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Pagoh EduHub Aquatic Centre Water PH Monitoring Application

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Abstract

Protecting water supplies becomes essential for our future as a species, not just our obligation. One location where hygienic issues are constantly present is the swimming pool. Swimming pools require a large amount of clean water for various water-related activities, but there is a challenge in maintaining hygiene. In this case, a pH scale is essential and this project aims to develop a basic monitoring application for the Pagoh Eduhub Aquatic Centre using Internet of Things (IoT) technology. The primary objective of the application is to track the pH level, which indicates the water quality and acidity, in the swimming pool. By offering real-time data on the pH of the water, the app seeks to facilitate the work of pool staff. It also helps staff maintain the water's safety for public usage by keeping it between 7.0 and 7.6, to prevent hygiene and health issues for users. The methodology used for this project is Waterfall, which includes the phases of requirements gathering, system design, implementation, validation, and maintenance. The research was done to identify the requirements of this project, develop a water pH monitoring application for Pagoh EduHub Aquatic Centre, and evaluate the application's effectiveness with the pool staff. The methodology used for this project is Waterfall, which includes the phases of requirements gathering, system design, implementation, validation, and maintenance. If the pH levels go outside of the acceptable range, staff members can get warnings on their mobile devices using Blynk. The application helps staff monitor the pH of water effectively, minimizes the need for manual checks, and guarantees a fun and safe swimming experience for all users.

1. Introduction

The monitoring and control of water quality in swimming pools is being revolutionized by the Internet of Things (IoT) [1]. This makes it simpler and more effective to guarantee that every user has a safe and happy experience in a swimming pool. However, maintaining the safety and enjoyment of these pools necessitates careful, continuous water quality control. Maintaining the pH level within a defined and safe range, generally between 7.0 and 7.6, is essential to preserving the quality of water. The water's acidity or basicity is indicated by its pH level. When the pH level and quality of the swimming pool water are not optimal and suitable for all users, it can lead to hygiene problems and ultimately health. Swimmers may have health problems such as skin irritation, eye pain, and other possible diseases if the pH level is outside of this range. Furthermore, incorrect pH levels can harm pool

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equipment, resulting in higher maintenance expenses and a shorter lifespan. Traditional techniques for monitoring water quality frequently depend on manual testing, which can be difficult and limit how frequently data is gathered. The conventional approach to assessing the quality of water involves gathering water samples from various locations and transporting them to a laboratory for analysis. However, the traditional method lacks real-time analysis and is costly and time-consuming [2]. This method may delay the implementation of preventative actions to guarantee water quality and postpone the discovery of issues. Manual testing, for example, might not detect pH variations soon enough to prevent possible health risks or equipment damage. These issues are resolved by the incorporation of IoT technology into pool water management, which makes it possible to continuously and instantly check water quality. IoT devices have the ability to gather and send data to a central system or mobile application on a variety of factors, including pH levels. This enables pool managers to remotely check the quality of the water and respond right away if pH levels go outside of the acceptable range.

1.1 Problem Statement

Maintaining water quality in public swimming pools is crucial for health and customer satisfaction, with discoloration often indicating underlying issues. Pool water quality significantly impacts health, as contaminated water poses hygiene risks [3]. Swimming is popular for fitness and recreation, engaging almost all muscle groups, but unclean water can cause infections like skin disorders, gastrointestinal issues, eye irritation, and respiratory problems. While chlorine disinfects effectively, it can form irritating chloramine vapor when interacting with sweat or urine [4]. Regular water replacement enhances quality and hygiene. Therefore, this project aims to develop an efficient, user-friendly application to monitor water pH levels and assist Pagoh Eduhub Aquatic Center staff in maintaining optimal water quality standards, including identifying features, developing the application, and evaluating its effectiveness.

1.2 Objective Scope

The research for the Pagoh EduHub Center Water pH Monitoring Application (PEACPMA) had three key objectives. First, it aimed to identify the specific requirements for developing a water pH monitoring system tailored to the Pagoh EduHub Aquatic Centre, considering the center's unique needs and technical specifications. Second, the project focused on developing a user-friendly application that provides real-time, accurate pH level monitoring, data storage, and instant notifications to help staff maintain optimal water quality. Finally, the project sought to evaluate the effectiveness of the application by testing it in a real-world setting with the center's staff, collecting feedback, and making necessary adjustments to ensure the system's functionality and usability.

