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Design of IoT-Based Water Quality Monitoring System in Freshwater Ornamental Fish Ponds

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This study presents the design and implementation of an IoT-based water quality monitoring system for freshwater ornamental fish ponds, with a focus on guppy fish (Poecilia reticulata). Utilizing an ESP32 microcontroller integrated with DS18B20 temperature, pH, and TDS sensors, the system enables real-time monitoring and automated control of critical water parameters. Data is transmitted via the Blynk platform, allowing remote access and management. The system triggers corrective actions—such as activating a water heater or solenoid valve—when temperature or pH levels deviate from optimal ranges (27–32°C and 6.5–8.5, respectively). Results demonstrate the system's effectiveness in maintaining stable conditions, reducing manual intervention, and mitigating risks to fish health. This approach offers a scalable solution for enhancing aquaculture efficiency and sustainability, with potential for expansion to include additional parameters like dissolved oxygen and ammonia in future work.

Kata kunci – Internet of Things, Fish Pond, ESP32, Water Quality Monitoring, Guppy Fish

I. INTRODUCTION

Maintaining high water quality is vital in aquaculture, especially for freshwater ornamental fish farming. Key parameters such as turbidity, temperature, pH, dissolved oxygen, and ammonia levels play a crucial role in determining fish health and development. Regular monitoring of these factors is necessary to sustain ideal aquatic conditions, ensuring fish well-being and enhancing productivity in aquaculture operations.

Turbidity measures water clarity, indicating the concentration of suspended particles like phytoplankton, clay, and silt. This parameter directly influences light availability for aquatic plant photosynthesis, making it a critical water quality metric. Typically quantified in nephelometric turbidity units (NTU), higher values reflect greater particle concentrations. For productive aquaculture operations, turbidity should remain within 25-80 mg/L. Excessive turbidity can impair fish development and disrupt normal feeding patterns, with effects varying based on the particle composition [1].

As a fundamental environmental factor, water temperature governs all biochemical processes in aquatic ecosystems. Since fish are poikilothermic, their metabolic functions including respiration and growth are temperature-dependent. Notably, a 10°C rise can accelerate biochemical reactions by 100%, profoundly affecting aquatic life. Warm-water species like tilapia and catfish perform best at 25-32°C, with peak productivity around 29°C. However, sudden temperature shifts exceeding 5°C may cause severe stress or mortality [1].

The hydrogen ion concentration (pH) determines water's acidic or basic nature, significantly influencing aquatic health. Measured on a 0-14 scale, pH affects nutrient bioavailability and physiological processes. Fish respiration releases CO_2, which forms carbonic acid and consequently lowers pH. For ornamental species, maintaining pH between 7.2-8.5 creates optimal conditions for growth and wellbeing [1,2].

DO concentration is vital for fish respiration, primarily generated through photosynthetic activity and supplemented by aeration systems. However, eutrophication from nutrient overload can trigger algal blooms whose subsequent decomposition creates oxygen-depleted zones. Aquaculture systems should maintain minimum DO levels of 5 mg/L to ensure fish health and prevent hypoxia-related stress [1].

This toxic nitrogen compound accumulates from metabolic waste and organic decomposition, particularly in overstocked or poorly maintained systems. Elevated ammonia concentrations cause physiological distress in fish, manifesting as reduced activity and feeding response. Effective management through biofiltration and controlled feeding practices is essential to maintain water quality and prevent ammonia toxicity in ornamental fish habitats [3].

Along with the development of technology, the problem can be solved by using the Internet of Things (IoT) as well as monitoring systems using web-based systems. Reliable human energy cannot be pH monitoring material, temperature and water quality at fish pond. For guppy fish ranchers that make up in large numbers can increase failure in large losses. For that, with this scrutiny can anoxic planning a tool that can monitor pH, temperature and water quality using Internet of Things (IoT) as well as the monitoring system using a web-based on a guppy fish pond intended to simplify the monitoring of water conditions and reduce the risk of failure on the guppy fish feeder.

