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INTEGRATED IOT- BASED WATER QUALITY SYSTEM USING FOUR PARAMETERS FOR SUSTAINABLE WATER RESOURCE MANAGEMENT

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Abstract— In Malaysia, the degradation of water bodies due to rapid urbanisation, agricultural runoff, and industrial waste highlight the urgent need for continuous, efficient water quality monitoring. However, current manual-based sampling methods are time-consuming, labour-intensive, and insufficient for real-time assessment, thus limiting proactive intervention. In response to these limitations, this study aims to design an integrated water quality monitoring system that focuses on four parameters which

Sensing, Four Parameters, Water Quality Monitoring

are Dissolved Oxygen (DO), pH, Temperature, and Turbidity. These parameters selected for their importance in assessing aquatic health and pollution levels. To achieve this, the system design incorporates Arduino as the central microcontroller for sensor integration, coupled with Long Range (LoRa) communication for energy-efficient, long-range data transmission. Sensor data are envisioned to be transmitted to a cloud-based dashboard for real-time monitoring and analysis. The proposed design is expected to lay the groundwork for a scalable and cost-effective solution that enhances monitoring accessibility, reduces reliance on manual sampling, and supports proactive water resource management aligned with Sustainable Development Goal (SDG) 6: Clean Water and Sanitation

I. Introduction

Water is one of the most valuable natural resources on Earth. It is not only essential for human survival, but it also plays an important role in maintaining health ecosystems. In Malaysia, water bodies are increasingly affected by pollutants from urban, agricultural, and industrial sources [1]. Monitoring key water quality parameters is essential for early detection of contamination and effective environmental management.

Conventional water quality monitoring methods rely primarily on manual sampling followed by laboratory analysis. Although these methods can deliver precise results, the system is labor-intensive, time-consuming, and lack real-time responsiveness [2]. Moreover, the long intervals between sampling and reporting delay the detection of pollution events, often resulting in reactive rather than proactive intervention. The infrequency of data also makes it difficult to detect sudden changes in water conditions [3]. These limitations hinder timely interventions, making it difficult to manage pollution events effectively, especially in remote or rural areas. This study presents the design of integrated water quality monitoring systems that use Arduino and LoRa to collect and transmit real-time data for four key parameters which are Dissolved Oxygen (DO), pH, Temperature, and Turbidity. These four parameters were selected based on their relevance to aquatic health and pollution detection. The Arduino microcontroller collects sensor data and transmits it via LoRa to a remote receiver or cloud-based platform for real-time visualization and monitoring [4]. This setup reduces reliance on manual data collection, enhances the frequency and responsiveness of monitoring, and enables early detection of pollution events.

The study is limited to the system design phase where it covers hardware selection, circuit integration, communication setup, and dashboard configuration for visualizing sensor data. The work does not include physical prototyping, calibration, or field testing. The system design provides a foundation for low-cost, scalable water quality monitoring in areas where manual methods are impractical.

II. Related Work

A. IoT-Based Water Quality Monitoring System

An IoT-based water quality monitoring system typically consists of three core elements which are sensors that detect environmental parameters, a microcontroller that processes and package sensor data, and a communication module that transmits the data to a cloud platform or user interface [5]. Among the microcontroller platforms available, Arduino has become a preferred choice due to its affordability, simplicity, low power consumption, and wide sensor compatibility.

Several researchers have successfully implemented Arduino based water quality systems. For instance, Mulyana et al. developed prototype system using Arduino to monitor pH, DO, and turbidity in river water, with results displayed locally on a LCD screen. Jain et al. [7] proposed an IoT-based Arduino system for smart fishpond, monitoring measuring temperature and DO using low-cost sensors, though the system used Wi-Fi, limiting its deployment range.

In addressing the limitations of range and power consumption, recent developments have incorporated LoRa communication technology. LoRa provides low-power, wide-area networking capabilities, enabling long-distance data transmission (up to 10-15 km in open areas) while maintaining minimal energy usage [8]. For example, Oubrahim et al. [9] developed an Arduino-LoRa-based system that monitored turbidity and temperature in agricultural reservoirs, showing reliable performance in rural deployments. Sheet et al. [10] tested a LoRa-enabled environmental sensing unit for use in aquaculture, but the system lacked integration of more than two water quality parameters.

B. Monitoring of Key Water Quality Parameters

Water quality is a complex measure influenced by various physical, chemical, and biological factors. Among these, DO, pH, temperature, and turbidity are widely recognised as core indicators of the overall health of aquatic ecosystems. Integrating all four into a single monitoring system provides a understanding of water conditions, making it suitable for sustainable water resource management.