2. Literature Review

The PEACPMA is intended to accurately control pH levels in the water by adjusting for variations brought on by user activity and outside influences like rain. To ensure user safety, it seeks to enhance water quality and maintain optimal pH levels. Using Internet of Things technology, the application monitors and controls pH in real-time, keeping pool water in the ideal range of 7.0 to 7.6. The application's control system is essential because it provides automatic and manual controls for regulating pH levels, scheduling monitoring cycles, and sending real-time alerts for fast immediate action. All of these features improve the effectiveness and safety of pool water management.

IoT technology, a network of interconnected electronic devices, enables data exchange and interactions beyond machine-to-machine communication via the Internet. This innovation interests industries such as information, transportation, agriculture, healthcare, and manufacturing [5]. There are a variety of IoT interactive projects that have been developed. For instance, one of the most popular IoT projects is the Water Quality Monitoring System for Fisheries using the Internet of Things (IoT), The project developed real-time fish pond monitoring and automation where they measure the water, temperature, pH, and DO levels integrated with aerating and water supply pumps using Arduino [6]. However, a great deal more interactive IoT projects have been created. A comparison of the projects that have been produced is displayed in 2.1.

2.1 Comparison between aspects of focused existing water pH monitoring systems

There are several existing water pH monitoring systems, among them, Development of IoT Based Fish Monitoring System for Aquaculture, An IoT-enabled smart pH Monitoring and Dispensing System for Precision Agriculture Application, and Smart Water Quality Monitoring System with cost-effective use of IoT. **Table 1** shows the difference in purpose for each system.

Table 1: Comparison between aspects of focused existing water pH monitoring systems

Scope	Explanation of the system
Development of IoT Based Fish Monitoring System for Aquaculture [7]	It intends to boost fish output and guarantee a wholesome aquatic environment for Bangladesh's aquaculture sector.
An IoT-Enabled Smart pH Monitoring and Dispensing System for Precision Agriculture Application [2]	Intends to enable corrective actions, such as the distribution of basic solutions when necessary, and enable remote monitoring by farmers via a smartphone app. It also seeks to provide real-time pH level monitoring.
Smart Water Quality Monitoring System with cost-effective use of IoT [8]	Water Quality Monitoring (WQM) is a cost-effective and efficient system designed to monitor drinking water quality that makes use of Internet of Things (IoT) technology.

Based on **Table 1**, there are different focuses of the three IoT-based systems. The Fish Monitoring for Aquaculture focuses on enhancing fish production and ensuring a healthy aquatic environment specifically for Bangladesh's aquaculture sector.

Secondly, The IoT-Enabled Smart pH Monitoring and Dispensing System for Precision Agriculture aims to provide real-time pH level monitoring and enable corrective actions in agriculture, allowing remote access for farmers via a smartphone app. The Smart Water Quality Monitoring System using IoT is designed to be a cost-effective solution for monitoring drinking water quality, utilizing IoT technology to ensure efficient and reliable water quality assessment.

2.2 Comparison of items used between existing pH monitoring systems

A comprehensive study of the existing system has been made. A comparison based on the items used is shown in **Table 2.** The differences in items are seen from the hardware and software according to each system.

Table 2: Comparison of items used between existing water pH monitoring

Scope	Hardware	Software
Development of IoT Based Fish Monitoring System for Aquaculture [7]	- pH Sensor - DS18b20 Temperature Sensor - Oxygen Kit Ammonia Kit - Esp-12E Module	- MIT App Inventor - Google Firebase
An IoT-Enabled Smart pH Monitoring and Dispensing System for Precision Agriculture Application [2]	- pH Sensor Module - Temperature and Humidity Sensor (DHT11) - Ultrasonic Sensor - Water Pump (Evolve 18) - Arduino UNO - Node MCU - Relay	- ThingSpeak - If This Then That (IFTT) - Blynk
Smart Water Quality Monitoring System with cost-effective use of IoT [8]	- Arduino Megah - Node MCU - pH Sensor - Turbidity Sensor - DHT-11 Sensor	- ThingSpeak

Based on **Table 2**, there are different hardware and software used by the three IoT-based systems for distinct environmental monitoring applications. The Fish Monitoring System uses pH sensors, DS18B20 temperature sensors, oxygen kits, ammonia kits, and the ESP-12E module to ensure water quality. It employs Google Firebase for real-time communication and data storage, and MIT App Inventor for mobile app development [1].

