i = 2; i < 8; i++)
    avgVal += bufferArr[i];
float volt = (float)avgVal * 5.0 / 1024 / 6;
phAct = -5.70 * volt + calibrationValue;

displayValues("pH", phAct, "", phThreshold);

// Temperature
sensors.requestTemperatures();
celcius = sensors.getTempCByIndex(0);
fahrenheit = sensors.toFahrenheit(celcius);
displayValues("Temperature", celcius, "C", tempThreshold);

delay(1000);
}

void displayValues(String sensorName, float sensorValue, String unit, int
threshold) {
    lcd.clear();
    lcd.print(sensorName + ": " + sensorValue + " " + unit);

    if (sensorValue >= threshold) {
        lcd.setCursor(0, 1);
        lcd.print("Threshold exceeded");
    }

    delay(1000);
}

```

Motor Connection Code

```
int sensorPin = A2;
int motorPin = 13;

void setup() {
  Serial.begin(9600);
  pinMode(motorPin, OUTPUT);
}

void loop() {
  int sensorValue = analogRead(sensorPin);
  float voltage = sensorValue * (5.0 / 1024.0);
  Serial.print("Turbidity Value in NTU: ");
  Serial.println(voltage);

  if (voltage > 1) {
    digitalWrite(motorPin, HIGH);
  } else {
    digitalWrite(motorPin, LOW);
  }

  delay(100);
}
```

Thing Speak Connection code

```
#include <SoftwareSerial.h>
#define RX 2
#define TX 3
String AP = "Ash#col"; // AP NAME
String PASS = "Ash#col395"; // AP PASSWORD
String API = "TMYFTX1YI4A422PI"; // Write API KEY
String HOST = "api.thingspeak.com";
String PORT = "80";
String field = "field1";
int countTrueCommand;
int countTimeCommand;
boolean found = false;
int valSensor = 1;
SoftwareSerial esp8266(RX, TX);

void setup() {
  Serial.begin(9600);
  esp8266.begin(115200);
  sendCommand("AT", 5, "OK");
  sendCommand("AT+CWMODE=1", 5, "OK");
```

```

    sendCommand("AT+CWJAP=\"" + AP + "\",\"" + PASS + "\"", 20, "OK");
}

void loop() {
    valSensor = getSensorData();
    String getData = "GET /update?api_key=" + API + "&" + field + "=" +
String(valSensor);

    sendCommand("AT+CIPMUX=1", 5, "OK");
    sendCommand("AT+CIPSTART=0,\"TCP\",\"" + HOST + "\",\" + PORT, 15, "OK");
    sendCommand("AT+CIPSEND=0,\" + String(getData.length() + 4), 4, ">");
    esp8266.println(getData);
    delay(1500);
    countTrueCommand++;
    sendCommand("AT+CIPCLOSE=0", 5, "OK");
}

int getSensorData() {
    return random(1000);
    return random(1000);
    return random(1000); // Replace with your own sensor code
}

void sendCommand(String command, int maxTime, char readReplay[]) {
    Serial.print(countTrueCommand);
    Serial.print(". at command => ");
    Serial.print(command);
    Serial.print(" ");
    while (countTimeCommand < (maxTime * 1)) {
        esp8266.println(command); //at+cipsend
        if (esp8266.find(readReplay)) //ok
        {
            found = true;
            break;
        }

        countTimeCommand++;
    }

    if (found == true) {
        Serial.println("OYI");
        countTrueCommand++;
        countTimeCommand = 0;
    }

    if (found == false) {
        Serial.println("Fail");
    }
}

```

```

countTrueCommand = 0;
countTimeCommand = 0;
}

found = false;
}

```

REFERENCES

- Ahmed F. Bijoy, M. H. I. Hemal, H. R. and Noori, S. R. H. (2024) Smart aquaculture analytics: Enhancing shrimp farming in Bangladesh through real-time IoT monitoring and predictive machine learning analysis, *Heliyon*, 10 (17) e37330. doi:10.1016/J.HELIYON.2024.E37330.
- Alam, T. Rokonuzzaman, M. Sarker, S. Abadin, A. F. M. Z. Debnath, T. and Hossain, M. I. (2024) Internet of Things-based Home Automation with Network Mapper and MQTT Protocol, *Comput. Electr. Eng.*, 120,109807. doi:10.1016/J.COMPELECENG.2024.109807.
- Arepalli P. G. and Naik, K. J. (2024) Water contamination analysis in IoT enabled aquaculture using deep learning based AODEGRU, *Ecol. Inform.*,79, 102405. doi:10.1016/J.ECOINF.2023.102405.
- Chowdury *et al.*, M. S. U. (2019) IoT Based Real-time River Water Quality Monitoring System, *Procedia Comput. Sci.*155, 161–168. doi:10.1016/J.PROCS.2019.08.025.
- El-Sayed A. F. M. and Kawanna, M. (2008) Optimum water temperature boosts the growth performance of Nile tilapia (*Oreochromis niloticus*) fry reared in a recycling system, *Aquac. Res.* 39(6)670–672. doi:10.1111/J.1365-2109.2008.01915.X
- Harun, Z. Reda, E. and Hashim, H.,(2018) Real time fish pond monitoring and automation using Arduino, *IOP Conf. Ser. Mater. Sci. Eng.*,340(1)012014. doi10.1088/1757-899X/340/1/012014.
- Preetham K, (2019) Aquaculture monitoring and control system: An IoT based approach, *Int. J. Adv. Res.* www.IJARIT.com
- Rejeb, A. Rejeb, K. and Keogh, J. G. (2025) The nexus of IoT and aquaculture: A bibliometric analysis, *Appl. Food Res.*,5(1)100838. doi:10.1016/J.AFRES.2025.100838.
- Shete R. P. Bongale, A. M.and Dharrao D., (2024) IoT-enabled effective real-time water quality monitoring method for aquaculture, *MethodsX*, 13, 102906. doi: 10.1016/J.MEX.2024.102906.
- Uddin M. H. *et al.*, (2024) Rainwater Quality Disparities Across Malaysian Peninsula Sites, *J. Graph. Era Univ.*, 12 (2) 223–242. doi: 10.13052/JGEU0975-1416.1223.
- Vijayakumar N. and Ramya, R. (2015) The real time monitoring of water quality in IoT environment, *ICIIECS 2015 - 2015 IEEE Int. Conf. Innov. Information, Embed. Commun. Syst.*, doi:10.1109/ICIIECS.2015.7193080.
- Vinod Kumar, T. M. Mohammed Firoz, C. Bimal, P. Harikumar, P. S. andSankaran, P. (2020) Smart Water Management for Smart Kozhikode Metropolitan Area, *Adv. 21st Century Hum. Settlements*, 241–306. doi:10.1007/978-981-13-6822-6_7.

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