The application of IoT technology has transformed water quality management in aquaculture through continuous, data-driven oversight. By deploying smart sensor networks, these systems deliver instantaneous measurements of critical aquatic parameters, enabling prompt corrective actions when values deviate from optimal ranges [4]. This technological integration facilitates automated control mechanisms, alarm notifications, and seamless interoperability with existing water treatment infrastructure, significantly improving operational efficiency while maintaining ideal growth conditions for aquatic species [5].

For ornamental fish farming, IoT adoption represents a pivotal step toward sustainable pond management. Real-time water quality surveillance ensures parameters consistently meet biological safety standards, mitigating risks to fish health. Through comprehensive monitoring of these vital metrics, aquaculturists can cultivate robust ecosystems that maximize both fish welfare and production yields, thereby elevating the success rate of aquaculture enterprises.

II. METHODOLOGY

This study utilizes a prototype-based approach featuring an integrated sensor-actuator system controlled by an ESP32 microcontroller. The system architecture incorporates the following key components as shown in Fig. 1.

a) A DS18B20 digital thermometer for precise water temperature monitoring
b) A total dissolved solids (TDS) sensor for water purity assessment
c) A pH sensor for acidity/alkalinity measurement
d) An automated solenoid valve for pH adjustment through chemical dosing
e) A thermostatically controlled water heater for temperature regulation
f) Relay module will serve as a voltage current manager on the draft to be made.
g) Water heater is used as a device of temperature control on water.

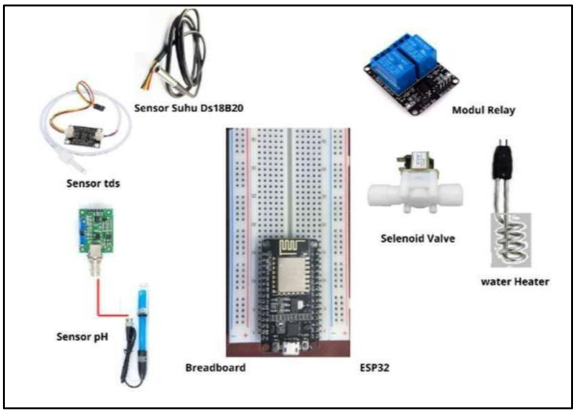

Figure 1. Key components of system

The ESP32 serves as the central processing unit, continuously gathering sensor data and transmitting it to the cloud-based Blynk IoT platform. This enables real-time remote monitoring via smartphone or computer interfaces. The system implements automated corrective measures when parameters exceed predefined thresholds, activating either the heating element or pH-neutralizing mechanism as required to maintain optimal aquatic conditions.

III. RESULTS AND DISCUSSION

Guppies (Poecilia reticulata) are popular freshwater aquarium fish prized for their ornamental value. As aquatic organisms, guppies are particularly sensitive to their water environment, with water quality parameters directly affecting their health, growth, and development. This research focuses on maintaining optimal water conditions for guppies, specifically monitoring three critical parameters: temperature, pH levels, and turbidity.

Water quality management is essential for breeding high-quality ornamental fish with desirable traits. Key parameters influencing water quality include:

a) Temperature (optimal tropical range: 28-32°C)
b) pH (tolerance range: 5-8 for most ornamental species)
c) Total dissolved solids (TDS) (safe threshold: <200 ppm)

The implementation of IoT-based monitoring systems in guppy aquaculture offers significant advantages, enabling farmers to prevent substantial economic losses through real-time water quality management and automated adjustments.

A. System Functionality and Benefits

This automated monitoring system enhances guppy cultivation by optimizing growth conditions and reducing developmental failures. The system operates through the following process:

a) Temperature Regulation: The DS18B20 digital temperature sensor continuously monitors water temperature in the guppy pond. When readings fall below the optimal range of 28-32°C, the system automatically activates the water heater to maintain ideal thermal conditions.
b) pH Management: The system maintains water acidity within the optimal pH range of 6.5-8.5. If pH levels drop below 6.5, an automated solenoid valve releases pH-neutralizing solution to restore balanced conditions. This stabilization process ensures consistent water quality for guppy health and development.