The Precision Agriculture System Monitors pH, temperature, humidity, and liquid levels using pH sensors, DHT11 sensors, ultrasonic sensors, water pumps, Arduino UNO, and Node MCU. It uses ThingSpeak for data storage, IFTTT for automation, and Blynk for device connectivity and real-time monitoring [2].

The Smart Water Quality Monitoring System measures the pH, turbidity, and temperature of drinking water using Arduino Mega, NodeMCU, pH, turbidity, ultrasonic sensors, and DHT-11 sensors. ThingSpeak is used for data collection and analysis [7]. In summary, each system uses specific hardware and software to meet specialized monitoring needs, such as aquaculture water quality, precision agriculture, and drinking water safety. Despite all using ThingSpeak, they differ in sensor types and monitored parameters, demonstrating IoT flexibility.

3. Methodology

A methodology is a systematic strategy for project management, planning, and implementation [9]. For our project, we choose to use the Waterfall methodology. The waterfall methodology is a popular approach to project completion that has to go through phases. Because the project criteria, scope, and objectives are all clearly defined from the beginning, this method works extremely well for Internet of Things initiatives. The waterfall methodology as shown in **Fig. 1**, involves 5 important stages: requirements, design, implementation, testing, and maintenance.

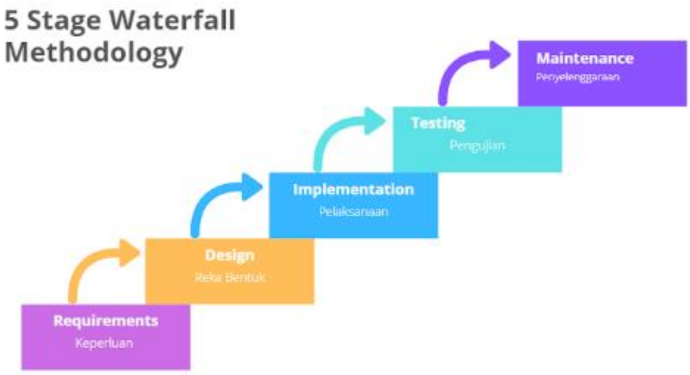

Fig. 1: Waterfall Methodology

3.1 Requirements

The requirement phase is the initial stage where information is gathered to collect, analyze, and document project requirements in a clear and testable manner. This phase is very important because it forms the basis for the next stage.

In the requirements phase of our project, we divided the requirements into hardware and software. Initially, we used Arduino Uno but switched to Arduino D1 due to its built-in Wi-Fi capabilities, making it the primary device for data collection from the pH sensor and communication with the Blynk application. The project also includes a water pH sensor to measure alkalinity and acidity, with calibration ensuring accurate readings.

For software, we initially considered ThingSpeak but chose Blynk for its mobile application focus, allowing users to visualize and interact with sensor data on their devices. Additionally, we used the Arduino IDE to develop and upload code to the Arduino D1.

3.2 Design

We have selected the Arduino D1 microcontroller, a pH sensor for water, and a Blynk application for our project design. The Arduino IDE is what we use to program.

The analog pin Po of the pH sensor is connected to the A0 pin of the Arduino, the ground pin of the sensor is connected to the Ground pin of the Arduino, and the V+ pin of the pH sensor is connected to the 3.3V pin of the Arduino according to the circuit diagram. The pH sensor calibration and the project as a whole rely on these three pins (V+, G, and Po).

The pH level is tracked via a gauge in the Blynk user interface, which also shows the pH reading over time on a graph. If the pH level falls outside of the safe range, an alert is programmed to activate.

3.3 Implementation

The implementation phase begins with calibrating the pH sensor. This requires a short wire to connect to the center of the probe connector. Calibration ensures accurate readings between 0 and 14 pH. If the sensor output deviates from 2.5 volts, the conditioner must be adjusted to set the output voltage to 2.5 volts, indicating a neutral pH of 7.

Initially, to calibrate the pH sensor, the coding needs to be modified to be used as a calibration, for the Arduino D1 board (similar to ESP8266). The code has been adjusted to account for the 3.3V connection instead of 5V and has achieved the correct 2.5V reading.