DO is important indicators of water quality, especially in aquatic environments where oxygen is necessary for the survival of fish or aerobic bacteria. Low DO levels can result from high organic

ISSN: 2180-3811 Vol. XX No. X

pollution, or thermal stratification and can lead to fish kills and the disruption of aquatic food chains while pH measures the hydrogen ion concentration in water and indicates whether the water is acidic or alkaline. The pH level affects the solubility and availability of nutrients and metals, influencing the chemical balance and biological activity in aquatic systems. Temperature plays as a role in controlling the physical and biological processes in water bodies. Warmer water holds less dissolved oxygen and can accelerate eutrophication, while sudden changes in temperature may cause thermal shock to aquatic organisms. Turbidity indicates the number of suspended particles present in the water. High turbidity reduces light penetration, disrupting photosynthesis in aquatic plants and increasing water temperature. While many previous studies have measured one or two of these parameters independently, integrating all four into a single, compact system adds substantial value. It for environmental assessment, facilitates data correlation across parameters, and improves the accuracy of overall water quality evaluation.

C. Communication Technologies in Remote Monitoring

Several communication technologies have been explored in previous water monitoring systems. LoRa technology has emerged as a superior alternative for environmental monitoring systems due to its unique combination of long-range coverage, low-power consumption, and low cost. LoRa is a Low Power Wide Area Network (LPWAN) protocol designed for battery-powered devices that need to communicate over long distance.

Several studies have demonstrated the effectiveness of LoRa technology for remote environmental data acquisition. For example, Jabbar et al. [11] developed a solar-powered, floating LoRaWAN-based water quality monitoring system for rural areas in Malaysia, tested at Gambang Lake, demonstrating reliable operation through a rechargeable battery when solar power was insufficient. Furthermore, Syed Taha et al. [12] evaluated LoRa network performance for a water quality monitoring system deployed on two rivers on the Universiti Malaya campus in Malaysia, testing different antenna gains and spreading factors, and found that LoRa demonstrated efficient signal performance for smart river monitoring even in an urban environment.

III. Research Methodology

This methodology is based on a design-based and system development approach, where the main focus is to design, implement, and evaluate a real-time water quality monitoring system using IoT technology. This methodology combines hardware design, communication system development, and software implementation into a structured workflow. As the Figure 1 shows the flowchart illustrate the overall research workflow where the final stage of this research involves system testing and validation to evaluate the performance, stability, and reliability of the proposed design.

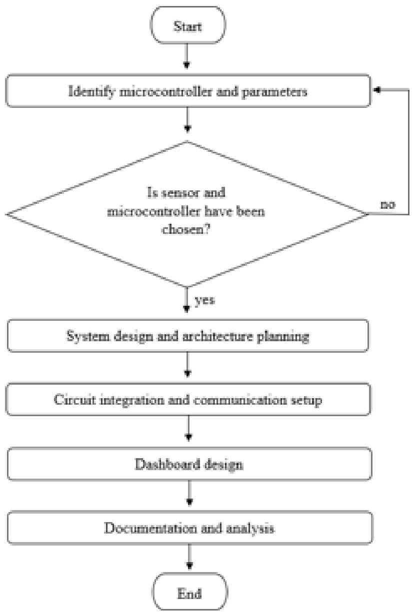

Figure 1: Flowchart

A. Research Design and Approach

This study adopts a design-based research approach focused on the development of a real-time water quality monitoring system using IoT technologies as shown in Figure 2. The process begins with the identification of the core monitoring requirements, which include the selection of four parameter (DO, pH, temperature

ISSN: 2180-3811 Vol. XX No. X

and turbidity). Arduino was

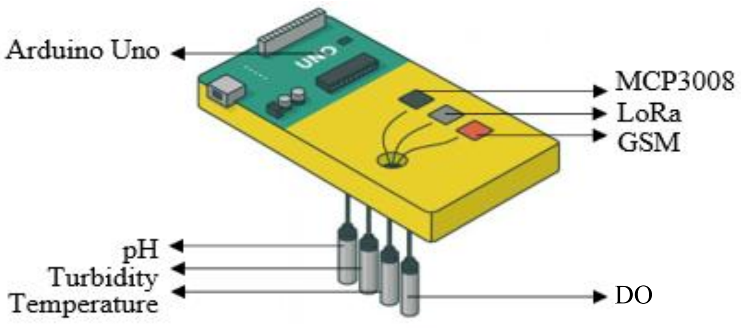

Figure 2: Project Design

selected as the microcontroller platform for its versatility, and sensor compatibility. Once the sensors and microcontroller were identified and validated, the research progressed to the system design and architecture planning stage, which includes outlining the physical layout, component integration, and environmental deployment strategy. The design also incorporates a LoRa communication module to enable long-range, low-power data transmission from the floating platform to a remote dashboard. The dashboard is conceptually designed to display real-time data visualisation for each parameter. Finally, the methodology concludes with documentation and system-level analysis to justify component choices, identify limitations, and support future development.