B. System Components Overview

Fig. 2. (Label 1) illustrates the top view of the fish pond monitoring system, featuring the following key components:

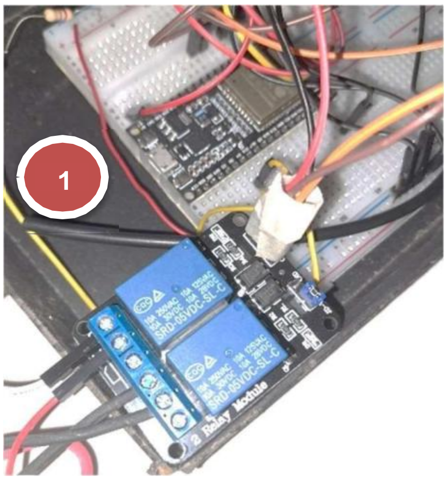

Figure 2. The fish pond monitoring system

a) ESP32 Microcontroller: The central processing unit that stores and executes the control program. A key advantage of the ESP32 is its built-in Wi-Fi capability, enabling wireless connectivity for remote monitoring and control.
b) Relay Module: This electrical component serves as a switching mechanism, controlling power distribution to both the water heater and solenoid valve based on sensor inputs. The relay safely manages higher current loads required by these actuators while being controlled by the low-power microcontroller signals.

Figure 3. a side view of the pond monitoring system

Fig. 3. presents a side view of the pond monitoring system with the following sensor components and their functions. The DS18B20 temperature sensor continuously monitors water temperature. When readings fall below the optimal range of 27-32°C, the system automatically activates the water heater to restore and maintain ideal thermal conditions for guppy health. The pH sensor measures water acidity/alkalinity levels, and The Total Dissolved Solids (TDS) sensor assesses water purity, providing measurements in parts per million (ppm).

Figure 4. The solenoid valve

Fig. 4. (Label 2) displays the front view of the fish pond monitoring system, highlighting the pH regulation mechanism. The solenoid valve serves as an automated corrective device that releases pH-neutralizing solution when the pH sensor detects water acidity below the optimal range of 6.5-7.5. This automatic adjustment maintains water conditions within the ideal parameters for guppy fish health and development.

```
21:49:13.881 -> Water Heater OFF
21:49:13.881 -> Solenoid Valve ON - Mengeluarkan cairan pH Netral
21:49:14.876 -> Temperature: 29.50°C
21:49:14.876 -> pH Value: 4.73
21:49:14.911 -> TDS Value: 711.84 ppm
```

Figure 5. Real-time data outputs

Fig. 5. demonstrates the fully operational system with real-time data outputs:

a) Water Temperature: 29.50°C (within optimal range)

b) pH Level: 4.73 (below threshold of 6.5–7.5), triggering the solenoid valve to release pH-neutralizing solution
c) TDS Measurement: 711 ppm

All components are functioning as designed, with the automated pH correction system actively maintaining water quality parameters. IoT-based water quality monitoring systems enhance aquaculture efficiency and significantly improve aquaculture siting decisions by providing real-time data on critical parameters such as pH, dissolved oxygen, and turbidity by providing real-time data on critical parameters like temperature, pH, and turbidity [6][7].

```
16:00:04.041 -> pH Value: 8.61
16:00:04.072 -> TDS Value: 725.03 ppm
16:00:04.147 -> Water Heater OFF
16:00:04.147 -> Solenoid Valve OFF - Katup tertutup
```

Fig. 6. System status

Fig. 6. displays the current water quality metrics:

a) pH Level: 8.61 (above the optimal threshold of 6.5)
b) Solenoid Valve Status: Closed (neutralizing solution remains inactive)