After finishing calibrating the pH sensor, the short wire will be removed and will connect to the pH sensor interface to run the full program. The coding for the actual program needs to be modified according to the Arduino d1 board and connected with Blynk to show the pH value on the Blynk interface board.

To execute the entire program after the pH sensor has been calibrated, the short wire will be taken out and connected to the pH sensor interface. The actual program's coding must be adjusted to fit the Arduino D1 board in order to connect to Blynk and display the Ph value on the Blynk interface board.

3.4 Testing

During the testing phase, the general functionality of the system as well as the pH sensor's accuracy and dependability were tested. First, a multimeter was used to verify the voltage output and validate the calibration of the sensor by confirming stability at 2.5 volts in a pH 7 buffer solution. Establishing the sensor's capacity to deliver accurate readings at the required pH values required this step.

Verifying the integrity of the connections made between the Arduino D1 board and the pH sensor represented the second testing phase. This involved examining the connections for the V+, G, and Po as well as maintaining an eye on real-time data for any signal changes that would point to a loose connection. In order to verify smooth data transfer and continuous connectivity, Wi-Fi connectivity testing was also done between the Arduino D1 board and the Blynk interface.

During the last testing stage, the system's data display and alert features on the Blynk interface were evaluated. To verify that the gauge and graph displays accurately depicted the pH sensor data over time, a variety of pH buffer solutions were used. In addition, the alarm feature was rigorously tested by subjecting the pH sensor to solutions whose pH values were outside the acceptable range, which effectively set off alerts. The system's accurate pH monitoring, stable connections, and useful warning capabilities were validated by these extensive testing procedures, which makes it a dependable option for real-time pH monitoring applications.

3.5 Maintenance

The maintenance phase is crucial for post-testing and validation to ensure reliable system functionality and consistent, accurate pH readings. This phase encompasses standard procedures to monitor and uphold system performance.

Step 1: Regular Modification

The weekly integration process involves immersing the pH sensor in a standard pH buffer solution and adjusting the conditioner to achieve the desired voltage output. This calibration is necessary to ensure accurate pH readings and is conducted once a week. Additionally, the verification of output voltage using a multimeter in a pH 7 solution confirms stability at 2.5 volts; any deviations from this value necessitate recalibration to maintain accuracy in pH measurements.

Step 2: Analyzing Elements and Connections

The assessment of sensor connections involves ensuring the secure connection of all components (V+, G, and Po) between the Arduino D1 board and pH sensor, promptly addressing any loose connections to maintain reliable data transmission. Additionally, a visual examination of the Arduino D1 board and sensors is conducted to check for signs of wear or damage. Thorough cleaning is essential to prevent any contaminants that could potentially alter pH readings, ensuring accurate and consistent monitoring of pH levels.

Step 3: Monitoring Software and Systems in Real-Time

PH Data Display Accurately: To ensure accurate pH data display, timely exploration, and resolution of anomalies or odd readings, continuous monitoring via the Blynk interface is necessary.
Updates for software: Updates to the Arduino D1 board's software and tests of the Blynk interface on a regular basis guarantee optimal performance, including enhanced data presentation, reliable connections, and alert functions.

Outcome:
The system's proper operation is ensured during the maintenance phase, which offers accurate pH level monitoring. Regular maintenance supports the long-term objectives of the project by facilitating quick issue resolution, maintaining reading accuracy, and enhancing overall system efficiency.

4. Result and Implementation

This project's goal is to create an efficient and user-friendly application to monitor water pH levels and assist Pagoh EduHub Aquatic Centre staff in maintaining optimal water quality standards, which includes identifying the fiber qualities of the application and evaluating its effectiveness. There was a discussion conducted by preparing a question platform for 7 respondents [5]. Through this discussion, the respondents were able to evaluate and give their views on the application that was established.

4.1 Result

A complete application that has been developed based on the objective and requirement is sketched and implemented, including the flow, functionality, and interface. During the planning stages, a list of the features that will comprise the PEACPMA flow and functionality was created to provide an interactive interface that can motivate users to engage with the application, the interface has undergone numerous refining processes before achieving the final look. **Fig. 2** shows the main page or dashboard to help Pagoh Eduhub Aquatic Centre staff to see the optimal level of water pH level. Several other features could help staff to see the pH value of the water, the staff can see it at two times, in the morning before the user uses the pool and in the evening after the user uses the pool. Through the gauge that is displayed, it is easier for staff to see the changes that are displayed. Additionally, the staff has access to a chart that displays the water's overall pH value, which varies over time.