B. System Architecture and Component

The architecture of the purposed system consists of three main layers (sensing, control, and communication) as shown in Figure 3. The sensing layer integrates four environmental sensors, each responsible for measuring a key water quality parameter. The DO sensor, turbidity sensor, pH sensor, and temperature sensor are interface with an Arduino Uno microcontroller, which serves as the core of the control layer. The Arduino reads, processes, and packages data from each sensor before sending it to the communication layer. For wireless transmission, a

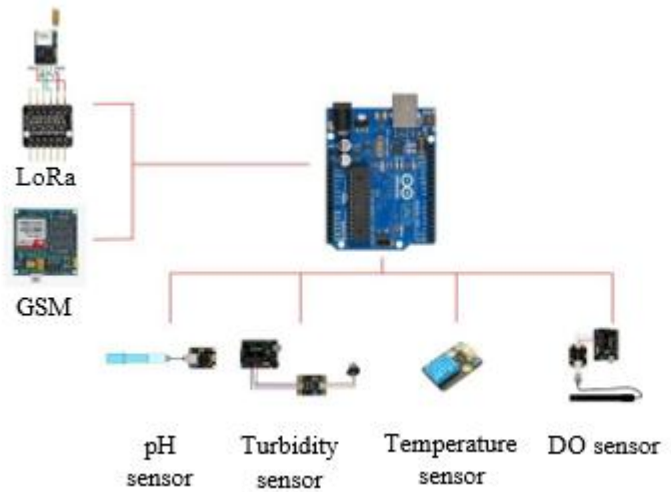

Figure 3: System Diagram

LoRa module is used due to its long-range and low-power capabilities, making it suitable for deployment in rural or infrastructure-limited areas [13]. All components are housed within a transparent dome mounted on a buoyant base, designed to float on water while protecting the electronics from environmental exposure.

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C. Data Acquisition and Transmission Flow

Use SI as primary units. English units may be used as secondary units (in parentheses). The Arduino microcontroller manages the data acquisition process by reading sensor values at predefined intervals, typically every 60 seconds. Raw data

ISSN: 2180-3811 Vol. XX No. X

from each sensor is converted into engineering units in milligrams per liter (mg/L) for DO, pH scale for acidity/alkalinity, degree Celsius for temperature, and nephelometric turbidity units (NTU) for turbidity using calibration formulas provided by sensor manufacturers [14].

The formatted data is structured into a transmission packet format and transmitted via the LoRa module to a remote LoRa gateway. The gateway forwards the data to a cloud-based IoT platform, such as Node-RED for real-time visualisation and analysis. In Node-RED, dashboard display the data through gauges, line graphs, and status indicators. Alerts can be configured to notify users when sensor readings exceed threshold values.

This seamless flow from sensor input to real-time dashboard enables effective, remote monitoring of water quality in real environments. The integration of long-range communication, reliable sensor interfacing, and low power consumption ensures that the system is suitable for unattended operation in isolated freshwater bodies, supporting sustainable water resource management.

The wireless module transmits the data via Wi-Fi to the cloud-based IoT platform Node-Red, which is hosted either on a local server or in a public cloud environment. Node-Red is used to develop a custom dashboard where real-time data can be viewed, recorded, and visualised using charts and indicator [15].

IV. Conclusions

This study presents the design of an integrated water quality monitoring system aimed at enhancing sustainable water resource management. The proposed system is structured to measure four key parameters (DO, pH, temperature, and turbidity) using an Arduino microcontroller and LoRa communication for long-range, low-power data transmission. The design includes a real-time visualisation platform that supports data tracking and

ISSN: 2180-3811 Vol. XX No. X

environmental from remote location.

The current work is limited to the design phase only, and the system includes core parameters that contribute to water quality assessment, it does not yet fulfil the full Water Quality Index (WQI) framework established by Malaysia's Department of Environment (DOE), which includes additional parameters such as Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Ammoniacal Nitrogen.

As part of future work, the system will be extended to include all WQI-relevant parameters in order to provide a complete and standardised evaluation of water quality. This will involve integrating additional sensors, enhancing calibration accuracy, and validating the system in real-world environments. By aligning with DOE's WQI guidelines, the future version of this system will offer more reliable data for environmental authorities, researchers, and stakeholders to make informed decisions regarding water resource management and pollution control.

Ultimately, this integrated monitoring system supports Sustainable Development Goal (SDG) 6 which is Clean Water and Sanitation, while also contributing to national efforts in environmental protection, food security, and public health

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