The system automatically maintains this state as the measured pH exceeds the minimum threshold, preventing unnecessary adjustment of water chemistry.

```
21:51:49.408 -> Temperature: 2.00°C

21:54:11.535 -> Water Heater ON
```

(a)

```
21:49:14.876 -> Temperature: 29.50°C

21:49:13.881 -> Water Heater OFF
```

(b)

Figure 7. Water heater setup

Fig. 7(a). demonstrates the system response during cold water testing. When water temperature falls below the optimal range (27-32°C), the system automatically activates the water heater to restore thermal conditions. Fig. 7(b). presents normal water conditions: Once temperature reaches the target range (27-32°C), the system deactivates the heating element to maintain stable conditions.

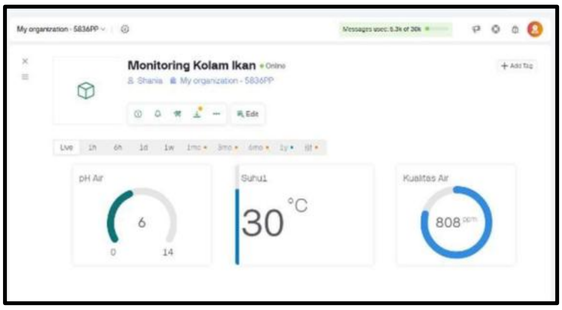

Figure 8. System Monitoring Interface

Fig. 8. demonstrates the fully operational system as displayed on the Blynk web interface platform. The dashboard successfully shows real-time sensor data transmitted to the Blynk application, including:

a) Water pH: 6.0 (within optimal range)
b) Water temperature: 30°C (properly regulated)
c) Total Dissolved Solids (TDS): 808 ppm

All system components are functioning as designed, with accurate data transmission and display through the IoT monitoring platform.

Figure 9. Real-Time Water Quality Monitoring

Fig. 9. presents the web-based monitoring interface displaying real-time data for water temperature, pH levels, and Water quality parameters. This system provides continuous reporting, enabling farmers to remotely track and assess pond conditions at all times. The live data feed ensures immediate visibility of any fluctuations in water quality metrics.

Aquaculture is essential for worldwide food security, offering a significant source of protein. With a rising population, sustainable growth in this sector is urgently required [8]. The FAO notes that global aquaculture production dramatically increased from under 8 million tonnes in 1980 to over 105 million tonnes in 2018, primarily in Asia, with China leading the way [9]. Nevertheless, traditional aquaculture methods often struggle with managing water quality, feeding practices, and disease control. Enter IoT technology, which provides a powerful solution by offering real-time data insights and automation to tackle these inefficiencies [10].

IV. CONCLUSION

This study successfully designed and implemented an IoT-based water quality monitoring system for freshwater ornamental fish ponds, specifically tailored for guppy (Poecilia reticulata) cultivation. By integrating an ESP32 microcontroller with DS18B20 temperature, pH, and TDS sensors, the system achieved real-time monitoring and automated control of critical water parameters. Key findings demonstrate the system's efficacy in maintaining optimal conditions:

a) Temperature Regulation: The system stabilized water temperature within the ideal range of 27–32°C, activating a heater when temperatures fell below the threshold.

b) pH Management Automated correction via a solenoid valve ensured pH levels remained between 6.5–8.5, preventing harmful acidity fluctuations.

c) TDS Monitoring: Real-time TDS measurements (e.g., 711 ppm, 808 ppm) enabled proactive water quality adjustments to safeguard fish health.

The Blynk platform provided remote, web-based access to sensor data, reducing reliance on manual checks and minimizing risks of aquaculture failure. This IoT solution not only enhances guppy growth conditions but also offers scalability for commercial operations, promising significant reductions in economic losses. Future work could expand sensor arrays to include dissolved oxygen and ammonia monitoring, further optimizing aquaculture sustainability. This research bridges technology and aquaculture, offering a replicable model for IoT-driven water quality management in ornamental fish farming.

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