Furthermore, this application is intended to send out alerts a high pH alert or a low pH alert when the pH sensor detects a pH value that deviates from the predetermined normal range. The application was successfully deployed. The chosen pH sensor functioned reliably after proper calibration, and real-time data transmission to the mobile application occurred without significant disruptions. The mobile application, developed using Blynk, offered a user-friendly interface displaying real-time pH values and clear visual alerts when readings fell outside the recommended range (7.0-7.6).

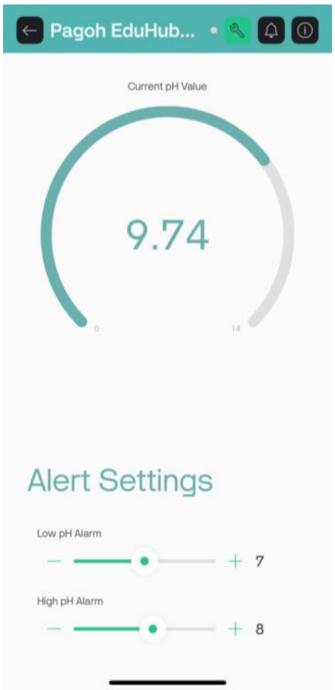

Fig 2: Main Page of the application

4.2 Discussion

This project was systematically created, covering a wide range of functionalities that were smoothly integrated and met all the stated requirements. Rigorous testing and verification processes have guaranteed that all the key functions run smoothly and efficiently, producing the anticipated results. Following the administration of a well-designed questionnaire to acquire useful insights from users, an array of constructive feedback was obtained, revealing invaluable suggestions and recommendations for further improving the application. These respondents' insightful feedback has helped to improve the application's overall user experience by making it more refined and better aligned with their expectations. Some shortcomings and potential additions to the application's power are also revealed by the feedback. This survey involves 2 types of responders, namely students and staff.

Based on the survey that has been made, a total of 21 respondents from the student and 2 staff members have been carefully selected and interviewed for this study to get their perspective on the effectiveness of the PEACPMA. Three important questions were asked of these respondents to evaluate their views and identify the benefits that may be obtained with the PEACPMA. The survey results indicate that the PEACPMA is very effective and user-friendly, with most users 60.9% rating the interface as excellent, noting that it helps them achieve goals quickly and accurately with few errors. The survey results show that users find the data presented in the PEACPMA to be dependable and reliable. Out of 23 responses, 43.5% rated the data reliability a 4, and another 43.5% rated it a 5. This indicates high confidence in the application's data accuracy. Additionally, users did not encounter any difficulties while using the application, with 43.9% giving it a 4 and 43.6% giving it a 5, further confirming its ease of use and effectiveness. Based on the results of the research, it is possible to infer that the project is a huge success in terms of meeting its objectives. The findings point to a beneficial conclusion, with the setup established to benefit Eduhub Pagoh Aquatic Centre in the future.

5. Conclusion

In conclusion, the PEACPMA, which was created with the use of Internet of Things technology, has successfully improved pool water quality management by offering automatic alerts and real-time monitoring. The Waterfall methodology-driven system effectively reduced the burden of pool staff and enhanced their ability to react quickly to pH level changes, guaranteeing a secure swimming environment. Despite the difficulties the project encountered—such as the need for reliable connectivity and large setup costs—its capacity to lessen water waste and human involvement is advantageous. Future developments might further boost system dependability and user experience, making PEACWPM an invaluable tool for managing public pools.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Nurhanan Syafiqah Suhaimi, Nur Elysha Atiqah Azhar;* ***data collection:*** *Nurul Azwany Abd Hussin;* ***analysis and interpretation of results:*** *Nurhanan Syafiqah Suhaimi, Nur Elysha Atiqah Azhar, Nurul Azwany Abd Hussin;* ***draft manuscript preparation:*** *Nur Elysha Atiqah Azhar, Nurul Azwany Abd Hussin. All authors reviewed the results and approved the final version of the manuscript.*

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