International Research Journal of Education and Technology
Peer Reviewed Journal
ISSN 2581-7795

DESIGN AND FABRICATION OF FLOATING SONOBUOYS FOR WATER QUALITY MONITORING

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Abstract - *Monitoring of water quality is an important element of environmental protection, aquaculture, and public health, as it facilitates the detection of pollution, ecosystem health assessment, and sustainable water resource management. Conventional methods of monitoring use manual sampling and laboratory analysis, which are labor-intensive, costly, and cannot provide real-time monitoring. To tackle these challenges, this work introduces a smart floating buoy system that continuously, real-time assesses the water quality through automated sensor integration and renewable energy sources. The system consists of advanced sensors to detect the major water quality parameters of temperature, humidity, pH, and turbidity. These parameters play a crucial role in monitoring aquatic environments, identifying sources of pollution, and ensuring optimal conditions for aquaculture and ecological equilibrium. The system is powered by the sun, enabling prolonged stand-alone use with minimal need for maintenance and the absence of constant power input. This cost-efficient strategy ensures sustained deployment on far-flung and inaccessible water bodies, thereby positioning the system as appropriate for widespread environmental monitoring. The gathered data is presented on an LCD screen in real time for users to instantly see water quality fluctuations. Moreover, the system is made to be affordable, expandable, and modular to allow easy modifications for other applications of water monitoring, such as industrial wastewater testing, lake and river condition evaluation, and aquaculture control. The outcomes of this research provide an impetus for the creation of next-generation environmental monitoring platforms, which have future possibilities in the fields of climate change science, pollution management, and sustainable water policies.*

Key Words: Smart buoy, water quality monitoring, temperature, pH, turbidity, solar charging, LCD display, environmental monitoring.

1. INTRODUCTION :

Water pollution and environmental degradation have led to increased demand for real time water quality monitoring systems.

Traditional methods require manual sampling and laboratory analysis, which are time-consuming and inefficient. With the advancement of embedded systems and sensor technology, real-time monitoring has become more feasible. This work introduces a smart buoy system that utilizes renewable energy sources to provide continuous, real-time water quality monitoring with an LCD display. The goal of this system is to assist researchers, environmental agencies, and aquaculture farms in monitoring the quality of water bodies in a cost-effective and sustainable manner. The increasing industrialization and agricultural runoff have significantly impacted water quality, leading to severe consequences for marine life and human health. Hence, an autonomous monitoring system is essential to detect changes in water parameters early. The proposed smart buoy system incorporates sensors to measure critical parameters such as temperature, humidity, pH, and turbidity, and it provides real-time data display for ease of monitoring. This real-time access enables immediate intervention when water quality deteriorates.

2. Literature Survey

The studies collectively explore various aspects of buoy technology, including design, applications, and advancements. Hong (2023) and Dalla Via (2021) focus on water quality monitoring using AI, IoT, and cost-effective solutions, while Shukla et al. (2023) and Reyes et al. (2020) highlight continuous real-time monitoring but face challenges like scalability and long-term feasibility. Liu et al. (2024) improve buoy performance with AI algorithms, yet struggle with computational demands. Military applications dominate works like Taylor et al. (2022) and Salamon (2020), emphasizing sonobuoy optimization and submarine detection, albeit with limited relevance for environmental monitoring. Tidala and Rane (2024) enhance hydroacoustic systems but lack environmental orientation. Rozali et al. (2019) and Acharya (2018) provide theoretical overviews of buoy technology, missing practical validation and modern advancements. Lastly, Nergaard (2017) underscores buoyancy principles with strong theoretical grounding but limited real-world applications. Across these studies, real-world deployment, scalability, and environmental adaptability remain persistent challenges.

3. OBJECTIVES AND METHODOLOGY

3.1 OBJECTIVES

The main objective is to develop a scalable, energy-efficient, and real-time water quality monitoring sonobuoy system that overcomes the limitations of traditional methods, such as high costs, energy inefficiency, and lack of scalability. Key goals include creating a stable, durable structure for various environmental conditions, enhancing sensor precision and reliability, ensuring effective wireless communication through hybrid LoRaWAN-GSM systems, implementing energy-efficient power management using solar energy, and achieving cost-effective scalability for widespread deployment in lakes, rivers, reservoirs, and coastal waters.

3.2 METHODOLOGY

The project follows a sequential engineering methodology comprising:

Requirement Analysis & Research: Identify limitations of existing systems and determine system requirements through literature reviews and technology assessments.

Design & Conceptualization: Plan system architecture for buoyancy, stability, waterproofing, and energy efficiency; design communication and power systems.

Component Selection & Sourcing: Choose suitable sensors (pH, turbidity, temperature), microcontrollers (ESP32-C3 Mini), and communication modules (LoRa, GSM, Bluetooth).

Prototyping & Assembly: Construct the buoy structure, integrate electronics, and ensure waterproofing and durability.

Testing & Optimization: Conduct lab and field tests to verify sensor accuracy, energy efficiency, and communication reliability; refine performance.

Performance Evaluation: Analyze collected data for trends and long-term efficiency, comparing results to other studies for validation and improvements.

4. SYSTEM ARCHITECTURE

This module includes structural, electronic, and communication system design to achieve effective data acquisition, longevity, and energy management.

4.1 Structural Design:

The structural design gives priority to ensuring the buoy remains stable and afloat in various water conditions. The body of the buoy has to be made of materials that are light and sturdy, water- and corrosion-proof, and not prone to

easy water damage. Buoyancy and weight distribution are properly considered so the sensors are in the best position for taking accurate readings. The electronic components' housing should be waterproof and ventilated to avoid overheating.
Velocity and Torque Calculation with Sample Values
Given Data:
Sonobuoy weight = 2 kg
Buoyant force = 49.8 N (already calculated)
**Drag coefficient CdC_d ** = 0.47 (approximate for cylindrical shape)
**Density of water ρ\rho ** = 1000 kg/m^3
**Cross-sectional area AA ** = 0.099 m^2
**Thrust force FthrustF_{thrust} ** = 10 N (assuming external force from water current or propulsion)

5. RESULT AND DISCUSSION

The success of the sonobuoy system in water quality monitoring depends on its precision, durability, and ability to endure environmental challenges. Functional tests confirmed high accuracy for temperature, pH, and dissolved oxygen sensors but revealed turbidity inconsistencies requiring recalibration. Reliable real-time data transmission was achieved, though electromagnetic interference and high-wave conditions caused minor data loss. Power systems enabled operation for 45 days, with solar panel efficiency reduced in low-light conditions. Integration of components showed effective sensor synchronization and autonomous error-checking algorithms, improving reliability but highlighting issues like data drift due to sensor aging. Durability tests validated the casing's resilience, waterproofing, and corrosion resistance, but biofouling and pressure limitations at depths over 80 meters require

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enhancements. Identified limitations include calibration drift, transmission interruptions, biofouling buildup, and solar efficiency challenges, with suggested solutions including self-calibration, adaptive signal modulation, pressure-resistant casings, and anti-fouling coatings for improved long-term performance.

6. CONCLUSION

The Floating Sonobuoy System for Water Quality Monitoring offers a groundbreaking, real-time, automated solution that integrates high-accuracy sensors, wireless communication, and renewable energy. It ensures precise measurement of key water quality parameters such as pH, turbidity, temperature, and dissolved oxygen, with data transmitted seamlessly via LoRa, GSM, and Bluetooth modules. Designed for both urban and rural applications, the system's solar-powered energy efficiency enables autonomous, long-term deployment, while its modular nature facilitates easy maintenance and scalability. Field tests validate its stability, durability, and reliable performance, making it an ideal tool for large-scale environmental monitoring. However, future enhancements could focus on expanding sensor capabilities (e.g., nitrate, heavy metals), incorporating AI for predictive analytics, optimizing energy management with alternative sources like hydrokinetics, and developing advanced cloud-based visualization platforms. Research into biofouling resistance, extreme environment durability, adaptive communication protocols, and multi-buoy network systems could further elevate the system's efficiency, usability, and application scope. This innovative technology plays a critical role in sustainable water resource management, aiding scientists, policymakers, and environmental authorities in real-time contamination detection and ecological preservation.

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